Digitizing the Geo-Cover of Greater Cairo Metropolis Supporting the Time of Transformation

Ahmed Abdelhalim M. Hassan
Institute of Landscape Ecology, Muenster University,
Muenster, Germany,
E-mail ahmedahalim@uni-muenster.de

***Abstract*—Nowadays, many cities in developing countries are striving for reconstruction and sustainable growth after a long time of corruption and conflict. Hence, the planners of different trends need to access different types of information easily and work firmly by the use of modern technology. Accordingly, this paper aims to present the geological and physiographic setting of Greater Cairo metropolis in the perspective of a digital city and reintroduce the geo-map concern to the whole area. To achieve that, this study tends to use the remote sensing techniques to differentiate the rock cover types and describe the topographic relief of the area dominated Greater Cairo. The applied classification and nomenclatures were based on field observations that take the previous geological studies published on the concerned area and its neighborhoods into strong consideration. As a general result, eleven units representing all rock outcrops have been observed, described, and classified. Analyzing of the digital elevation model (DEM) delineated the structure relief of the study area. These outputs could support the stakeholders and earth-scientists to refine and develop a geological data bank in a digital form, to be directly processed by suitable software. And also, the familiarity with the geo-setting of such a megacity would help to detect the rapid spatial changes in some protected areas.**

Keywords-digital geo-cover; Greater Cairo physiography; rock unit classification

I. INTRODUCTION

Generally, applications of techniques to obtain information about an object without touching the object itself are used widely and extensively in geological investigations. These techniques mainly are geophysical tools (e.g. electromagnetic induction, ground penetration radar, aeromagnetic…etc.) and satellite sensors. These were located far apart hence the distance between the object and sensor being of several kilometers or hundreds of kilometers [1]. In the recent past, the remote sensing technique plays a very important role in geological mapping starting from aerial photographs interpretation and jumping to sophisticated enhancement, processing, and interpretation of images acquired by space satellites. These are able to show features and patterns which may not be distinguishable on aerial photographs due to the lack of color information in these (aerial photographs) [2]. Therefore, the remote sensing techniques used do not only allow geological mapping but also lithology and mineral differentiation and exploration on small and large scales, respectively. Accordingly, the use of satellite images for geological mapping and for exploring economic resources is becoming an increasingly important issue for earth-scientists.

Furthermore, the 3D or elevation remote acquisition data provide mitigation and hydrological investigation for geo-hazards rather than topographic description and relief description and measures. The later proved that the application of digital elevation model analysis (DEM) is a potentially efficient, reliable, reproducible and effective technique for under taking geological terrain mapping. Abd Manap et al. [3] concluded that the advantage of 3-D draping technique compared to the conventional stereoscope interpretation is that the geological terrain features such as hillcrest, side slope, foot slope, straight slope, concave slope and convex slope can be observed not only from the normal vertical view but also to be viewed from different scales, orientations and perspectives.

A Study done by Nalbant and Alpiekin [4] showed that thematic mapper (TM) imagery can be used as a valuable tool together with field studies for geological mapping and structural patterns. This procedure can save an appreciable amount of time, money, and man power compared to the efforts exerted by earth scientists and is also useful in undertaking geological terrain mapping in inaccessible areas. The U.S Geological Survey carried out a research program in 1985 to produce 1:250,000 scale land-cover maps for Alaska using Landsat MSS data [5]. Sultan et al. [6] and, Gad and Kusky [7] demonstrated that TM data can be reliably used to distinguish mineral potential from surrounding rocks in arid regions and to generate detailed maps over wide regions by using quantitative, reproducible mapping criteria. In addition, possibilities for locating suture zones over the less well known parts of arid continents are clear.

Ingram et al. [8] evaluated the relationships between the geology, land use, and elevation parameters in north Mississippi and addressed a strong correlation between the different rock formations and slope degrees. Since, land use information was extracted from satellite imagery, topographic parameters were derived from elevation data, and textural characteristics were generated from these datasets to provide a basis for surface mapping. However, an integrated GIS (geographic information system) and remote sensing techniques can be used effectively to develop a more comprehensive geologic database to facilitate geological field studies have been occurring for large areas.

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The most geological studies describing Greater Cairo lack the application of techniques of remote sensing in an advanced way. Hence, the most work deals with raw image data by traditionally using color combination of multispectral satellite images to prepare preliminary maps regardless of the georeference, radiometric character or spectral analysis. Also, the most maps were traced based on Thematic Mapper (TM) and Enhanced Thematic Mapper (ETM) which are recently available freely in many open sources. Such studies conducted by Egyptian geologists (e.g., [9]) who modified the geologic map of Eastern Greater Cairo, area based on false color composite and utilization of band combination 7, 4, and 2 for the R, G, and B, respectively, which is the best for the general lithological discrimination in the study area.

II. T STUDY AREAYPE

The selected area of study is the metropolitan area of Greater Cairo (G.C) and its surroundings, which is known as the capital of Egypt and one of the fastest growing megacities worldwide (Fig. 1). The area covers about 600 km2, encompassing major parts of the governorates of Cairo, Giza, 6th of October, and Helwan. The Nile forms the administrative division between these governorates, with Cairo and Helwan on the east bank of the river and, Giza and 6th of October on the west bank. Also, the area is geologically divided into two main parts, eastern part and western part, with the Nile valley between them. In relation to the later, the nomenclature and facies subdivision of the stratigraphic succession, described by many authors on both sides, are quite different. Therefore, the rock type characters, classified in this study, have been implemented on the identification and chronology of previous studies.

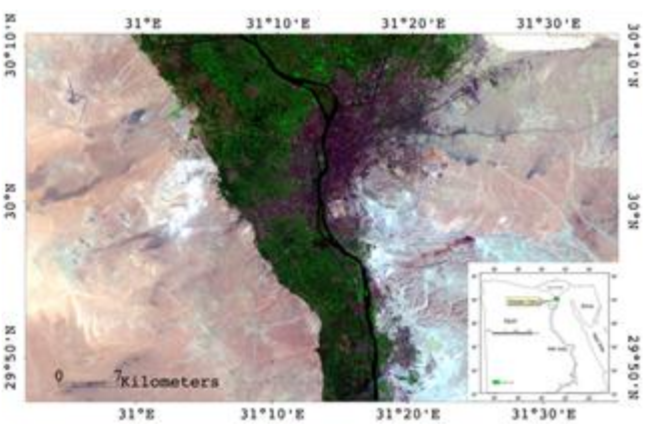

Figure 1. Location of the study area.

III. MATERIALS AND TECHNIQUES

A. Data availability

Because of the rapid development and extensive human activities in the area around the Nile valley in Greater Cairo (hinterland and/or Nile valley terraces) the selected data are characterized by less cover of land use for a better discrimination of the rock units. Accordingly, Landsat 5 TM image data acquired in 1984 with seven bands of (three invisible wavelengths, four in infrared) most of which have 30 meter resolution, except band six with 120 m resolution, has been selected. Then to increase the spatial accuracy of TM-5 image the moderate resolution panchromatic image with 10m pixel resolution acquired in 1997 by Spot-2 sensor (TT station) is merged with it. The high resolution (5 m pixel resolution) of multispectral Spot-5 images acquired in 2006 by Spot-5 is available too for a good and accurate glance of surface exposures in the study area. Moreover, there is another sort of satellite data with elevation information that has been used to construct 3D visualization for the entire area of interest. This elevation data is obtained from ASTER GDEM which is generally characterized by 30 m pixel resolution at 95 % confidence horizontally and about 10 m at 95 % confidence vertically. Furthermore, ancillary data such as scanned topographic sheets and geologic map of scale 1:100,000 are utilized for required nomenclatures and location detection.

B. Methodology

In this study, the work procedure is based on different techniques of image processing to extract some interesting geologic and physiographic features. First of all, all satellite images and scanned sheets are georeferenced to UTM Zone 36 North projection with WGS-84 datum. Moreover, TM and Spot satellite data are enhanced to insure radiometric balance between individual scenes and the DEM data were mosaicked to cover the study area. This step was followed by fusion technique to increase the pixel size and resolution of all TM image bands (Fig. 2) to get more spatial information of surface exposures. However, the produced maps based on TM reached to scale 1:100,000, but the maps based on merged image reached to scale 1:32,000 without remarkable pixels.

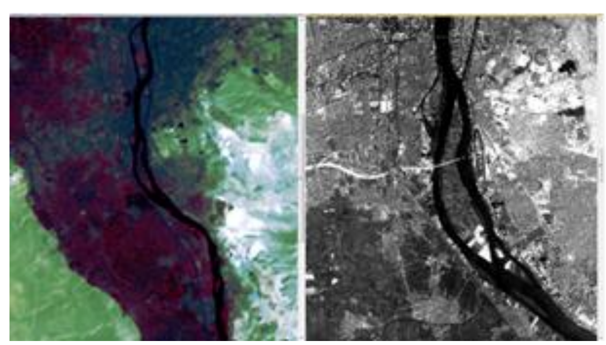

Figure 2. TM image (1984) to left and Panchromatic Spot band (1997) to right represent low and high resolutions respectively.

The fusion process occurred by using the sharpen module which is provided with different merge algorithms in Erdas Imagine software. Therefore, the subtractive resolution merge algorithm is used in this study. Consequently, the different band combinations are tested for first impression on lithology discrimination. So, the combination between bands 7, 4, and 2, and 5, 3, and 2 were reviewed in R.G.B false

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color and presented the best image composites in the study area.

The principal component analysis used in this study to reproduce the merged high resolution image allows inordinate and excessive data to be computed into fewer bands [10]. In addition, Principal component algorithms are image enhancement techniques to visualize the maximum spectral contrast from many spectral bands to three primary display colors [11]. These lead to a stretching of the pixels to differentiate different rock types. Moreover, the bands of PCA data are non-correlated and independent and are often more interpretable than the source data [12]. The PCA technique was applied onto two different kinds of multispectral satellites data TM with 7 bands and Spot with 3 bands separately. The difference after the removal of redundancy information showed that differences exist between the different bands of each image. Because of the wide range of spectral wavelength of TM data which have seven channels, the author preferred to use principle component analysis of TM merged image in rock discrimination to compose a geo-digital thematic map rather than the multi-spectral Spot data which have only three channels.

Consequently, it could found that the first principal component channel (PC1) has the largest possible variance, while the next two PC channels (PC2 and PC3) contain all other interband variations. Therefore, each one of the components from 3 to 7 in TM merged image is dominated in less than 1.3% of information and seems unnecessary in lithological information (Fig. 3).

So that, the first three principle components, these were calculated from preferred and enhanced TM merged image beside the field observations and experiences, have been mainly used in classification process.

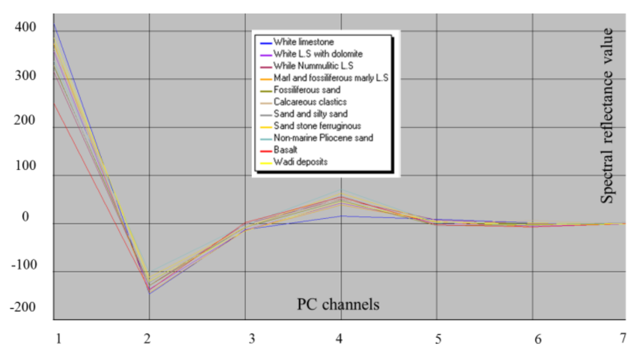

Figure 3. The spectral reflecance of the classifies rock typs regardind the PC channels.

The classification step is provided by the supervised classification method which assembles the surfaces that have similar spectral signatures. Once signatures are examined, the classifier is then used to attach labels to all image pixels according to the trained classes. The procedure of supervised classification was processed by using maximum likelihood algorithm, which assumes that each spectral class can be described by a multivariate normal distribution [13]. In spite of that, the accuracy assessment is behind the objective of this study; but, there are many control points acquired from ground and estimated by GPS used and interpolated in the process of classification to enhance the pixel selection and refine the rock type identification.

Finally, the morphological information and topographic features were extracted from the available mosaicked digital elevation model (DEM) (Fig. 4).

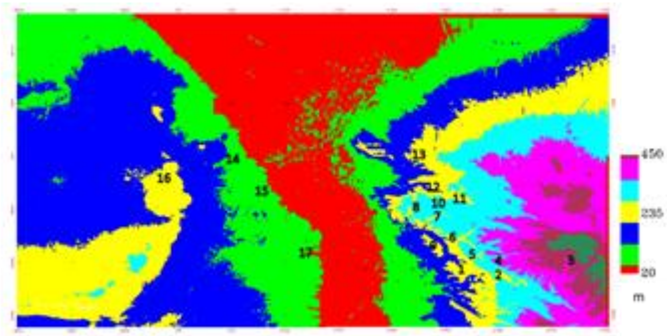

Figure 4. Coloured DEM for elevation information concerns the Greater Cairo area.

1-15th of May City. 2- Wadi Garawi. 3- El Halawana Height.
4- El Qurn Height.. 5- Wadi Gibbu.. 6- Wadi Abu Silli.
7- Wadi Hof. 8- Gabal Hof 9- Obesrvatiory Plateou.
10- Wadi Abu El Rokham. 11- Wadi Degla. 12-.Wadi El Tih.
13- El Mokattam Plateou. 14- Abu Roash. 15- Pyramids Plateou.
16- 6 th of October City.17- Wadi El Tafla.

The techniques used to obtain and analyze the elevation information are mainly supported by ENVI 4.7 software. As well, the produced digital maps could be reached to scale from 1:75,000 to 1:50,000.

IV. GEOLOGY OF GREATER CAIRO

A. Rock Cover and Type

Many authors studied the different time rock units cropping out in the eastern and western sides of Greater Cairo and reported that in geographic maps and geologic correlations e.g., [9][14][15][16][17][18][19][20][21].

The present application of remote sensing image processing techniques and field observation supplemented with the previous geological studies and nomenclatures in West-and-East Greater Cairo came to subdivide the rock exposure of the study area into the eleven rock types. Besides that, two dominating classes of the fertile Nile valley area are concerned too. One of them represents the urban materials and roads, and other one is concerned as a mix class representing the green cover and water bodies.

Moreover, the spectral analysis of the exposed rocks in the area of interest is summarized and reported to show the relation between each band of PC image and reflectance spectrum of selected pixel for classification. (Fig. 3).

In short, the eleven litho-types covering the study area are mainly dominated by 1-white limestone (Chalk), 2- white limestone with dolomite, 3- white Nummulitic limestone, 4- marl and fossiliferous marly limestone, 5- sands and fossiliferous sandstone, 6- calcareous sandstone and/or eroded surface 7- sand and silty sand with subordinate clay intebeds, 8- sand stone (Ferruginous) with Gravels, 9- non-marine Pliocene sand, 10- basalt, and 11- wadi deposits (Fig. 5).

These exposed rock succession that builds up the study area ranges in age from Upper Cretaceous to Quaternary (Fig. 6).

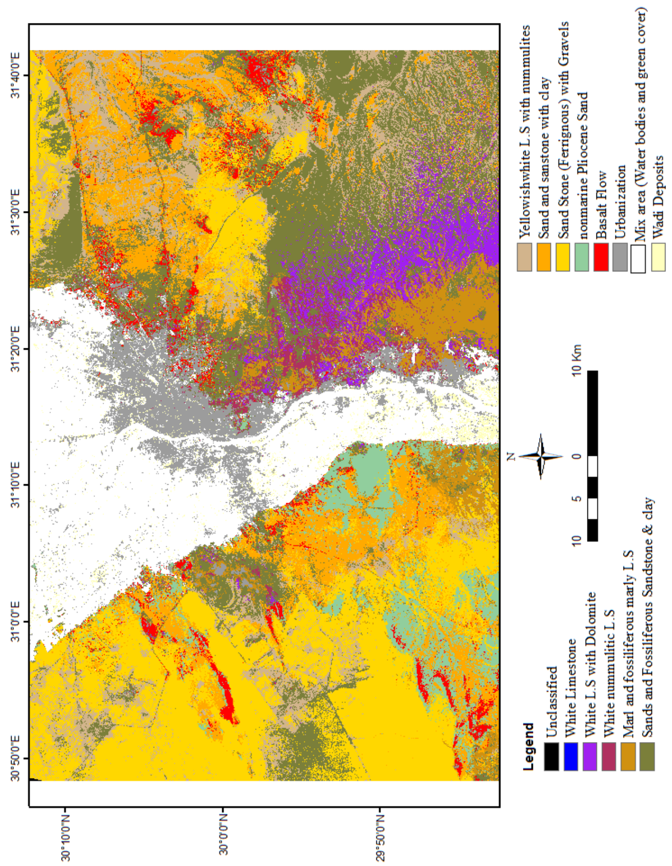

Figure 5. Rock cover classification based on PCA.

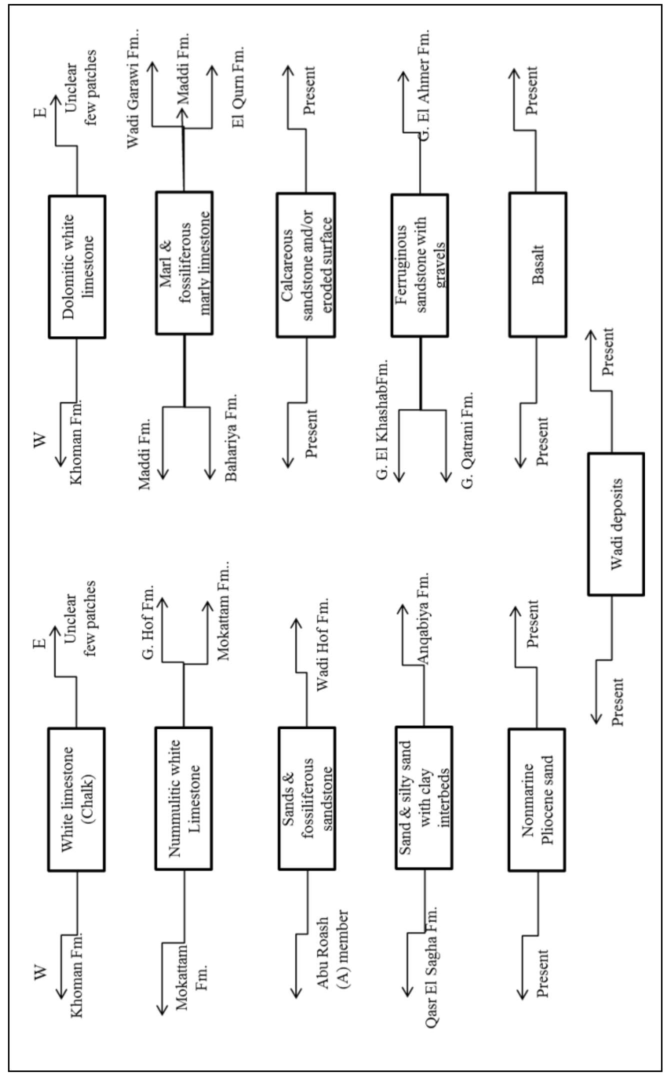

Figure 6. Rock type and its equivalent formation

1) White limestone (L.S)

White limestone or chalk unit is distinguished by the first appearance of snow-white massive thick bedded chalk, with thin chert bands and nodules (Fig. 7 Left). The chalk is exposed only in the Western part of the study area mainly in Hassana Dom. According to Said [15], the age of Chalk unit ranges from Campanian to Masstrichtian with a maximum exposed thickness of about 78 m. While in western part of the desert this formation belongs to the Khoman Chalk and Senonian age [22].

2) White limestone with dolomite

The white limestone contaminated with dolomite and / or marl is represented in the eastern part of the study area mainly by Observatory Formation and slightly by Abu Roash Formation or AbuRoash "D" member in Western part (Fig. 7 Right). Furthermore, the Observatory Formation belongs to the Middle Eocene and constitutes the foundation bedrock of the northern eastern part of 15th of May city and its northern extension [9]. Swedan [20] mentioned that the formation is composed of white to yellowish white, marly and chalky limestone, intercalated with several interbeds of hard, grey, dolomitic limestone. The type section of this rock unit measured by Frag and Ismail [14] in the northeast of Helwan below the Observatory establishment is about 77 m thick.

On the other side, the Abu Roach Formation or “D” member [16] is dominated mainly by white to yellowish white, dolomitic limestone with large amounts of large fauna (e.g. *Acteonella*). [15], named the Turonian-Santonian beds in many parts in northern Egypt (included the study area) as Wata Formation, commonly used in Sinai.

3) White Nummulitic limestone

The white Nummulitic limestone class refers to the beds built up mostly with grayish-white, slightly chalky beds rich in *Nummulites gizehensis, Nummulites Beaumonti, N. subbeaumonti*, *Schizaster africanus*, and *Turbinella frequens* [14]. These beds exposed in the Eastern part to the North of Helwan province which is composed by upper part of the Gabal Hof Formation. The former named and subdivided into two units (up to 80 m in thickness) in its type locality at Wadi Abu Rakham by Frag and Ismail [14]. This formation is equivalent to the Middle Eocene rock unit cropped out at the escarpment of El Mokattam Plateau, East of Cairo city. While, along the western side of the Nile, the spectral analysis of this rock type does not show any good and/or obvious cover except at the area of Pyramid plateau.

4) Marl and fossiliferous marly limestone

The marl and/or fossiliferous marly limestone are mainly represented in the eastern side of the study by Upper-Middle to Upper Eocene time unit of El-Quran and Wadi Garawi Formations in southeast part and EL-Maddi Formation in northwest part. Osman [9], Frag and Ismail [14], Swedan [20] and we mentioned that the El Qurn Formation is composed mainly of about 70 m thick marl, marly limestone with thick gypsum veinlets, and hard dolomitic bands. In addition, they stated that the Wadi Garawi Formation is extremely equivalent to the Maddi Formation, which dominated by *Carolia Placunoides, Plicatula polymorpha, Ostrea reili, Nummulites Beaumontai*, and *N. striatus.*

On the West side, this rock class is recorded southwest and west from the Pyramid plateau with maximum thickness of 154 m measured by Frag and Ismail [14] and named Maddi Formation. To the north of the Pyramid plateau, this unit cropped out at the flanks of macro structure of El Hassana Dom. In contrast, the spectral signature of this class has referred to the marl and fossiliferous marly limestone units which intercalated with sand and shale in the small part of the core of Abu Roash structure (Fig. 8). These units belong to the Cenomania (Lower Cretaceous) Baharyia Formation [15].

5) Sands and fossilifreous sandstone

The sand stone facies cover a large area east and west of Greater Cairo, which constitute the foundation bedrock of many parts in new cities such as New Cairo, and 6th of October City. This rock type is composed mainly of sand stone, marl, yellowish green clayey marls, sandy limestone and bioturbated marly limestone. According to the describtion of Frag and Ismail [14], Moustafa et al. [18] and Swedan [20] the spectral signature of this class could be represented by Late Upper Eocene Wadi Hof Formation and Anqabiya Formation in eastern side of Nile valley. While, on the other side this reflectance spectrum belongs to the upper part of Qasr El Sagha Formation. This formation concerned by Said [15] and Swedan [20]. The upper most part is of the Eocene age and consists of poorly fossiliferous clay and channel deposits with minimum thickness regarding the original thickness. Also, this signature reflected the Coniacian-Santonian beds exposed in some areas at El-Hassana Dom.

6) Calcareous clastics and/or eroded surface

This spectral reflectance is very ambiguous all over the study area, but the field check oriented to identify it to be under the erosional surfaces of clastics and calcareous-clastics outcrops, in addition to some eroded Nummulitic limestone with clay contamination.

7) Sand and silty sand with clay

The exposed part of this rock type is found mainly at Gabal el Mokattam area eastwards and very close to the area west to southwest of The Pyramids Plateau composed mainly of fine grained calcareous sand stone, grading upward silty sand and shale [20] and [9]. The unit could be represented in the Anqabiya Formation due East of the study area and some most upper Eocene and Oligocene units due West (Qasr El sagha Formation). Generally, this pixel reflectance represents the unconsolidated sandstone and silt to shale outcrops in many parts of the study area.

8) Sandstone (ferruginous) with gravels

This exposure is widely distributed in the study area, especially East of el Mokataum plateau including the East of Cairo (Nasr City), New Cairo City, and protected areas (forest of petrified wood) along the Cairo-Red Sea high way. This rock exposure belongs to the Gabal Ahmar Formation. On other hand, this rock cover mainly dominates the region of 6th of October City and belongs to Gabal Qatrani Formation and Gabal El Khashab Formation [20]. However, Skukri [23] and Said [15] stated that, this formation constitutes the extension of a narrow belt of Oligocene-Miocene age from Suez via Cairo and onward into the north western desert, which is mainly dominated by distinct red bed sequences with coarse-grained sand and gravels with large amounts of petrified wood separated by basaltic sheets in between (Fig. 9 Left). The pixel signature information is reported as following;

9) Non-marine Pliocene sand

This rock unit in the area of interest consists mainly of fine to coarse, friable sands and conglomerate sandstone of yellowish to brownish-white color [15] and [20]. Its spectral reflection appears on the western side of the G.C obviously accompanied with basaltic sheets rather than on the eastern side (Fig. 9 Right).

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10) Basalt

The distribution of Oligo-Miocene deposits was governed by the volcanicity and tectonic activity which affected the Red Sea regions and the high belt between the stable and the unstable shelves in Egypt during the Oligocene [15]. Therefore, the basaltic sheets in the study area recorded within the sandstone beds of Oligo-Miocene beds in 6th of October city towards the West and New Cairo area towards the East.

11) Wadi deposits

In the study area which is filled with recent fine clastics deposits mainly of clay, this rock unit represents its often being reworked by eolian processes and stream deposits near to the River Nile bank.

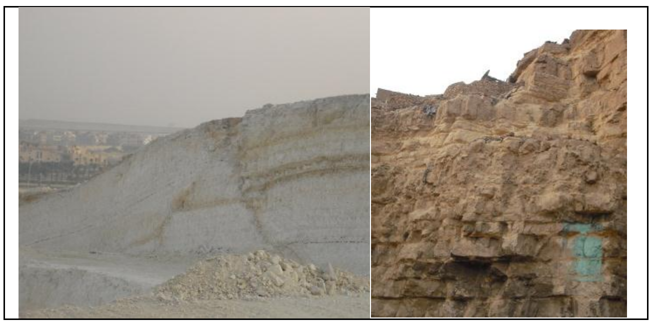

Figure 7. Chalky limestone (Khoman Fm.) observed in the western part of study area (Left). Well bedded limestone at Gabl Hof Fm. (Right).

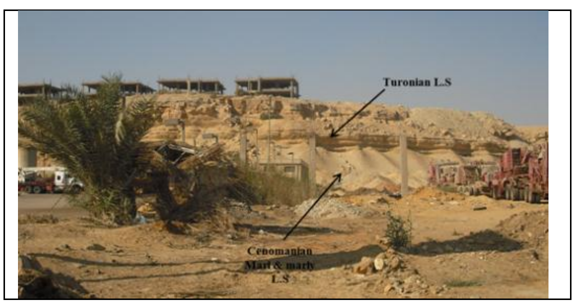

Figure 8. The core of Abu Roasch structure shows the marl and limestone rock units.

Figure 9. Petrified wood at Gabal El Khashab, West of G.C (Left). Non-marine Pliocene caped by basaltic sheet (Right).

B. Physiography

Topographically, the study area could be divided into three parts, the first one is represented by the lowest elevation corridor of the River Nile valley, the second is dominated by two plateaus detached by two low areas at the eastern side of the area under investigation, while, the last is the western side which represented by topographic features forms an almost featureless plain with the exception of some small structure related heights

According to the analyzing and slicing of the digital elevation model (DEM), the contour lines and elevation information, slope degradation, and three dimensional visualization are extracted (Figs. 4 and 11).

Therefore, the area around River Nile mainly occupied by different human activates such as agricultures, houses, and industries with elevations ranging from 20 to 100 m above sea level.

The topographic features expressed on the East side of G.C characterized by moderately rough relief, occupied by soft rocks ranging in age from Middle Eocene to Recent.

The highest elevation is about 450 m above sea level (a. s. l) recorded due East of the El Halawana Hieght. In general, the landscape in the part of study area is characterized by numerous rugged, isolated hills of mostly made up of hard Eocene limestone beds. Those are arranged from south (close to 15th of May City) to north (El Mokattam area), e.g. El Qurn Hieght (~270 m a.s.l), Obesrvatory table land (~175 m), Gabal Hof (~330 m a.s.l), and El Mokattam Plateau and New Cairo area (maximum ~287 m a.s.l). The wadies are usually controlled by faults of different trends mainly of NE to N-S and E-W to ENE trends. The main wadies traversing the study area are Wadi Garwi to the southeast from 15th of May City, Wadi Gibbu and wadi Abu Silli which dissect the 15th of May City and Helwan area towards due West, to North of Helwan area present Wadi Hof which is extending ESE-WNW and joined with Wadi Abu El Rakham at Gabal Hof area, Wadi Degla which is the most important protected area and largest drainage line on the east side of G.C delineated the southern scarp of El Mokattam plateau, and due North of the Wadi Degla is small stream called Wadi El Tih bounded the New Cairo from south. These wadies are generally of dendritic and sub-parallel types.

Most of the surface of the area West G.C is covered with very gentle-dipping Tertiary-Quaternary strata including 6th of October City (Fig. 23 A). However, the area in some parts characterized by different topographic features mainly consists of Giza plateau (~120 m) and small folded and faulted Abu Roash complex and El Hassana Dom to the north of Giza pyramids (Fig. 10). The latter is highly manifested and controlled by both the lithologies and structures. The drainage lines have a very low degree of shaded relief (hill shading) (Fig. 4 and 11) on western side of the G.C and only Wadi Tafla south of the Pyramid could be detected.

Figure 10. Hassana Dom at Abu Roash area

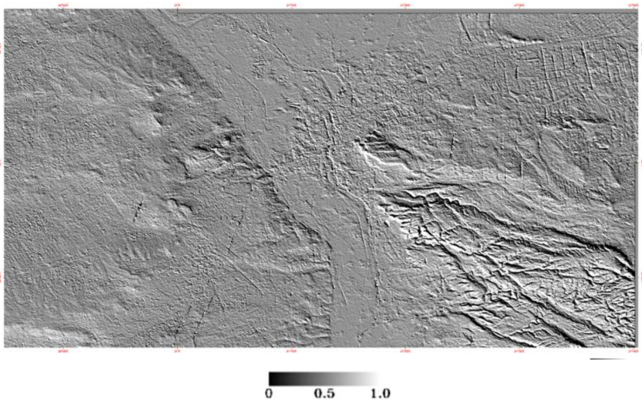

Figure 11. Shaded relief (hill shading) of the Greater Cairo area.

V. CONCLUSIONS

Digital maps gain not only all ground and rock cover information but also are flexible for updating based on addition of new data and/or applications of advanced remote sensing techniques, which could be used for different purposes and to build a data base for large areas.

A study of Greater Cairo as the biggest city in MENA (Middle East North Africa) arid region shows that the geological setting might be one of the effective driving forces for further studies concerning the growing trends of the city and developing plans.

There are eleven rock types covering the Greater Cairo metropolis, composing mainly of carbonates and clastics with dispersed basaltic exposures. Although, these coverings are not dominated by any valued ores, some areas contain native structures and land forms. While the field observations and false composite high resolution satellite images (SPOT) showed degradation of protected areas; e.g. destroying land forms of El-Hassana Dom and misuse of Fores of Wood at Wadi Degla.

The statistical report of spectral signatures derived from PC merged TM image showed that the carbonate covers have higher numbers than clastics deposits (ex. Mean of band 1 addresses that more than 350 could be carbonate and between 350-320 could be clastics, while the basalt between 210-240 and wadi deposits reflects high value about 380).

Because the western part of G.C metropolis is dominated manly with clastics and characterized by a low relief and less roughness, the eastern part is built up mainly of carbonates and a rough relief, it can be mentioned that the western side has a higher opportunity for development than the eastern part.

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