1-1-General Statement

What have been studied in history of geology in Iran on Zagros Structural Belt (ZSB) of South-West of Iran, is more noticeable to many internal and external scientists because of presence of oil and other natural resources and beautiful geological structures.

Eurasian plate in north and Arabian plate in south (Fig. 1-1) are respectively two plates, which are bounded by Iranian region in the Alpine-Himalayan System. Two main belts, related to Alpine fold are: a) Alborz Belt in north b) Zagros Structural Belt (trend NW-SE). In fact these two belts have formed V shape in such a way that they are meeting each other in the end of Azarbeyejan province.

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On the other hand earth scientists received their first glimpses of the earth from space in photographs from Ballon missions in the early 1960s. Satellite imagery has a great impact on the scientific understanding of the geology, although most widely used comprehensive space data are for the earth sciences. Tectonic landforms visible on space imagery can thus aid in deciphering the structural history of an area in context with adjacent areas.

The pioneer work for the division of geology of Iran was done by Stocklin (1968). He divided Iran into nine regions of different history, structure and sedimentation. Later other workers (Berberian 1976, Colman-Sadd 1978, Darvishzadeh 1992, Rangzan 1993) redefined these divisions, which are as follows:

1- Kopeh dagh
2- Alborz Belts
3- Makran Accretionary Complexes
4- East of Iran Belt
5- Central Iran Blocks (including Lut and Tabas blocks)
6- Urumieh Dokhtar Arc
7- Sanandaj-Sirjan Zone (SSZ)
8- Imbricate Zone (IZ)
9- Zagros Fold Belt (ZFB)
10- Molasse Cover Sequence (MCS), characterized by distinct geological signatures.

With reference to plate tectonic theory and tectonic activities the collision of the Neo-Tethys and their later compressional movements were responsible for development of Zagros Structural Belt. The collisions of Iranian and Arabian plates in Miocene age...
resulted in the formation of Zagros Mountains. The Zagros Structural Belt extends for 1500 km from Tarus Mountains in southeast Turkey, through south-west Iran, and terminates near the strait of Hurmoz at the mouth of the Persian Gulf abutting against the Minab Transcurrent fault (Berberian 1976).

The Zagros Structural Belt comprises five litho-tectonic units from NE to SW, are Urumieh-Dokhtar Arc (UDA), Sanandaj-Sirjan Zone, Imbricate Zone, Zagros Fold Belt, and the Molasse Cover Sequence (Rangzan and Iqbaluddin 1998).


The continuing tectonic deformation of the Zagros can be demonstrated with cases of active faulting (Berberian 1976). He reported that the vertical movement and rapid growth of anticlines are mostly in southwest flank. Due to tectonic activities and related movements in the Zagros belt the early deformation are continuing to the present day resulted in the formation of another major structure, called the “Main Recent Fault” (Tachalenko and Braud 1974).

In order to study the structural and tectonic behaviour of Zagros Structural Belt various digital satellite data such as Landsat Thematic Mapper (TM) dated June 1991 and Landsat Enhanced Thematic Mapper (ETM) dated October 2002 have been acquired for the study of parts of SW Iran, i.e. Andimeshk to Brojerd city. The digital topography maps on the format of Digital Graphic Number (DGN) have also been acquired from Iranian Surveying Organization (ISO).

The study has been carried out using Remote Sensing and GIS techniques to interpret, analyze and generate various maps and Digital Elevation Model (DEM) of the total study area for structure and tectonic geomorphology evaluation of Zagros Structural Belt of southwestern Iran.
1-2- Study Area

The study area (Fig 1-2) extends from Dezful of Khuzestan province to Khorramabad and Doorud-Brojerd of Lorestan (Lurestan) province in the north.

Administratively the study area is in parts of Khuzestan and Lorestan provinces of the Islamic Republic of Iran. The important cities in the study area are Dezful, Andimeshk, Pule-Dukhtar, Sepiddasht, Khorramabad, Durud and Brojerd.

These two provinces are most important from geological point of view as both of them are located in such within the Zagros Structural Belt. Both the provinces have different lithostratigraphic and geomorphologic settings. Zagros Mountains vary in elevation from about 142 meters to 4000 meters above Mean Sea Level (MSL).

The study area is bounded by Longitude 47° 58' 1.42" - 49° 18' 50.63" E and Latitude 32° 21' 40.94" - 34° 29.10" N of Landsat imagery-9-Nov-2002, with Path/Row number 166/037 (Fig 1-2) and is covered by digital topographic sheets of Dezful and Khorramabad blocks of ISO numbers (5654, 5655, 5656, 5657, 5755, 5756, 5757, 5855, 5856) on scale 1:25000 (Fig 1-3).
Chapter 1  

Background & Introduction

Fig. 1-2) Map showing the study area in SW Iran

- SSZ - Sanandaj Sirjan Zone
- ZFB - Zagros Fold Belt
- HZ - High Zagros
- MZT - Main Zagros Thrust
- MCS - Molasse Cover Sequence

Fig. 1-3) Shows 1:25000 Index map blocks of the ISO. Study area is based on toposheets of Dezful Block & Khorramabad Block

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1-3-Materials Used

1-3-1-Data Acquisition

Landsat-5 TM and Landsat-7 ETM-2002 satellite data were purchased from Iranian Remote Sensing Center (IRSC) whereas digital topography maps in the scale 1:25000 were provided by ISO. The various maps like geology, geomorphology and tectonic were provided by the Remote Sensing and GIS centre of Shahid Chamran University, Ahwaz, Iran.

The Global Positioning System (GPS) was procured to check the ground control points (GCP) during the field visits.

1-3-2-Landsat TM -1991 (Fig. 1-4) Data

Scene ID (Fig.1-4) : 2233074-01 WRS =166/03700
Date (YYYYMMDD) : 19910630
Satellite : L5
Instrument / sensor : TM
Product Type : ORBIT ORIENTE
Projection : SOM
USGS Projection # : 21
USGS Map Zone : 166
Pixel size (meters) : 28.50
List of bands on tape : 1234567
Pixels per scan line : 6967
Scan lines per image : 5965

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Chapter 1  Back Ground & Introduction

<table>
<thead>
<tr>
<th>Longitude</th>
<th>Latitude</th>
<th>Easting</th>
<th>Northing</th>
</tr>
</thead>
<tbody>
<tr>
<td>DDDMMSS.SSSSH</td>
<td>DDDMMSS.SSSSH</td>
<td>(meters)</td>
<td>(meters)</td>
</tr>
<tr>
<td>Upper-left: 0471115.9147E 340534.9360N 385471.841 16310323.148</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper-right: 0491812.1741E 334712.2477N 583672.010 16321779.635</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower-right: 0485836.3260E 321645.2629N 573863.441 16491470.391</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower-left: 0465345.8391E 323449.5090N 375663.273 16480013.904</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig.1-4) Satellite TM data of the ZSB, SW-Iran

1-3-3-Landsat ETM+ Data (2002)

FORMAT

Landsat data are provided in GeoTIFF as radiometrically and geometrically corrected (level-1G) products. GeoTIFF defines a set of publicly available TIFF tags that describe cartographic and geodetic information associated with TIFF images. GeoTIFF is a format that enables referencing a raster image to a known geodetic

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model or map projection. The initial tags are followed by image data that in turn, may be interrupted by more descriptive tags.

DATA FILE NAMES

The file naming convention for Landsat-7 (GeoTIFF) is as follows:

L7ppprrr_rrrYYYYMMDD_AAA.TIF where:

- L7 = Landsat-7 mission
- f = ETM+ data format (1 or 2)
- ppp = starting path of the product
- rrr_rrr = starting and ending rows of the product
- YYYYMMDD = acquisition date of the image, 2002-NOV-9
- AAA = file type:
  - B10 = band 1
  - B20 = band 2
  - B30 = band 3
  - B40 = band 4
  - B50 = band 5
  - B61 = band 6L (low gain)
  - B62 = band 6H (high gain)
  - B70 = band 7
  - B80 = band 8
  - MTL = Level-1 metadata
  - TIF = GeoTIFF file extension

The file naming convention for other Landsat GeoTIFF is as follows:
\[ \text{LTNpppprOOYYDOY10-AA.TIF} \] where:

- **LT** = Landsat thematic mapper
- **N** = satellite number. This should be valid against the satellite field if used exclusively
- **ppp** = starting path of the product
- **rrr** = starting row of the product
- **OO** = WRS row offset (set to 00)
- **YY** = last two digits of the year of acquisition
- **DOY** = Julian date of acquisition
- **1** = instrument mode
- **0** = instrument multiplexor (MUX)
- **AA** = file type:
  - **B1** = band 1
  - **B2** = band 2
  - **B3** = band 3
  - **B4** = band 4
  - **B5** = band 5
  - **B6** = band 6
  - **B7** = band 7
- **TIF** = GeoTIFF file extension
Chapter 1  
Back Ground & Introduction

1-3-4-Softwares Used

The different software were used to access the goal for the complementation of the present research work are as follows:

- Microstation J, used for monitoring the topography maps, to change in required formats and to make possible corrections
- Rivertools2.4 software, used for creation of DEM and extraction of geomorphic parameters
- ER-Mapper 6.1 software used for geo-referencing and DIP on the images and generation of 3-D images

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• ENVI 3.5 software was used for DIP and creation of different False Colour Composite (FCC) images
• PCI software was used for generation of DEM of the total study area.
• Arcinfo software was used to make topology for the digitized objects on the satellite image as well as on the scanned maps.
• Arcview 3.2 software with great extensions such as Stability Index Mapping (SINMAP) were used for GIS analysis and to store datasets
• R2V was used for digitization
• The other softwares used include Microsoft Excel and Microsoft Word.

1-4-Methodology

Remotely sensed data of the study area were interpreted using image interpretation techniques and several field visits (before and after) were also carried out to analyze and extract accurate input data. Data collection (Table-1-1) was one of the most time-consuming and expensive matter. GIS tasks was most important tool to interpret structure and tectonic of Zagros Structural Belt. Basically, two methods of data collection were carried out as follows:

1-Data capture 2-Data transfer.

Our primary geographic data sources were captured specifically for use in GIS by direct and indirect measurement. Secondary sources from earlier studies were also calibrated to increase our accuracy. The study carried out to collect data are given in Table 1-1.
Image restoration and image enhancements have been done to remove errors and noise in data to increase interpretation ability of analyst. The satellite data for both the images used in the study area were geometrically rectified using ER-Mapper and ENVI software.

Table 1-1- Classification of Geographic data for data collection purposes in the ZSB.

<table>
<thead>
<tr>
<th>Type</th>
<th>Raster</th>
<th>Vector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary</td>
<td>Digital remote sensing images</td>
<td>GPS measurements and</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Survey measurements</td>
</tr>
<tr>
<td>Secondary</td>
<td>Scanned maps and Photographs, Digital</td>
<td>Topographic maps,</td>
</tr>
<tr>
<td></td>
<td>Elevation Model (DEM)</td>
<td>Toponomy (place name)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>databases</td>
</tr>
</tbody>
</table>

The Landsat ETM data of 9-Nov-2002 was registered with 100 Ground Control Points using Global Positioning System and topography maps. Another Landsat TM image of 30-June-1991 was registered using image to image registration techniques. Generally, different FCC images were developed in each step of the research work.

The DEM of the study area (Fig. 3-1) was generated using digital topography maps of the standard DGN formats of ISO. These formats were converted to text (.txt) format using Microstation J software and then introduced to different remote sensing and GIS software to create DEM. Data were edited and made for GIS environment for analysis. This is termed as GIS ready. Basically DEM was made in different software to use the technical advantages of each softwares. For example DEM was made in Rivertools software to analyze topographic profile and river profile for tectonic

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geomorphology. DEM was also made to create 3-D image of the study area (Fig. 4-3 and Fig 4-4) using ENVI software.

However, in this study different methodology was used for interpretation of structure and tectonics of the study area. So the methodology has been described separately in each chapter. For example in geological prospective the methodology was basically on image and geological map calibration, field visits (before and after), to extract different litho-tectonic and lithological formations of the study area. Tectonic geomorphological studies were made on the basis of DEM, calibrated to satellite images and field checks. Structural analysis was also carried out using image element techniques by on screen digitization. Finally importance of the GIS was proved, by representing the modern analysis and method for the interpretation of the structure and tectonics of Zagros Structural Belt. So for this reason different types of spatial analysis were carried out to study structures and tectonics of the Zagros Structural Belt. These are as follows: 1) queries, 2) measurement, 3) transformations and 4) descriptive.

In the present work the following steps (Fig 1-6) have been processed for the data analysis of Zagros Structural Belt in GIS environment.

Fig. 1-6) Procedure for a GIS in the present study

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1-4-1- GIS Coverage

To achieve a fully comprehensive tectonic and structural analysis (Table 1-2) of the Zagros Belt, data "coverage" or "layers" within a GIS have been constructed (Figure-1-7).

The coverage may be generated from various provenances. Some have been digitized through the datasets and others are results of interpretations. During the construction of the coverage, strict control on uncertainty and errors ensures the highest accuracy both within and among the datasets. This means that care should be taken during creation of map projection parameters, digitization and cross-checking.

Presently the Universal Transverse Mercator (UTM) projection has been used for all the work. Storing data within a GIS has tremendous advantages in comparison with hard-copy records or independent computer databases. Once all the data are entered, data access becomes much faster.

Fig.1-7) Theme codes in the digital data can be used to separate into thematic layers

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Table 1-2 - All coverage currently included, for GIS platform

<table>
<thead>
<tr>
<th>NO.</th>
<th>Coverage Type</th>
<th>Source/reference</th>
<th>Original scale</th>
<th>Quality extent</th>
<th>Feature type</th>
<th>Special note</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Imagery</td>
<td>IRSC</td>
<td>30 m ground resolution 166/0 37</td>
<td>ZSB</td>
<td>Image</td>
<td>7 spectral bands</td>
</tr>
<tr>
<td>2</td>
<td>Topography</td>
<td>ISO</td>
<td>1:25000</td>
<td>ZSB</td>
<td>Text format</td>
<td>The DGN formats data converted to text.</td>
</tr>
<tr>
<td>3</td>
<td>DEM</td>
<td>Prepared with the help of Softwares</td>
<td>1:25000</td>
<td>ZSB</td>
<td>Grid</td>
<td>Resolution pixel is 30 meters</td>
</tr>
<tr>
<td>4</td>
<td>Drainages</td>
<td>Drawn with the help of Softwares</td>
<td>1:25000</td>
<td>ZSB</td>
<td>line</td>
<td>Dendritic, Sub-dendritic, Trellis</td>
</tr>
<tr>
<td>5</td>
<td>Faults</td>
<td>Identified in Image</td>
<td>1:25000</td>
<td>ZSB</td>
<td>line</td>
<td>Strike, Normal, reverse fault seen.</td>
</tr>
<tr>
<td>6</td>
<td>Folds</td>
<td>Identified in Image</td>
<td>1:25000</td>
<td>ZSB</td>
<td>line</td>
<td>Anticline, Syncline, Open, Close folds seen</td>
</tr>
<tr>
<td>7</td>
<td>Thrust Faults</td>
<td>Identified in Image</td>
<td>1:25000</td>
<td>ZSB</td>
<td>line</td>
<td>Four thrusts fault seen like MZT</td>
</tr>
<tr>
<td>8</td>
<td>Lineaments</td>
<td>Interpreted from Image</td>
<td>1:25000</td>
<td>ZSB</td>
<td>line</td>
<td>Many other lineaments could be drawn</td>
</tr>
<tr>
<td>9</td>
<td>River Basin</td>
<td>Drawn &amp; Calculated</td>
<td>1:25000</td>
<td>ZSB</td>
<td>Polygon</td>
<td>8109.68017578 Sq.Km-for Dez River basin</td>
</tr>
<tr>
<td>10</td>
<td>Stability Zone</td>
<td>Identified from Image</td>
<td>1:25000</td>
<td>ZSB</td>
<td>Grid</td>
<td>Landslides and rock falls</td>
</tr>
<tr>
<td>11</td>
<td>Saturation Zone</td>
<td>Identified from Image</td>
<td>1:25000</td>
<td>ZSB</td>
<td>Grid</td>
<td>Wetness and moisture zones</td>
</tr>
<tr>
<td>12</td>
<td>Slopes</td>
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<td>1:25000</td>
<td>ZSB</td>
<td>Grid</td>
<td>Slope directions</td>
</tr>
<tr>
<td>13</td>
<td>Geology</td>
<td>Satellite images, geological maps, topography maps</td>
<td>1:100000, 1:250000, 1:250000</td>
<td>ZSB</td>
<td>Polygon</td>
<td>Geological, Geomorphological &amp; Structural map was prepared</td>
</tr>
</tbody>
</table>

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1-5-Programme Of Study

In the present study mainly focus has been given in parts of the Zagros Structural Belt southwestern of Iran for detail study of geology, structure and tectonic geomorphology with the help of remote sensing and GIS techniques.

Using Landsat-5 TM-1991 and Landsat -7 ETM – 2002 (Fig. 1-4) satellite images of different bands FCC and GIS techniques with existing geological information, the interpretation of the structural and tectonic geomorphology of the Zagros Mountains has become more reliable.

An approach under the thesis involves interpretation of tectonics and structure using remote sensing data merge with existing interpreted field data sets. Digitization, interpretations, integrations, analysis, and map preparation are all performed within a remote sensing and GIS platform. The GIS also used to create a database for the Zagros Structural Belt.

The study is carried out to map the lithostratigraphy of the Zagros Structural Belt. This has been done using remote sensing and GIS techniques to generate the digital geological map of the study area. The capability and advantages of the GIS is utilized to calculate the percentage of each lithological unit in the study area.

In the present study critical portion has been identified for evaluation of natural hazards (landslides, rock falls). For this purpose the satellite data was interpreted and verified with field checks and introduced in GIS environment to analyze the data input.

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The study of the geomorphic elements in the Zagros Structural Belt was planned for understanding the tectonic geomorphological control in the structural evolution. The geomorphic elements are recognized from space data using DEM within the GIS environment. The tectonic geomorphology of the Zagros Structural Belt has interpreted in different aspects. For this purpose GIS software like Rivertools 2.4 are used to create DEM of the study area. The profile of Dez river has extracted in GIS environment to analyze the stream-gradient indices and various geomorphological parameters that finally direct for a good tectonic interpretation in the study area. The Dez river, which is one of the main rivers, crosses the Zagros mountains from NW-SE direction. The extracted cross-sections of topographic profiles of the study area in different regions were also used to calculate the net erosion rates.

To study the structural behaviour of the Zagros Structural Belt, the digital image processing was carried out. The image interpretational techniques was given as key to identify the structural features. Digital mapping of the structural features are defined as coverage in GIS to identify the density of lineaments on the image and further used to interpret the tectonic activity in the study area. The GIS techniques were applied to construct the topological relationship between the structural features. 3-D model of the study area is created using remote sensing and GIS software.

The Conglomerate of Bakhtiary formation of the Zagros Structural Belt in the southern part of the study area is selected for the Strain analysis. The strain analyses were carried out using different methods to evaluate the strain magnitude, maximum elongation (i.e. long axis) and deformation of the pebbles.
Broadly the purposes of this study are (1) to study the tectonic and structural behaviour of the Zagros Structural Belt applying new and modern technologies (2) to show the applicability of the remote sensing data in structural behaviour and tectonic study in the Zagros Structural Belt (3) to prepare various map based on the remote sensing data and GIS technology. (4) creation of database and easy assessment for data. (5) interpretation of Zagros Structural Belt in respect to structure, tectonic configuration and setting, and (6) strain analysis of conglomerate of Bakhtiary formation to evaluate the finite strain.