

# QUICKBIRD STEREO-PHOTOGRAMMETRY FOR GEOLOGICAL MAPPING (CYRENE-LIBYA)

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**KEY WORDS:** Geology, Photogrammetry, Interpretation, Orthorectification, GPS, QuickBird, Stereoscopic

## ABSTRACT:

QuickBird satellite image stereo-interpretation together with geological survey allowed the creation of geological and geomorphological map at the scale of 1:10,000 of the Shahhat area (the old Cyrene, Libya).

Before interpretation, the satellite image underwent fusion between panchromatic and multispectral data; the orthorectification has been performed by using the Rational Polynomial Coefficients together with the GCPs from DGPS measurements and the DEM which has been created from the topographic map at the scale of 1:50,000.

From the QuickBird orthorectified image, a synthetic stereo scene was created by the introduction of an artificial parallax giving a different relative shift in proportion of the terrain height. The geological and geomorphological maps have been created by the restitution of the stereopair that has been oriented in digital photogrammetry.

## 1. INTRODUCTION

The activities carried out had the aim of evaluating the possible correlations among geological and paleo-anthropic elements supporting archeological diggings in the Ain Hofra area (Shahhat, Libya), an important sanctuary that is actually topic of study by the University of Chieti (Italy). For such work modern and traditional methodologies of analysis, with the purpose of getting detailed geological and geomorphological data, were applied. In order to achieve the objective, the analysis of the site has been carried out by means of detailed geologic-geomorphologic survey, ancillary data, high resolution remote sensed space data, differential GPS measurements and digital photogrammetry of the whole Cyrene area.

## 2. STUDY AREA

The Shahhat area (the old Cyrene, Libya) is located in the north-eastern side of the country, east of the Sidra Gulf nearby the Mediterranean sea (Figure 1).

The Cyrenaica area is characterised by two relevant morphologic escarpments, the upper dated to the Late Miocene and the lower to the Thyrrenian (Middle-Late Pleistocene) that are subordinate to the Al Jabal al Akhdar Mountains. The shape and the structure of these escarpments, south-west north-east oriented in the study area, are related to the tectonic and geomorphological activity of the last 10-15 millions of years (Carmignani et al., 1990). The elevation of the study area ranges from 200 up to 700 meters o.s.l.. The area is geologically characterised by a monocline gently dipping towards southward, sometimes crossed by transcurrent high angle faults; from the lower to the upper part the lithologies show quite a lot of variations: the lower part is made up by thin limestone of the Darnah Formation (lower lithofacies) followed by, on the top, marly and poorly marly limestone, rich in macro-foraminifers (nummulites s.l.), which are part of the upper lithofacies; on the upper part thin levels of marly silts in discordant contact, crop out overlapped by marly limestone very fossiliferous (red seaweed s.l.) belonging to the Al Bayda

Formation (Member of Shahhat Marl and Member of the Algal Limestone, Abdulsamad, 2000).

The stratigraphic sequence ends with heterogeneous deposits belonging to the Al Abraq Formation characterised by an alternation of glauconitic sandstones, marly silts and shales. The age of the sediments goes from 40 million of years at the bottom up to 25 million of years at the top.



Figure 1. Study area

## 3. MATERIALS AND METHODS

### 3.1 Available Data

The following data has been utilized for the execution of the work:

- Panchromatic (Figure 2) and multispectral QuickBird satellite imageries dated May, 7 2002 provided with the

Rational Polynomial Coefficient (RPC) file for orthorectification;

- Panchromatic photomosaic, realized by USA Army, at a nominal scale of 1:25,000, dated July, 20 1943;
- Panchromatic orthophotomosaic, realized by EIRA (Ente Italiano Riprese Aeree), at a nominal scale of 1:20,000, dated year 1965;
- Topographic map at a scale of 1:50,000 (Quadrant Susah, by USA Army, dated year 1964).

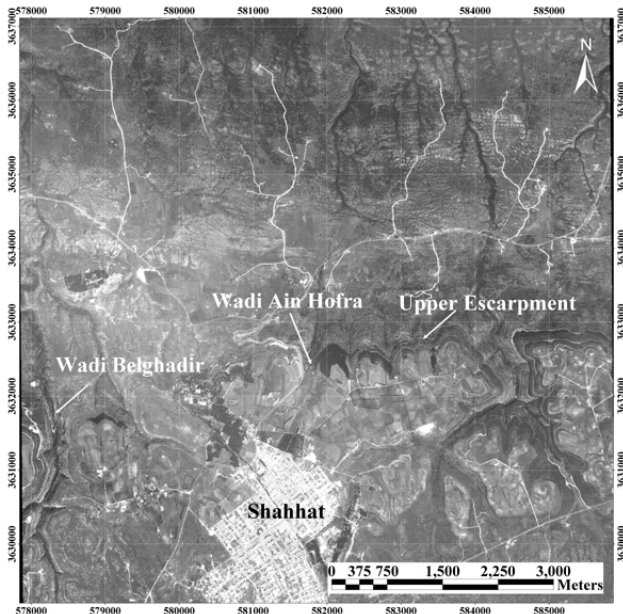


Figure 2. QuickBird Panchromatic satellite imagery

### 3.2 QuickBird Image pre-processing

The satellite scene has been purchased standard type and it represents a subset of 8x8 Km<sup>2</sup>. As a consequence the fusion between the panchromatic and the multispectral imageries (at lower spatial resolution) it must be done. The Resolution Merge between them has been executed by using the Principal Component method on Erdas Imagine 8.7 software. Moreover the standard type scene is only rectified and it has to be orthorectified in order to make it available for geological interpretation, by removing the effects of geometric distortion, dues to the orography and to the acquiring pushbroom manner. Considering the high spatial resolution (70 cm), accurate GCPs must be collected and a proper Digital Elevation Model (DEM) had to be created.

### 3.3 Fieldwork (geological survey and DGPS measurements)

Geologic and geomorphologic survey has lead to the production of preliminary fieldwork cartography at a scale of 1:10,000 and the measurement and the analysis of a complete stratigraphic column located along the road connecting Shahhat to Susah (Figure 3).

During the fieldwork DGPS measurements necessary for the orthorectification of the satellite data have been gathered. Two Leica System 530 instruments were utilized for measuring 83 GCPs collected in RTK modality all over the scene. Because of the lack of known reference points, the accuracy of the measurements has been verified, during DGPS post-processing,

by crossing the data with simultaneous records taken in the closest permanent reference stations of Noto (SR-IT) and Lampedusa (AG-IT); 60 cm mean displacements has been observed.

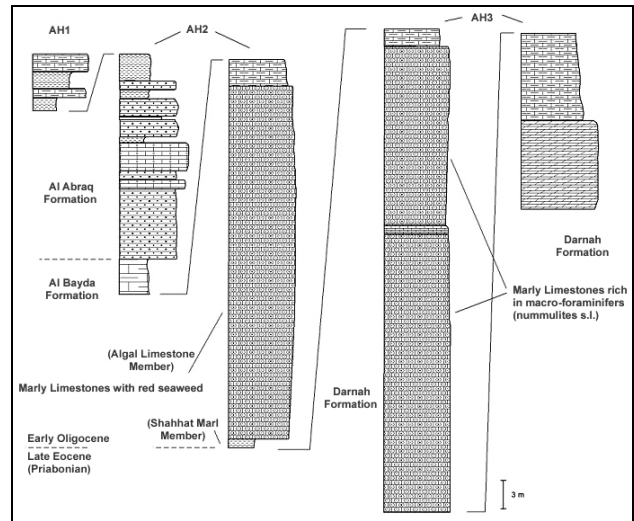


Figure 3. Stratigraphic column measured along the road connecting Shahhat to Susah

### 3.4 QuickBird Image processing

The orthorectification of the satellite data has been carried out by using the DGPS GCPs and the DEM created from the topographic map. This last was produced by digitising 20 meters interval contour lines, spot heights and hydrography from the topographic map at a scale of 1:50,000. According to National Imagery and Mapping Agency (NIMA, 2004) from a 50,000 scale topographic map, a Level 2 DEM can be created. The spatial resolution of such a DEM is approximately 30 meters and an RMSE of one-half contour interval is the maximum permitted (USGS, 2004). According to Kolbl (2001) the orthorectification of high resolution satellite images can be obtained from a DEM with an accuracy of approximately ±10 meters. It means that the created DEM could be utilized for QuickBird image geometric correction (Toutin and Cheng, 2002).

Then, initially the orthorectification of the image has been performed by using a rational “non-rigorous” method by means of the RPC file, the GCPs and the DEM. The accuracy of the correction was assessed by using 21 checkpoints among the 83 collected during DGPS survey; it averagely results of approximately 6 meters with a minimum of 2 and a maximum of 14 meters. The rational method doesn’t allow a perfect orthorectification of the satellite image especially in non-flat areas; the lack of the “basic” type full scene and of the image acquisition geometry can only be mediated by the polynomials (Volpe and Rossi, 2003). Finally the satellite scene could be correctly orthorectified in respect of the terrain only by using polynomial functions of high order, the so-called rubber sheeting method.

This operation required all the available GCPs because high polynomial functions fit locally to the GCPs but not the area between GCPs. This choice made impossible the positional accuracy assessment by checkpoints but, at the same time, it made allowable the internal imagery deformation.

### 3.5 Synthetic Stereo-Image creation

The geological and geomorphological characters of the area could be better analysed using the stereo instead the mono vision. Traditionally the stereoscopic vision is based on a couple of aerial photographs or satellite images following the geometric characteristics of acquisition. In order to obtain the stereoscopic viewing from a single QuickBird imagery, a second synthetic stereo-image on a PC must be created. The PCI Geomatica 8.0 software was utilized to introduce an artificial parallax to the orthorectified image in order to create the new synthetic scene. Following the DEM, the synthetic image was created analytically by the introduction of parallax values directly proportional to the ground elevation (Batson et al., 1976). The value of the artificial parallax ( $DP$ ) for a single pixel on the image is expressed by the following formula:

$$DP = Dh * K \quad (1)$$

where  $Dh$  = elevation of the pixel above the minimum ground elevation  
 $K$  = constant value determining the strength of the stereoscopic vision

The STE (STereo image pair from Elevation data) module, of PCI Geomatica 8.0, based on the above relation and it works with single band images. The following are the STE module's parameters:

- Stereoscopic Factor: defines the strength of the artificial parallax introduced on the orthorectified image. The stereoscopic factor is proportional to the vertical exaggeration. The more shifts introduced to the image, the more vertical exaggeration the stereomate has (Methakullachat, 1994). The  $K$  value of the relation is the mutual one of the Stereoscopic Factor. The Stereoscopic Factor utilized for the production of the QuickBird synthetic imagery was 2.92;
- Elevation Step Size: defines, in meters, the variation of ground elevation correspondent to unity. The correct creation of a synthetic image depends on right specification of this value. In this work it was defined equal to 1.
- Port settings: indicates the algorithm of resampling used in the creation of the new synthetic imagery (the nearest neighbour was selected).

### 3.6 Stereo-photogrammetry

After the creation of the synthetic imagery for the stereo vision, the choice was among the hard print of the stereopair to be observed under a mirror stereoscope, the production of an anaglyphic image, and the orientation by means of a photogrammetric workstation. This last was taken on, and the Leica Photogrammetric Suite (LPS) Module of Erdas Imagine 8.7 software was utilized. For the interior orientation the "Non-Metric Camera" Model has been selected. The exact QuickBird focal length by DigitalGlobe communication (2004) was made known. The pixel size ( $PX$ ) was determined by the following formula:

$$HS : RG = FL : PX \quad (2)$$

where  $HS$  = orbital altitude (450000 m)  
 $RG$  = ground resolution (0.7 m)  
 $FL$  = focal length (8.836202 m)

The calculated pixel size is 13.745 micron.

The exterior orientation was realized by using 50 GCPs from the DGPS measurements. 198 Tie Points automatically generated by the software and accurately edited integrated the relative orientation.

Taking into account the DGPS data accuracy, the triangulation was performed with a standard deviation of 1 meter for the coordinates X, Y and Z of each GCP; the RMSE results 0.9785 pixels (approximately 0.68 meters).

## 4. RESULTS

The described methods allowed the digital stereo-interpretation of the QuickBird satellite imagery. Basing on archaeological priorities, the geological map at a scale of 1:10,000 of the Ain Hofra Wadi (Figure 4) and the Belghadir Wadi were first created.

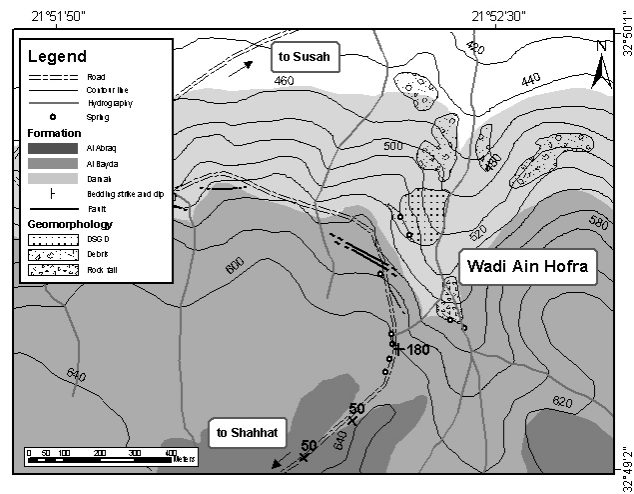


Figure 4. Geological map of the Ain Hofra Wadi

The whole necropolis of Shahhat expands basically on two types of rocks, limestone with nummulites at the bottom and marly seaweed limestone at the top.

In the Ain Hofra area, the one actually under archaeological digging, the geomorphology is characterised by the presence of paleo-springs just below the present ground level; about 15 meters below, an active spring-rising, coming from karstic phenomenon and/or from jointing, is present. The geomorphological evolution, that is a consequence of climatic factors and gravity, has actively contributed to the erosion and the engraving of the canyon of Ain Hofra and to the selective erosion of the outcropping bedding. Rock falls have been noticed on the upper part of the canyon, just under the present archaeological diggings and on the western side deep-seated gravitational deformations have been observed.

From a technical point of view, the present work gave several remarks. The accuracy of the orthorectification, is basically related to the following factors: a) input data type (a raw "basic" data, which on the other hand is geographically bigger, much more expensive and it requires a proper software to be processed, can be better orthorectified; Toutin and Cheng, 2002); b) the small scale of the topography; c) the accuracy of the DGPS measurements. The first factor is essentially a matter of money, the second and the third depend on data availability; for instance, a better result on DGPS measurements would have been achievable with either reference points of known

coordinates or nearer recording stations (Noto and Lampedusa are nevertheless the closest to Cyrenaica and therefore the best that could be used during the survey).

From the orthorectification process, the synthetic image for stereo viewing and consequently the orientation in digital photogrammetry came out. The main influence on the synthetic image creation comes from the Stereoscopic Factor which has been chosen referring to the paper of Batson et al. (1976); a simple proportion between spatial resolution of the utilized images and Stereoscopic Factor was computed.

The RMSE in triangulation and the consecutive output from stereorestitution finally demonstrate that the stereopair can be adequate for geological mapping at a scale 1:10,000.

## 5. CONCLUSION

Stereo images have been utilized in geology for a long time, since they can provide a better understanding of the terrain landform and result in a better interpretation of the terrain. Stereoscopic vision of QuickBird satellite images is traditionally impossible because of the sensor acquiring pushbroom method. The creation of synthetic imageries for stereo viewing results an alternative solution that additionally enables the maintenance of the multispectral bands and the high spatial resolution (70 cm).

The described method, although not so-highly accurate to be used at a bigger scale or for topographic mapping, allowed the geological photointerpretation at a scale of 1:10,000 with adequate positional accuracy.

Furthermore it has to be considered the difficulties encountered in collecting data: topographic maps at a bigger scale and known reference points for DGPS measurements or data from permanent recording stations could allow positional accuracy increasing.

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### Acknowledgements:

The work has been realized in the framework of the Project “Ricognizione e scavi nel santuario agreste di Ain Hofra (Cirenaica) e studio dei materiali per l'allestimento del Museo di Bengasi” (Ministry of the University and the Scientific and Technological Research) which is coordinated by the Prof. E. Fabbrocotti of the University of Chieti (IT). A particular thank to the Department of Antiquity of Shahhat for the availability of consulting aerial imageries and topographic maps.