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GIS AND REMOTE SENSING APPLICATION IN GEOLOGICAL MAPPING AND 3D TERRAIN MODELING: A CASE STUDY IN EGHEI UPLIFT, LIBYA

GEOGRAFSKI INFORMACIONI SISTEM I APLIKACIJA ZA ISTRAŽIVANJE NA DALJINU U GEOLOŠKOM MAPIRANJU I MODELOVANJU 3D TERENA: STUDIJA SLUČAJA U EGHEI UPLIFT, LIBIJA

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Abstract:
Almost all digital or topographic mapping and most mapping projects require the digital maps generated using the integrated geographic information systems (GIS) and remote sensing techniques with geo-spatial databases. The use of remote sensing (RS) and radar images to produce geological maps is seen as making it possible to reveal those elements of geological features from images which should be reflected in the geo-spatial databases and digital maps. This study presents a way to incorporate digital data handling with both GIS and remote sensing techniques combined with geospatial databases and thus contribute to filling the gap between traditional geological mapping and modern geological studies performed with GIS and remote sensing techniques.

The main part of this research relates to the development of a new and detailed geological mapping system that has been constructed to present geological and topographic information in a geo-databases frame in an easy-to-use way. The methodology and legend of the mapping system and geospatial databases which are suggested in this study have been successfully applied to various types of landscapes in the study area. The study area in the southeast of Libya has been mapped during the period of geological mapping system development.

Key words:
Spatial database, geological mapping, 3D modeling, image processing.

Apstrakt:
Skoro svako digitalno ili topografsko mapiranje kao i većina projekata za izradu mapa zahteva postojanje digitalnih mapa koje se izrađuju korišćenjem integrisanih geografskih informacionih sistema i tehnika ispitivanja na daljinu uz podršku geoprostornih baza podataka. Smatra se da korišćenje ispitivanja na daljinu i radar slika omogućava da se na osnovu slika otkriju oni elementri geoloških karakteristika koji bi se odrazili u geoprostornim bazama podataka i digitalnim mapama. Ovaj rad prikazuje način kako da se objedine podaci dobijeni na osnovu geografskih informacionih sistema kao i tehnika ispitivanja na daljinu u kombinaciji sa geoprostornim bazama podataka i da se na taj način doprinese premošćavanju jaza koji postoji između tradicionalnog geološkog mapiranja i modernih geoloških studija zasnovanih na GIS sistemima i tehnikama ispitivanja na daljinu.

Glavni deo ovog istraživanja odnosi se na razvoj novog i detaljnijeg sistema za geološko mapiranje koji je napravljen kako bi prikazivao geološjke i topografske informacije u okviru geo baza podataka na način koji je lak za korišćenje. Metodologija i legenda sistema za mapiranje i geoprostorne baze podataka , čija se upotreba predlaže u ovom radu, uspešno se primenjuju na razne tipove pejzaža u proučavanoj oblasti. Oblast istraživanja u jugoistočnoj Libiji mapirana je u periodu razvoja sistema za geološko mapiranje.

Ključne reči:
prostorne baze podataka, geološko mapiranje, 3D modelovanje, obrada slika.

MATERIALS AND METHODS

The following methods were adhered to:

- Field work (two to three weeks) using digital geological mapping data collection
- The use of radar technology to produce a 3D model of elevation points and apply it over the geological maps, structural maps, and topographic maps.
- Remote sensing data processing: data such as Landsat 7 ETM 9 bands were processed for the identification and separation of the lithologic units. Landsat 7 images with different compilations of bands were also used to identify structural features.
- Creation of a geo-database using a geographic information system (GIS) to store all digital features of geological and topographic maps with attributes data.

MAIN OBJECTIVES

The aim of this study is to present the power of synergy between the geo-database and GIS with a view to developing digital geological mapping and 3D modeling. GIS is currently the best way to display spatial data and the Geo-databases are currently the most efficient way to process or request information from any huge dataset and to make new digital geological maps (Figure 1).

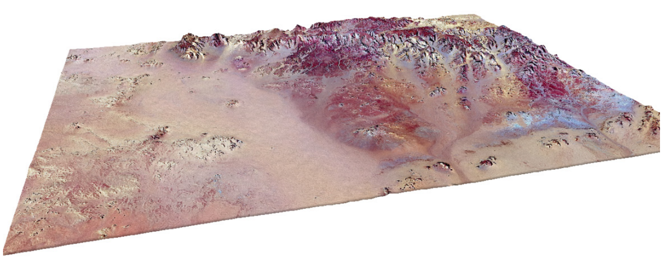

Figure 1. The integration between GIS and remote sensing technology to produce a digital geological map and 3D terrain model
Source: Ezabti (2011)

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LOCATION OF STUDY AREA

The study area is located in southern Libya, in the eastern part of Eghei area. It occupies the eastern part of Jabal Eghei, about 350 km south of the city of Tazrbo, as shown in Figure 2; and is located at 23°00”00’ to 20° 00”00’ N and 22° 00”00’ to 19° 00”00’ E”. This area is known as the Eghei Uplift. The considered study area can be reached from Tazrbo city (Libya) along several desert routes with a general direction approximately to the south and the southwest (Figure 2).

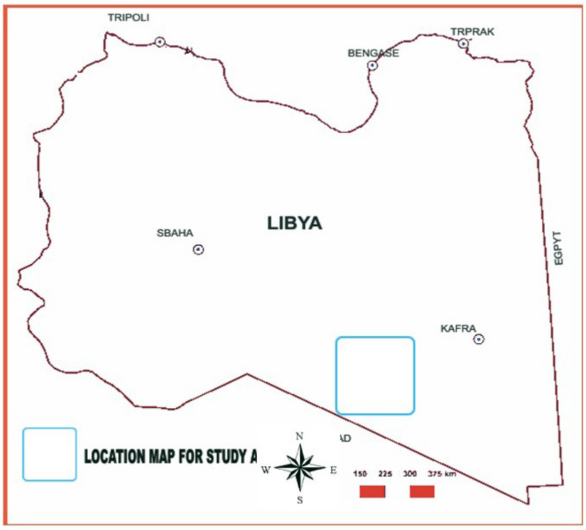

Figure 2. General location of study area in southeast Libya

TOPOGRAPHY

The area of study covered about 2865.1 square kilometers (km²), on the terrain covered by sedimentary rocks, east of the basalt flows between latitudes 23° 00' 00 and 23° 30' 00 N and longitudes 20° 00' 00 and 20° 30' 00 E. The prevailing high features are in the western and southeastern parts of the study area, where the elevation reaches up to 800 m. A large spring was running through the northeast and southwest of the study area, whereas now the drainage system slopes eastwards. The surface level of the study area varies between 368 and 925 m above sea level. The main morphological features (study area) Wide, mountain ranges along the north–south direction are the dominant features in the study area. The recent landscape is typical desert, shaped and formatted by intensive aeolian erosion, corrosion, deflation, and deposition. There are three types of deserts in the Sahara: sand desert, pebble desert, and rock desert. As a result of the desert climate, where wind erosion and low precipitations are dominant - several types of geomorphologic phenomena are present, out of which the most important are sarir, caliche, and sabkha, as shown in Figure 3. Sarir were formed in very large areas in wadi valleys as a consequence of wind erosion, where small grain size particles blow out while coarser ones (gravels and coarse sands) stay in place. Caliche is evaporate, mostly made of carbonate with less cherty crust, which occurs over the older sedimentary rocks where groundwater is very near to the surface. The thickness of these evaporate rocks can reach more than 5 m. Sabkha (playas) are formed in small deflation hollows (continental area) by evaporates deposition of various salts which have reached the water table. In the investigated area, only a few small sabkhas are present; they reach a few hundreds of meters in diameter.

INTERPRETATION OF SATELLITE IMAGES

The interpretation of satellite images has recently become a topical issue; it is very reliable for obtaining data from a combination of Landsat bands, and each combination has special proposals and implementations. First of all, three bands are assembled (4, 7, and 2) and increased the density by adding panchromatic bands, which have a resolution of 14 m per pixel, which improves the resolution of the whole image from 28 m per pixel to 14 m per pixel. When rectification algorithm image and/or vector is used, the column and row coordinates of the image can be fitted to the geodetic datum WGS84 and the map projection UTM 34 coordinate system is built into the vector using the linear method. The chosen reassembly method was the nearest neighborhooding method, which preserved the original reflectance value (Hadeel, Mushtak & Chen 2010)

There are many tools in remote sensing software that are designed for the enhancement of satellite images. These tools have different and special proposals and implementations as performed in this research by pre-processing the satellite images and following the typical raster data capture workflow (Figure 4).

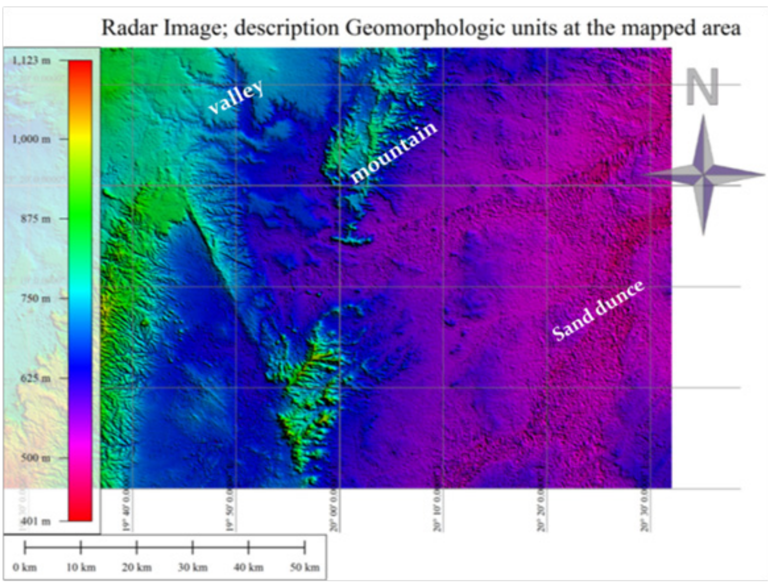

Figure 3. Radar image for study area
Source: Ezabti (2011)

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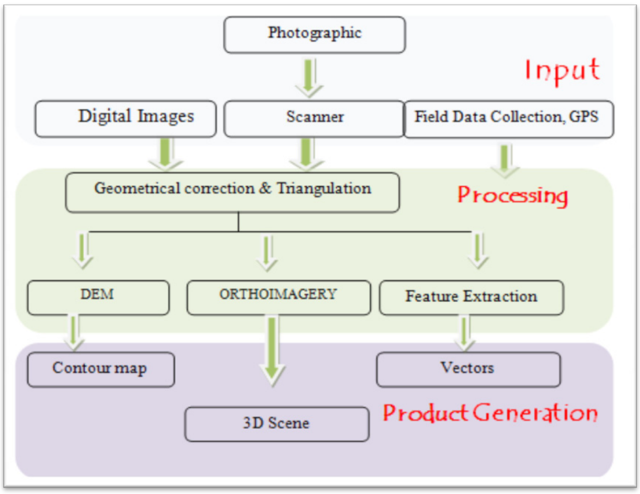

Figure 4. Workflow of data capture

PRE-PROCESSING OF THE IMAGES

The Landsat 7 ETM+ images dated 2000 were downloaded for the full scene of the study area from a global land cover facility site. The acquired raw images had file formats such as TIF or MrSID. Pre-processing such as geometric and atmospheric corrections, which is a prerequisite for the analysis of energy and land cover parameters, was performed. The false colour composite of the study region was constructed using the visible and NIR bands of the ETM+ sensor. Classification approaches are statistical methods that attempt to map each pixel by assigning it exclusively to one specific class. These methods assume that the landscape is made up of discrete entities with well-defined boundaries, that spectrally similar data will describe thematically similar objects, and that there is a dominant scene component for each pixel (Buenemann 2007).

All the operations, from data import to data analysis, were carried out in the GIS and RS software of Intergraph Geomedia Professional (6.1) and Global mapper 13.2. Figure 5 shows the false colour composite of the study region constructed using the visible and NIR bands of the ETM+ sensor.

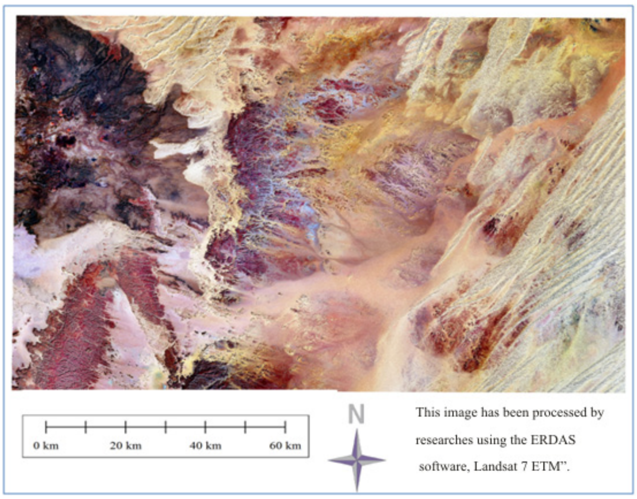

Figure 5. False colour composite of the study region constructed using the visible band of the ETM+ sensor

Different combinations of three bands are recommended for geological mapping purposes. Pontual (1988) recommends composites based on Thematic Mapper (TM) bands 7, 5, and 4 or 7, 4, and 2 in red, green, and blue, respectively. The combination of TM bands 7, 4, and 1 has been designated as a kind of standard product for geological mapping (*e.g.* Kaufmann 1988; Davis and Berlin 1989). There are steps for choosing and compiling the three bands to make one Red Green Blue (RGB) view that can be recognized by the human eye and that will be ready for visual interpretation. First, we must assemble bands 7, 4, and 2 using one of the remote sensing applications (ERDAS and MGE RS Intergraph), as shown in Figure 6, by using a special tool which provides principal component analysis. RS Intergraph image processing has been used in this study because of the power of its image processing techniques (Schowengerdt 2007).

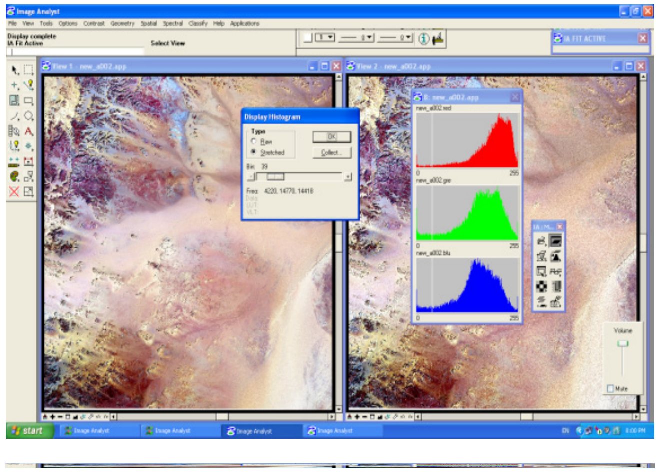

Figure 6. Histogram and image processing on MGE Image system
Source: Ezabti (2011)

GEOLOGICAL MAPPING AND 3D MODELING

All field research work was done during one field season which began in January 2010 and ended in February 2010. Based on the field experience, the digital and classical geological mapping of the field must be started by taking a cross-section from old to recent units, which was from west to east in the study area. This approach was selected to follow the geological succession and sequence from the base of the geological units in the area, where the oldest formation units accrue, while towards the east the sequence shows the recent and younger formation units, which continue by superposition in the direction of the eastern part of the study area (Figure 7).

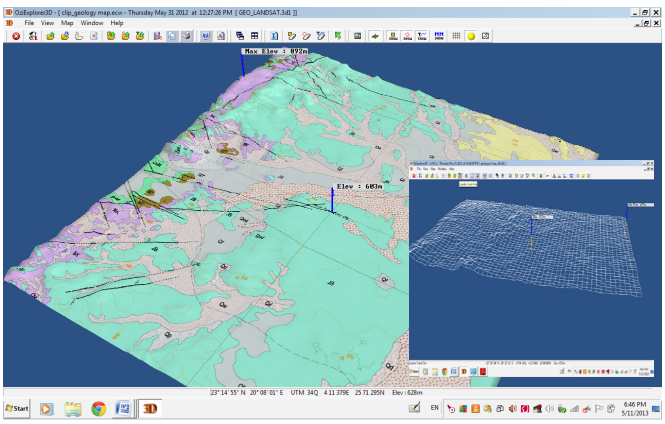

Figure 7. Geological map with elevation surface (southeastern Libya)
Source: Ezabti (2011)

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Geological units (stratigraphy)

1. Paleozoic Era, Mamuniyat Formation, OuM (Upper Ordovician)
2. Tanezzuft Formation, SlT (Lower Silurian)
3. Mesozoic Era: Zarzaitine Formation, TrZ (Triassic); Taouratine Formation, JT (Jurassic); El Burg Formation (Lower Cretaceous)
4. Tertiary rocks and Quaternary sediments (Q)
5. The digital version of the geological map is shown in Figure 7 with a 3D surface model.

The thematic map with all the geological units in the area study is shown in Figure 8.

Topographical features such as measurement, geological boundary, feature lines, sand sheets boundary, geological unit of the study area contain a description of the rock units and the geological boundary. All data obtained from Landsat 7 ETM satellite images are shown in Figure 6. Three bands 4, 7, and 2 with 28-pixel resolution are used with a panchromatic band of 14 pixels to improve the resolution and shape in the mosaic Landsat 7 ETM images. IT is a basic background to reduce and visually interpr*et al*l features and phenomena in our study in zone 34 (Figure 9), which covers all of the study area and Eghei Uplift.

CLASSIFICATION OF GEOLOGICAL UNIT LAYERS AND THEMATIC MAPS DESIGN

GIS promotes a view of maps that is quite different from traditional cartography. In a digital format, the maps can be generated quickly on a computer screen. This supports a mode of work that is optimized for data validation, exploration of data patterns, and data analysis.

GIS and desktop mapping packages provide a wide range of cartographic functions to present a digital map as dynamic mapping on which a user can make any change or update and select any feature to be shown on the map. Maps can also be published on the Internet with thematic layers in raster format. This data structure can provide the most comprehensive modeling for layers analysis for special purposes (Hadeel, Mushtak, & Chen, 2010), after raster conversion and classification, the geological map will be separated into different geological units.

Three thematic layers were used in a GIS application: the raster geology unit layer, the raster structure layer, and the digital elevation model layer. The scale value is hypothetically the numbers that have been entered into the system and represents how the rock unit can impact the value of radiation in the area.

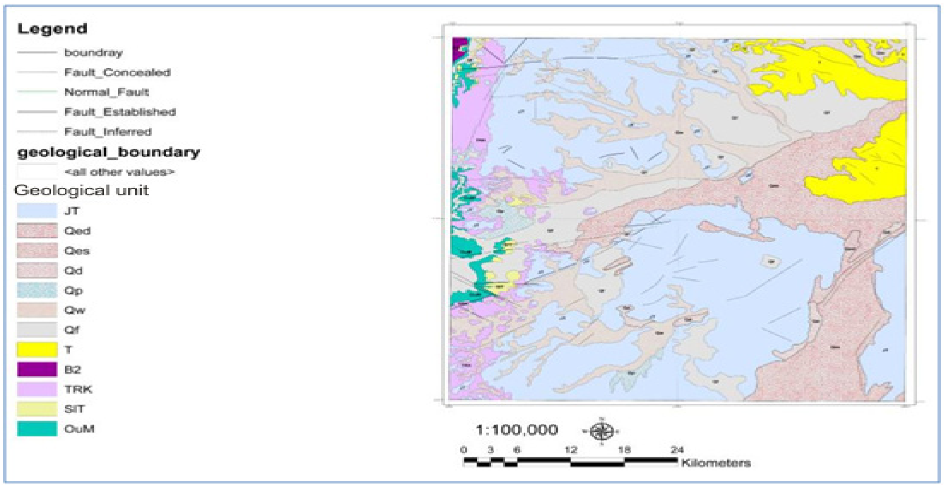

Figure 8. Geological map of the studed area (thematic map)

Source: Ezabti (2011)

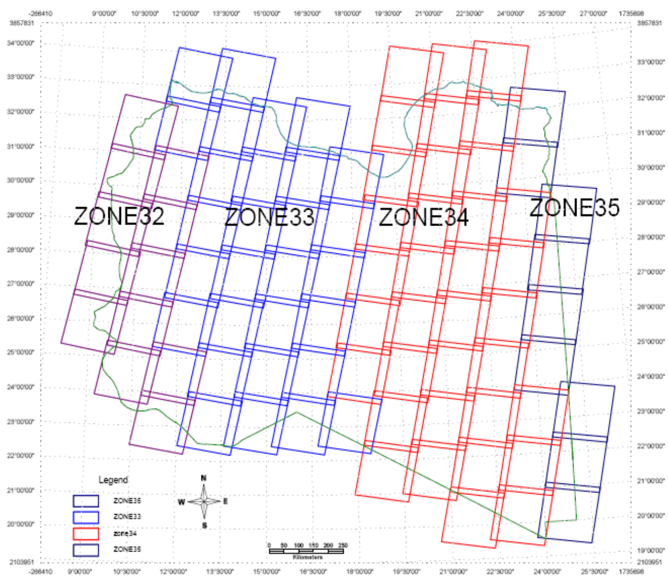

Figure 9. UTM zones For Libya

Source: Ezabti (2011)

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RESULTS AND CONCLUSIONS

The surface geometry of the study area in southeast Libya, including the geological unit, structure lines, and topographic surface, was investigated using integrated GIS methods and a remote sensing dataset with a digital elevation model, combined in one Geo-database; significantly, it was possible to define many new layers and primary data by applying manipulation and analysis tools and GIS functions to Landsat ETM and radar images at 30 m resolution. These primary maps contain interactive geological maps which were joined with a structure map combined with a spatial geo-database, offering the possibility of digital classification of the geological unit layers and structural features, digital elevation modeling of the study area. By combining GIS and RS methods and techniques we created maps of slope that represent the dip of the strata in the study area: thematic maps with the direction of the slope faces, contour maps with labels representing the elevation point in the study area in xyz format, and hill-shade maps which enable the shadow and surface light to be calculated.

The data attributes have been also connected to the geopersonal database and used to produce the geological units in the map and to process and apply important queries by using SQL language to obtain new results depending on the input data and calculation using the tubular data and spatial data, such as calculations of where the structural features have impacted the rock unit and for how long or where the features are covered and where they are exposed, along with their relation to geological features.

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