Integration of Remote Sensing and Magnetic Methods for Geological Mapping of Central Zagros Area

By

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ADEOS	Advanced Earth Observing Satellite
AS	Analytic Signal

AVNIR	Advanced Visible and Near Infrared Radiometer
ALOS	Advanced Land Observing Satellite
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
DEM	Digital Elevation Modeling
DN	Digital Number
DWCON	Drainage Watershed Conditioning
EOS	Earth Observing System
ETM	Enhanced Thematic Mapper
ERSDAC	Earth Remote Sensing Data Analysis Center
GCP	Ground Control Points
GIS	Geography Information System
GLCF	Global Land Cover Facility
GPS	Global Positioning System
HG	Horizontal Gradient
HH	Horizontal Horizontal
JAROS	Japan Resources System Organization
JERS	Japanese Earth Resources
MERIS	Medium Spectral Resolution Imaging Spectrometer
METI	Ministry of Economy, Trade, and Industry
MNINT	Natural Neighbor Interpolation
MSS	Multispectral Scanner System
NASA	National Aeronautics and Space Administration
NIR	Near Infrared
PALSAR	Phased Array Ttpe L-band Synthetic Aperture Radar
PCA	Principle Component Analysis
PRISM	Panchromatic Remote Sensing Instrument for Stereo Mapping
RGB	Red Green Blue

RMS	Root Mean Square
SAR	Synthetic Aperture Radar
TM	Thematic Mapper
UTM	Universal Transverse Mercator
USGS	United States Geological Survey
VH	Vertical Horizontal
VV	Vertical Vertical
WIST	Warehouse Inventory Search Tool

INTERGRASI KEADAH PEDERIAAN JAUH DAN MAGNET UNTUK

PEMETAAN GEOLOGI KAWASAN TENGAH ZAGROS UNTUK PEMETAAN

ABSTRAK

Projek ini yang mengkaji rupa bentuk geologi dua kawasan di Iran iaitu Kuh-e-Djahan Bin dan Gardaneh Rokh menggunakan imej-imej Pemeta Tematik (TM) dan Model Ketinggian Berdigit (DEM). Data magnetik untuk dua kawasan tersebut juga digunakan dalam kajian ini. Imej-imej TM dan DEM telah digabungkan dengan peta geologi yang telah dibuat pembetulan geometri untuk mengesktrak maklumat geologi yang berkaitan. Peta geologi di sini digunakan sebagai peta rujukan. Antara analisis yang telah dilakukan terhadap imej-imej tersebut adalah komposit warna, analisis prinsip komponen, nisbah jalur, dan pengelasan terselia. Untuk menilai hasil daripada analisis pengelasan terselia, penilaian ketepatan telah dilakukan. Statistik ketepatan menjadi kayu pengukur untuk penilaian analisis ini. Selain itu, analisis kontur dan pola saliran juga dilakukan untuk mendapatkan maklumat ketinggian, arah aliran dan tumpukan aliran. Daripada data magnetik, permodelan magnetik telah dihasilkan untuk menambah baik hasil analisis geologi sebelum itu. Untuk pengkelasan imej bagi dua kawasan, nilai ketepatan adalah antara 43-40 peratus dan beberapa permukaan batu dapat dipetakan dengan baik. Model magnet menunjukkan nilai kesesuaian 16.30 dan 104.87 yang merupakan nilai kesesuaian antara profil model dan profil standard. Pola saliran di kawasan Kuh-e-Djahan Bin agak mudah untuk diterjemahkan berbanding dengan pola saliran di kawasan Gardaneh Rokh. Pola saliran sebenarnya memberi maklumat tentang arah aliran setelah digabungkan dengan peta kontur. Kesimpulannya, analisis-analisis yang telah dilakukan memberi maklumat litologi dan struktur geologi yang berguna untuk kegunaan kajian ini.

Integration of Remote Sensing and Magnetic Methods for Geological Mapping of Central Zagros Area

ABSTRACT

In this project, Thematic Mapper (TM), Digital Elevation Model (DEM) images and PALSAR Radar images were used to study the geological features of Gardaneh Rokh and Jahan Bin area in Iran. Magnetic Grand Survey data and Aero Magnetic data from these two areas were also used for the purpose of the study. The scanned geological maps and Aero Magnetic maps which were geometrically corrected were used with TM, PALSAR and DEM images to extract geological information. The geological map was used as reference or ground truth data. Several analyses have been done to the images such as colour composite, principal component analysis, ratio, supervised classification, and lineament. In order to evaluate the classification process, accuracy assessment was done to the classified images. The accuracy statistics were the measuring scales of the classification. Besides, contour and drainage patterns analyses were also done to extract elevation, flow direction and flow accumulation to provide further information. Magnetic modelling which was processed from the magnetic data was employed to compensate the geological interpretation. For the classified images, the accuracy for both areas was about 44-74 percent with several outcrops which can be mapped appropriately. The TM and PALSAR images were used for lineament to determine the joints, faults and rivers. The magnetic models for these two areas have misfit of 16.30 and 104.87 which are the degree of suitability between the modelling and the standard profiles. The drainage patterns which can be correlated with elevation contours gave information about the flow direction of the drainage in the areas. Therefore, these few named analyses were flawlessly facilitated in interpreting lithologic and structural geological features which were the matter of interest in this study.

CHAPTER ONE

INTRODUCTION

1.1 Research Background

Remote sensing in general is the small or even a large scale acquisition of information of an object or phenomenon by using of either recording or real-time sensing devices that are wireless. Remote sensing can be defined as any process whereby information is gathered about an object or phenomenon and interpreted without being in contact with the object being observed. In practice, remote sensing is the science of acquisition, collection, processing and interpreting the collected data from satellite and aircraft. The device is recording the interaction between object and electromagnetic energy.

The aim of this study was to interpret the geological characteristics of two locations in Iran. These locations are Kuh-e-Djahan Bin, and Gardaneh Rokh. These two zones are located in different provinces of Iran which are Chaharmahal va Bakhtiary and Esfahan accordingly. Since each of these areas has a different and distinctive geological feature and particular climate, this can be a good investigation to compare dissimilar places.

The study actually was emphasized on two parameters that were lithologic and structural interpretation. The first parameter was more on determination and distribution of rock types. The second one was to determine faults, lineaments, contours and drainage patterns.

The required data for this study was obtained from satellite images of Landsat 5 (Thematic Mapper TM) and Digital Elevation Model (DEM) images can be useful to extract geological features as well as geological maps which were used as reference data to the interpretation. Besides, magnetic data from field survey in these two areas which was done in Iran were used to correlate with the geological interpretation.

Data which needed for this project were gathered from satellite images of Landsat 5 Thematic Mapper (TM), ASTER for Digital Elevation Model (DEM), ALOS for Phased Array type L-band Synthetic Aperture Radar (PALSAR) images. They were utilized to derive geological characteristics and geological maps which were used as reference data for interpretation and analysis. In this study, magnetic data from field survey in these two areas used to show the relationship with the geological and aeromagnetic map interpretation.

Geologic maps represent a fundamental scientific foundation on which land-use, water-use, and resource-use decisions can be facilitated. Geologic maps introduced the distribution of rock and soil material sand near the land surface, and are the best scientific product to display the information. As a result it becomes easier for the decision makers to identify and protect valuable resources avoiding risks from natural hazards to perform in this thesis is important and can be considered as a right step in the development process of geological science. The efforts made to implement geological maps using remote sensing and magnetic data are being observed.

1.2 Statement of the Problem

Iran is a vast country which has constantly been the matter of geological investigation for its numerous mines which most of them have not been discovered or exploited yet. On the other hand Iran is a seismic country with various faults and plates which needs to be studied accurately. Therefore, it is necessary to explore on different techniques of geology to discover new information about that. The problem is that in Iran most of the techniques which have been used up to now have been useful and based on field survey by geologists and consequently the geology, topography, and aeromagnetic maps collected from these locations will be afterwards analysed. Therefore, this study will present techniques which do not require the presence of geologists as much as before. This will be done by using satellites remote sensing techniques survey.

1.3 Objectives of the Study

The current thesis tries to follow these objectives:

- To produce terrains maps by using vectors tracing methods.
- To produce rock type maps by supervised classification of TM data.
- To determine the ferriferous areas by magnetic data.
- To extract structural information (faults and joints) from Land sat TM, DEM and PALSAR radar data.

1.4 Scope of Study

Since the area of geology is vast, the researcher tried to limit the discussion to some specific areas which are Gardaneh Rokh and Jahan Bin. Image processing technique was used to analyse satellite data of this study area.

1.4.1 The Study Area

Iran has many geological sections and the area of this study is one of them which is situated partly in Zagros zone (in south east) and partly in Sanandaj-Sirjan (in east north). Since the general appearance of the area is affected by topography of Zagros, the normal direction of the elevations is congruent with the geological structure of the area and normally it is west north-east south. The highest mountains in Zagros zone are Hezargazi Mountain, Jahan Bin Mountain, Darreh Arjin Mountain, Falat Mountain, and Shahda Mountain. Besides, there are some rivers flowing through these routes.

Stratigraphy of this area mostly consists of sedimentary rocks belong to the second, third, and forth geological periods. The petrology of them on the profiles channel is made by Sandstone, limestone, and marl which belong to the third period and these limes have mainly thick layers which are related to cretaceous. Besides, shale-marl and conglomerate units are also seen in some parts of profiles channel along with igneous rocks. Generally, the direction of the layers are west north-east south and the slope are mostly toward east north.

The structural pattern of the area mainly consists of multiple thrusts which led to the elimination or reappearance of some layers. The movements of various faults cause the crush in most parts of this structure and create different joints.

Additionally, regional anticlines and synclines which are mostly incised by the faults are normally found in this area. It seems that the most important and susceptible part of this geological project is crossing the thrust faults, especially passing the main thrust of Zagros.

Based on seismology of the area, this site found to be located in two seismic regions, namely Rezaiye and Zagros and therefore, it is more probable to have several earthquakes especially in the west south part of the area. The earthquake of Naghan in 1977 serves a clear evidence of this fact.

1.4.2 Gardaneh Rokh

The first part of this study has been done in Gardaneh Rokh which is located in the province of Esfahan (Figure 1.1). The province of Esfahan covers an area of approximately 107,027 square km and is situated in the center of Iran. It is surrounded by Markazi (Central) Province and the provinces of Qom and province of Semnan from north and by the provinces of Fars, and Kohgiluyeh and Boyer-Ahmad Province from south. To the east, it is bordered by the province of Yazd. To the west, it is bordered by the province of Lurestan and to the southwest by the province of Chahar Mahal and Bakhtiyari.

In the west part of Esfahan province “Zagros” mountain range is located which starts from North West and continues to the South part of the province and the east part of the province is covered by dessert and low Elevation Mountains. Esfahan, with Zayandeh River at the foothills of the Zagros mountain range has a temperate climate and regular seasons but it is still very hot during the summer with maximum typically around 36 °C (97 °F). However, with low humidity and moderate temperatures at night, the climate can be very pleasant. During the winter, days are mild but nights can be very cold and snow is not unknown.

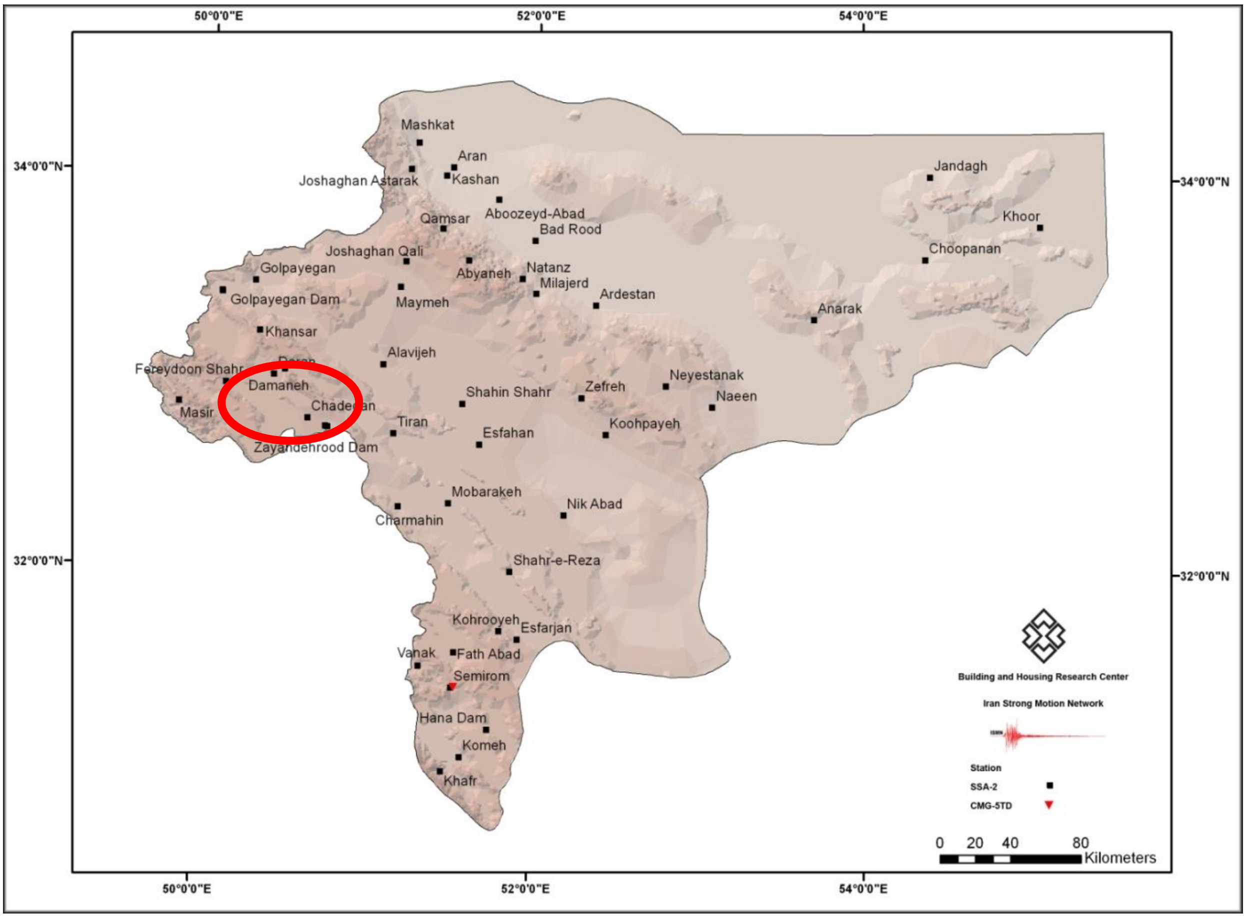

Figure 1.1: Map of Esfahan province

Source: http://www.ngdir.ir/States/StateDetail

The coordinates of the study area were covered from 51^{0}01'11.0549"E and 32^{0}23'02.1025"N (upper left coordinates) to 51^{0}11'45.7990"E and 32^{0}13'49.9072"N (lower right coordinates). There are different minerals to be found in this area such as shale, sandstone, conglomerate, limestone, andesitic volcanic, old and sub recent terraces deposits.

1.4.3 Kuh-e-Djahan Bin

Kuh-e-Djahan Bin in province of Chaharmahal va Bakhtiary (Figure 1.2) is the second area to be investigated in this study. With an area of 16,532 square kilometers, the province of Chahar Mahal and Bakhteyari is located in the center of the mountain chains of Zagros Mountains by two mountain chains of the interior Zagros Mountains and the province of Isfahan. It is formed of two main regions, Chaharmahal va Bakhtiary. The capital of this province is Shahr-e-Kord.

The province of Chaharmahal va Bakhtiary is one of the coldest places in Iran. The annual average of temperature in different parts is under the cause of different regional factors and freezing days are different in the different parts of the province. Because of heights and huge sources of water also rivers and entering the humid flows (rain – snow), relative humidity is in a good condition.

From North to South of this province, temperature rises gradually. Generally, the climate in South is warmer than in North. In this province also, the precipitation is not uniform. In high mountainous area of North, the precipitation is in the form of snow while in lowlands it is in the form of rain. Snowy highlands of this province are the origin of many high springs and rivers. Besides, vegetation of this province has a direct relation to the altitude and soil type. In general, the density of vegetation is increasing from East to West, which is shown in Figure 1.2.

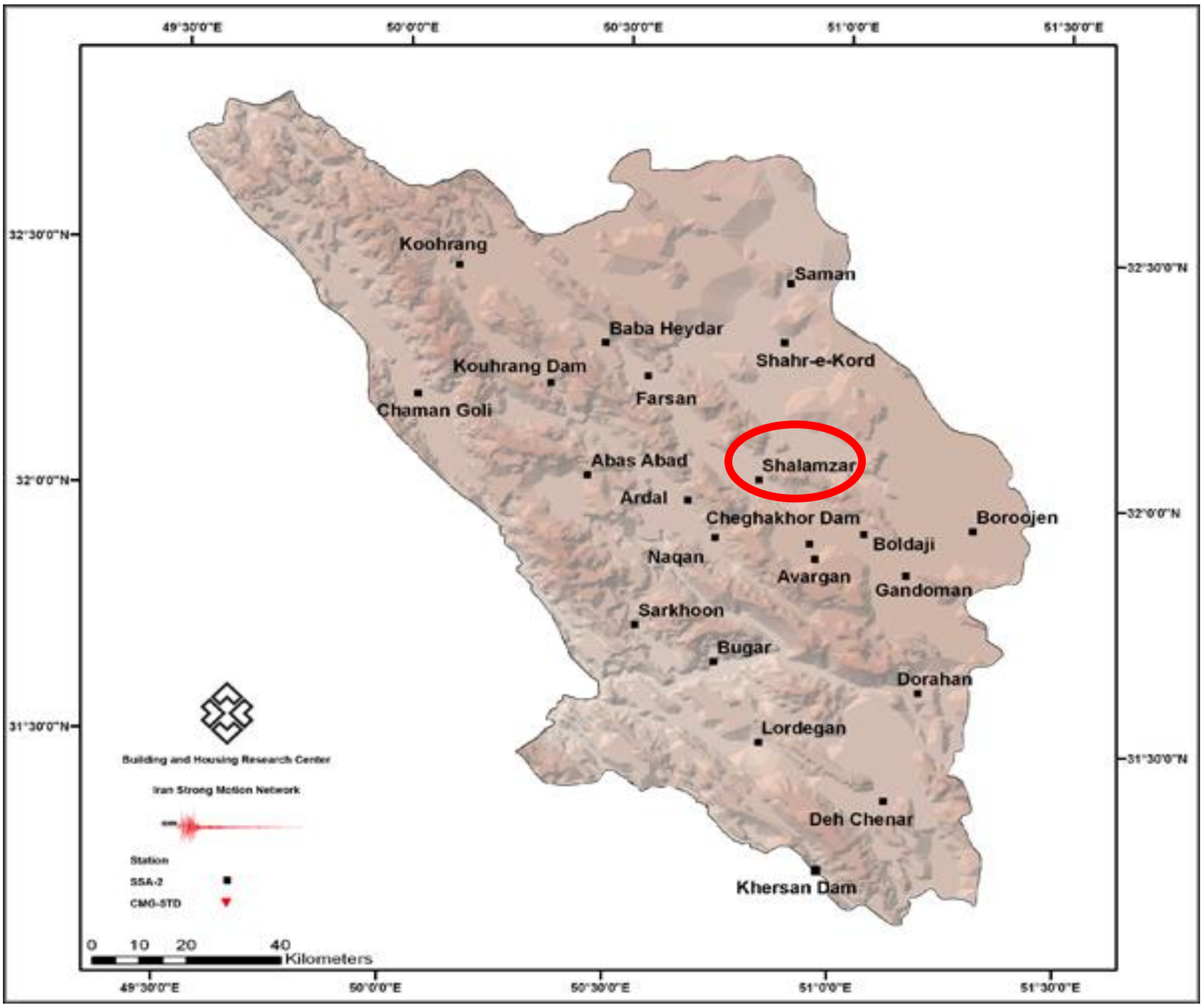

Figure 1.2: Map of Chaharmahal va Bakhtiary province

Source: http://www.ngdir.ir/States/StateDetail

The covered area of Chaharmahal va Bakhtiary for this study starts from 50^{0}44'08.1446"E and 32^{0}09'02.5211"N (upper left coordinates) to 50^{0}54'42.9775"E and 31^{0}59'56.3598"N (lower right coordinates) as shown in areas of the province. The temperature of this area has been found to be warmer than others. The minerals found in this area are sandstone, limestone, conglomerate, shale, marls and quaternary deposits.

1.4.4 Techniques used in data processing

There were several techniques used in data processing as means of ensuring the efficiency of geological interpretation in the study. To interpret lithologic and structural features, the techniques which have been used were colour composite, principal component analysis, band ratio and image classification. The classification part was the most important and the efficiency can be evaluated by accuracy assessment. All these techniques were done by using PCI Geomatica V9.1 software. Modelling of magnetic data was part of the technique as well. This was done by using Mag2dc software which was used to correlate with the geological interpretation from previous techniques.

1.4.5 Data

Data was used in this study was selected from three satellites which are namely Landsat5 TM, Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) and Phased Array type L-band Synthetic Aperture Radar (PASLAR).The ground magnetic data and aero magnetic used to produce magnetic maps. The geological maps was used for comparison the results as references.

1.5 Significance of the Study

This study, by using the techniques mentioned above, and with the collected results from them paves the way for analysing geology of the scoped areas including terrain and type of rocks.

Therefore, the significance of this study is to compare the grand magnetic survey result by satellites with the ones achieved by direct observation. By utilizing vector tracing methods on terrain maps, all distributed joints and faults can be recognized in the regions in which in some of them alluvium field and sedimentary rocks are recognizable. By understanding the abrupt changes in distribution of ores, one will be able to recognize the existence of joints and faults so that by integrating and comparing the obtained TM and radar maps, the joints and faults can obviously be seen. Besides, by using the classification maps which are gained by TM and then integrating and comparing those maps with those obtained from magnetic survey, one can clearly recognize the distribution of iron in Gardaneh Rokh and Jahan Bin area.

1.6 Summary of the Thesis

Generally, the outline of this thesis is organized as follows. In Chapter two the theories used in this study are briefly explained which are namely remote sensing and magnetic survey.

Chapter three will show the data acquisition and methodology of magnetic data and images. These data are explained with respect to parameter used, survey design and related matters.

Chapter four is assigned to present the results and also the discussions of the produced map and correlated the magnetic survey and remote sensing for easy interpretations.

Finally, Chapter five includes conclusion of the magnetic survey, satellites images and Aero magnetic survey to integrate the geology.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Geological investigations can be effectively carried out by integrating different data analyses and techniques (Lunden et al., 2002; Hirn et al., 2008).). In geological investigations, an understanding of the geomorphology, structure, and geophysical characteristics is required to accurately targets areas and reduce the ambiguity of geological interpretations (Saadi et al., 2008). Identification of morphological feature using remote sensing technique is often a powerful tool for classifying and locating water sources, minerals, quarries, gas and precious metals or for reconstructing the paleo-s .By 1997, at least six civilian land remote sensing satellite systems were beginning operated by the United States, France, India, Japan, Canada, Russia and The European Space Agency. On command, all of them make measurements of the land sat surface, transmitting spectral data from this earth-Observing satellite are used to map, monitor, and manage the earth's natural and cultural resources.

Most histories of remote sensing identify Gaspard Felix Tourna chon as first person to photograph "remotely", using balloons above Paris n 1859. Balloons were also used for areal reconnaissance during the American Civil War. By 1909, aerial photographs were being taken from airplanes for a wide range of uses, including warfare, land-use inventory, and publicity. Aerial photography remains an important application of remote sensing, with a sophisticated range of cameras, forestry, water pollution, natural disasters, urban planning, wildlife management, and environmental impact assessments (Lillesand and Kiefer, 1987). Evelyn Pruit of the office of Naval research originally coined the term remote sensing. cenery (Blumberg et al., 2004).

Since remote sensing can reveal information that is beneath the ground and not observable on ground, thus they are used for mineral exploration (Sabins, 1999). However, the penetrate depth of energy within a soil layer is dependant upon wavelength and the soil water content (Blumberg et al., 2004).

The current context for the application of remote sensing in geomorphology is presented with a particular focus upon the impact of new technologies, in particular: (1) the wide availability of digital elevation models; and (2) the introduction of hyperspectral imaging, radiometrics and electromagnetics. Remote sensing is also beginning to offer capacity in terms of close-range (<200 m) techniques for very high-resolution imaging (Rabus et al., 2003; Sithole and Vosselman, 2004).

Several previous studies are using remote sensing systems for geological mapping. Some are deploying only on single remote sensing system such as satellite (Landsat, Thematic mapper) or deploying only on aircraft. But some are deploying on Radar systems which are using both satellite and aircraft. Thurmond et al. (2005) used integration of optical (Landsat), radar and Digital elevation models (DEM) remote sensing data for geological mapping in the Afar Depression. The data integration by combination of several comparable spatial resolution remote sensing data sets can effectively measure the different properties of terrain images. Multispectral optical remote sensing data record information based on material composition whereas radar data emphasizes on surface roughness and morphology (Thurmond et al., 2006). Thus, the integration of these data sets allows analysis of two properties in a single colour (Red, Green and Blue) combination image.

Introduction of digital elevation models (DEM) allows analysis of geological features such as morphological structures. The DEM data were used for the identification of geological lineaments in the study area. In this study, a multisource investigation was performed, including mapping and analysis of the tectonic structures and their surface expressions in the Zagros Mountain, using DEMs, Landsat ETM+ images (visible composite), geologic maps, and aeromagnetic data. Geological lineaments that have topographic expression are conspicuous in because DEMs avoid bias caused by the illumination direction (Smith & Wise, 2007).

The lineaments were extracted by calculating and interpreting DEM precuts, including shaded relief maps, slope maps, and traverse profiles. The identification of geological lineaments was a valuable tool for improving their knowledge of the surface structure of the Zagros Mountain.

The analysis and interpretation of the extracted lineament lengths and trends based on the age of the geological formations provided information about the tectonic evolution of the study area. Geophysical data record the physical characteristics of subsurface geological features, allowing subsurface structures to be identified and interpreted. Aeromagnetic data was utilized to gain a general picture of the subsurface structure in the study area. Horizontal Gradient (HG) and Analytic Signal (AS) filters were used to locate the edges of the subsurface structures (Dolmaz, 2007; Saadi et al., 2008).

2.2 Image Processing

The modern remote system records the image data in a digital raster format that is suitable for computer processing by using the market readily available software. The images that acquired from remote system (satellite) cannot be transferred to maps, because they are geometric distorted and subject to other image distortions. The images are distorted due to noise which degrades the images. Satellite images need to be processed to transform into meaningful map information. The digital processing includes several methods to provide a useful map for visual interpretation and multispectral land classification. Sabins (1997) groups image-processing methods into three functional categories: image restoration, image enhancement and information extraction.

Image restoration compensate for image errors, noise and geometric distortions that introduced during scanning, recording and playback operation. The noise or distortions degrade the image. The two common errors that occur in multi-spectral image are stripping and line dropouts. The stripping are errors that occur in data transmission and recording and it result in shift of pixels between rows while the line dropouts are errors in the data recording and transmission which loses a row of pixels in the image. The purpose of image restoration is to construct the restored image to resemble the scene on the terrain. The typical processing practice is including correcting geometric distortions, filtering random noise, restoring line offset, line dropout and periodic line stripping.

According to Sabins (1997), the image enhancement is altering the visual impact on image to improve the information content of the image by altering the pixels values. The image is conversed to a more understandable level for image interpretation and information extraction. There are several technique can use to enhance an image such as contrast enhancement, edge enhancement, density slicing and intensity, hue and saturation transformations. While the third category information extraction is purposely to display spectral and other characteristics of restored and enhanced image. Information extraction utilizes computer to combine and interact between different aspects of a data set.

2.2.1 Geometric Correction in Satellite Image

The remote sensing images typically are geometric distorted. Geometric distortions in an image mean that the image feature is not accurately related to the map position or ground landscape. The geometric distortions or geometric errors can be categorized into two groups: systematic and nonsystematic geometric error. The systematic geometric error is usually predictable and is easier to identify and corrected compared to the nonsystematic geometric error. The internal geometric errors are introduced by the remote sensor itself or combination of curvature and movement of Earth. These internal geometric error generally is systematic thus can be identified and corrected by using pre-launch ephemeris such as the knowledge about the orbit parameters, the nature of the sources of distortion during the acquisition time.

External geometric errors are generally introduced by the phenomena that vary through time and space. Thus, the external geometric errors are unpredictable or random distortions. The random movement either attitude or altitude changes of aircraft at the exact time of collection is most commonly contributes to the external geometric distortions. The random distortions are corrected by establishing mathematical relations between the coordinates of pixels in an image and the corresponding points on the ground, without prerequisite of knowledge or information about source and type of distortion.

All the remote sensing images from satellites are subjected to geometric distortions, therefore geometric corrections, as preprocessing operations are required prior to imagery interpretation, analysis and information extraction (ELtohamy et al., 2009). Because of the movement and curvature of the Earth and the rotation of sensor platform, the remote sensing images always have geographic distortion. The geometric distortion is also a representation of the irregular surface of the earth. Moreover, earth rotation, terrain and atmospheric effects also cause significant distortion in satellite images.

The geometric errors can be corrected to a certain extent with detailed instrument and spacecraft information that provide instrument calibration data, spacecraft attitude, altitude and velocity of sensor platform at sufficiently small time interval. However, these data are not accurate enough for high resolution image. It is necessary to through pre-processing by using ground control point to correct the geometric distortions. The most common approach for geometric correction is the use of mapping polynomial by the selection of several clearly points, called ground control point (ELtohamy et al., 2009).

The goal of geometric rectification is to rearrange the location of features in an image to agree with some desired scheme. Typically, the analyst wants to make the image conform to some standard cartographic projection used in geologic mapping, such as the Universal Transverse Mercator (UTM) projection.

The digital techniques of removing distortions are introduced solely by the imaging system and those which are a function of the viewing geometry. The removal of geometric distortions can be accomplished in two ways:

1. The actual location of the pixels can be changed during construction of a picture.
2. The pixel grid can be retained and the individual pixels assigned new Digital Number (DN). This is called "resampling".

The first approach is useful primarily for simple geometric corrections such as normalization of aspect ratio, the ratio between the scales (meters per pixel) in the horizontal or sample and the vertical or line directions of an image. Because this method adjusts image geometry after all other processing is complete, it is not useful if rectification is necessary for any stage of the image processing during construction of the display picture.

Resampling, the second approach is a flexible, powerful technique used to restructure the geometry in an image. There are two approaches illustrated in Figure 2.3. In each of them some attempt is made to recreate or model the scene that was sampled to form the image. This modelled scene is then resampled to form an image with the desired geometric characteristics. The severity of image degradation resulting from resampling increases as the size of local area and the computation time decrease.

In resampling an image, a feature in the scene to be located at pixel (l, s) in the geometrically corrected image being constructed will be found at (x, y) in the distorted image. Resampling techniques differ in the method by which the DN which should be stored at pixel (l, s) of the output picture is derived from the input picture.

In nearest neighbour resampling algorithm it does not degrade the representation of fine detail as other resampling algorithms do. This happens because no interpolation which smoothes the data takes place. On the other hand, at the discontinuities in the resample sites the geometry of the image itself will be seriously disrupted. By comparing with bilinear interpolation resampling algorithm, nearest neighbour involves less computation time but bilinear interpolation is geometrically more accurate (Siegal & Gillespie, 1980).

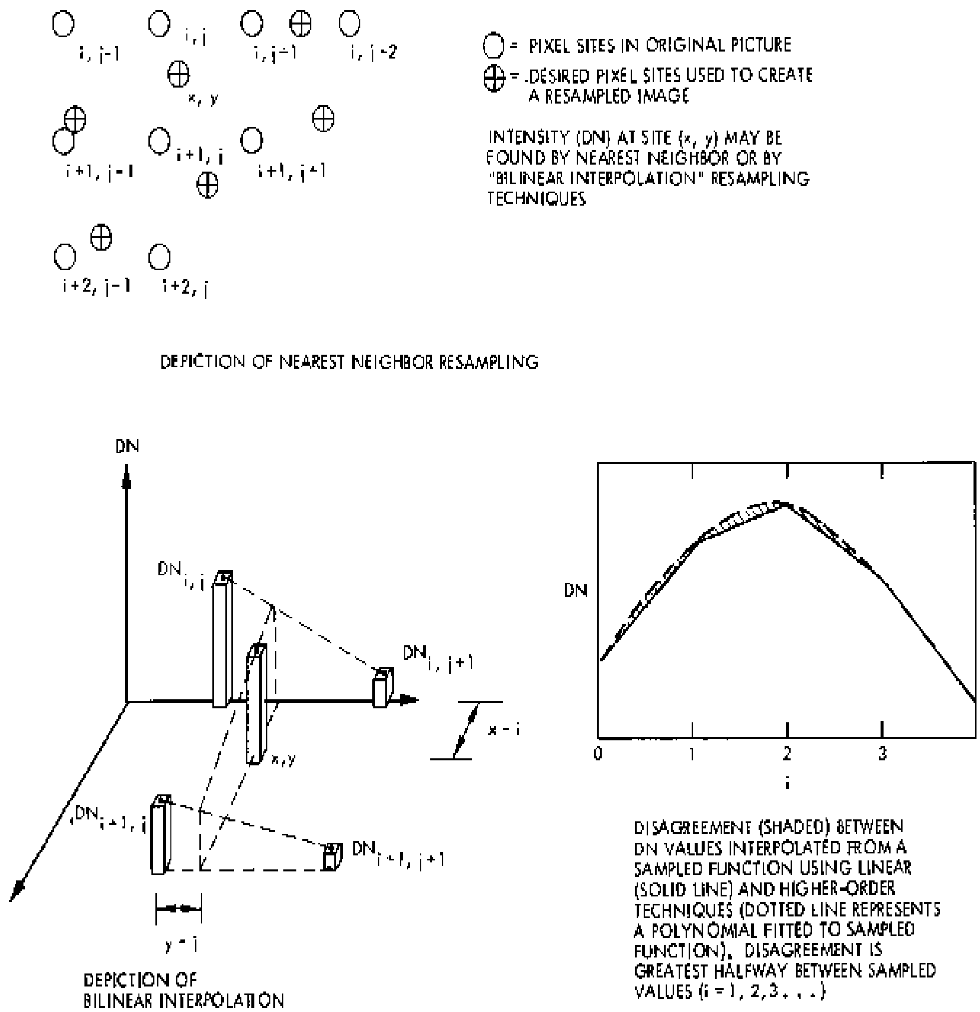

Figure 2.1: Nearest neighbour and bilinear interpretation resampling techniques

2.2.1.1 Ground Control Points (GCP)

In order to correct the geometric distortion and register to a reference map, the Ground Control Points (GCP) are needed. GCP is used for geometric distortion correction in an image by matching the image coordinates with map coordinates. A ground control point (GCP) is a location on the surface of the Earth with known geographic coordinates which can be located on the imagery and identified accurately on a map. GCP normally is a small point with distinctive features that selected from the topography maps and with relatively small possibility of changes in surface feature (Yang et al., 2009).

In order to collect a GCP two distinct sets of coordinates: image coordinates and map coordinates must be obtained. These GCPs are very important in the geo-rectification process. Because the paired coordinates form many GCPs (eg. 20) can be modeled to derive geometric transformation coefficients and these coefficients are used in geo-rectification. The more points are collected and used, the more accurate the image will be as it will minimize the errors.

Geo-rectification is the process of assigning geographic coordinates to a digital image using ground control points (GCPs). Geo-reference involves matching the coordinate systems of two digital images with one image acting as reference image and the other as the image to be rectified. The digital image is geo-reference to a map coordinate system. Each pixel is attached with a specific location based on a coordinates system (latitude and longitude) during the computer geo-rectification. The digital image is adjusted to scale and rotated to be aligning with the Earth geological criterion.

However, rectification is not necessary if there is no distortion in the image. For example, the image that produced by scanning of a paper map in the desired projection system is not required to rectification as the image is already planar. But, the image does not containing of coordinate information. So, the image needs to be geo-referenced.

2.2.2 Colour Display of Image Data

Colour display of remote sensing data is important for visual interpretation. There are two types of color display methods. One is colour composite and the other colour display method is pseudo- colour display.

2.2.2.1 Colour Composite

Colour composite is used to generate the colour with multi-colour band. The image colour normally can be generated by composing the three selected multi-band image with the use of three primary colours. The three primary colours are including blue, green and red. Sabin (1999) mentioned that colour composite ratio images are produced by combining three ratio image in blue, green and red. However, different color image can be obtained depending on the selection of there band images. There are two method of colour composite method. One is additive colour composite by uses of three primary colour light sources (blue, green and red) and the second method is subtractive colour composite which is using of three pigments of three primary colours (cyan, magenta and yellow).

Satellite images are not always divided into same spectral regions of three primary colour filters. The satellite images are capturing the electromagnetic energy that not only from visible wavelength range but also from invisible region, such as infrared. Colour composite make fullest use of the capabilities of human eyes for visual analysis. So, the infrared band is required to display in colour. A colour composite with an infrared band are referred to false colour composite.

The advantage of colour composite images is can display the spectral difference and vegetation distribution. In project of Sabins (1999) demonstrated that the advantage of colour ratio image is that it combines the distribution patterns of both iron minerals and hydrothermally clays. However, colour composite image also have disadvantage; as the colour patterns are not as distinct as in the individual density-sliced images.

The use of colour pictures to display three channels of multispectral image data provides a dramatic increase in the amount of information that is available for interpretation. There are two reasons for this. First, the same gray level information that can be displayed in a black-and-white picture can also be displayed as brightness in a colour picture. In addition, the extent of correlation among the three channels can be displayed as colour. Second, in a colour picture all the information contained in three black-and-white images is contained in a single picture, so that the information is easier to interpret.

It is important to emphasise that only rarely do the colours in which image data are displayed correspond to the spectral region in which they were acquired. One particularly productive use of colour is the ‘colour ratio picture’ in which three different ratio images are displayed as a colour picture. This colour ratio pictures is perfect in revealing lithologic differences (Siegal & Gillespie, 1980).

2.2.2.2 Pseudo Colour Display

Pseudo colour display is allocation of different colours to the gray scale of a single image. The three primary colours are applied in order to produce a continuous colour tone.

2.2.3 Image Ratio

Ratio images are prepared by dividing the value for one band by that of another band, after atmospheric corrections have been made (Sabins, 1997). It is possible to divide the digital numbers of one image band by those of another image band to create a third image. The ratio image may used to remove the influence of light and shadow on edge that due to sun angle. The ratio image can enhance the vegetation and geology by calculate certain indices. In Sabins (1999) project, ratio images were used to identify areas with high concentrations of iron oxide mineral, clays and alunite which were used to plot on the map. Moreover, ratio images can used to emphasize and quantify the spectral differences (Sabins, 1999). Sabins (1999) demonstrated that higher ratio values represent hydrothermally altered rocks while low ratio values represent unaltered rocks.

Just as any three channels of an image can be displayed as a colour image, they may also be analyzed in terms of colour. Principal component pictures can be regarded as describing “colour” in a scene, even though this “colour” does not correspond to human perception of colour. Another way of measuring colour is to create a “ratio picture” in which the DN at any pixel represents the ratio of the DN from two channels:

$$DN'_{ls} = a \frac{DNi_{ls}}{DNj_{ls}} + b$$

where DN' is the ratio of the DN from channels i and j at line l sample s, scaled to fit in the dynamic range by constants a and b. Ratio values can range from zero to infinity, but because reflectivity in terrestrial scenes is strongly correlated across much of the spectrum, most observed ratio values lie between about 0.25 and 4.0. Typical values for a and b are 400.0 and -300.0, but these vary over about an order of magnitude with different scenes and spectral regions.

Ratio pictures are useful because they exaggerate colour differences. If DNi > DNj, DN' is high or bright; if DNi < DNj, DN' is low or dark. If the albedo or the illumination changes across the scene but the colour does not, the ratio picture will show no change. Thus ratio pictures have the effect of suppressing the detail in a scene which is caused by topographic effects, while emphasising colour boundaries. This property has made ratio pictures quite useful in geologic applications because they exaggerate subtle colour differences in a scene, and many geologic problems require the distinction between rock types that may appear to be quite similar. However, ratioing suppresses the ability of the analyst to discriminate between rocks with strikingly different albedos, but similar reflectance spectra (Siegal & Gillespie, 1980).

2.2.4 Principal Component Analysis (PCA)

Principal component analysis (PCA) determines the eigenvectors of a variance-covariance or a correlation matrix (Ranjbar et al., 2001). PCA has been called one of the