Mapping of Geological Formations in the Bi'r Zaltan Area Using Remote Sensing Technique

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Abstract:

Remote sensing and satellite images are useful scientific methods for geological investigations and to obtain direct geological surveys in the Bi'r Zlatan area, which belongs to the northern part of the Libyan Desert. Through the current study, ENVI 5 program was used to apply different digital processors to the Landsat 7 ETM+ image to determine the geological units. A supervised classification process was applied through a false color composite image with bands 741 was taken as a basis in the classification and cartographic processes and then compared with a published geological map of the same region to identify the names of the geological formations exposed. geological classified map of the study area was produced based on the principles of visual interpretation by calling the classification map in the GIS environment and then matched with the geological map in order to evaluate the accuracy of classifying with the regulation of the transparency level for the upper layer to 50% through ArcGIS 10, thus, the overall spatial accuracy of the obtained map was 70%, which was in agreement with the geological map of the study area. Finally, the digital geological map of the Bi'r Zaltan area can be linked to a wide database that is prepared for all the available geological information about this area. As well, this data can be updated in the future when any geological developments occur.

Keywords: Remote sensing, Landsat image, False-color composite images, Supervised Classification, Geological map.

تخريط التكوينات الجيولوجية بمنطقة بئر زلطن باستخدام تقنية الاستشعار عن بعد

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الملخص:

يعد الاستشعار عن بعد وصور الأقمار الصناعية من الأساليب العلمية المفيدة للاستقصاءات الجيولوجية وللحصول على مسوحات جيولوجية مباشرة في منطقة بئر زلطن التي تنتمي إلى الجزء الشمالي من الصحراء الليبية. من خلال الدراسة الحالية، تم استخدام برنامج ENVI 5 لتطبيق معالجات رقمية على صورة + Landsat 7 ETM وذلك لتحديد الوحدات الجيولوجية. تم تطبيق عملية التصنيف الخاضع للإشراف من خلال صورة مركبة ملونة زائفة ذات النطاقات 741 كأساس في عمليات التصنيف ورسم الخرائط ثم مقارنتها بخريطة جيولوجية منشورة لنفس المنطقة لتحديد أسماء التكوينات الجيولوجية المنكشفة، تم إنتاج الخريطة الجيولوجية المصنفة لمنطقة الدراسة بناء على مبادئ التفسير المرئي من خلال استدعاء خريطة التصنيف في بيئة نظم المعلومات الجغرافية ثم مطابقتها مع الخريطة الجيولوجية من أجل تقييم دقة التصنيف مع تنظيم مستوى الشفافية للطبقة العليا لتصل إلى 50٪ من خلال برنامج ArcGIS 10 ، وبالتالي كانت الدقة المكانية الإجمالية للخريطة التي تم الحصول عليها 70٪ وهو ما يتوافق مع الخريطة الجيولوجية لمنطقة الدراسة. أخيرا، يمكن ربط الخريطة الجيولوجية الرقمية لمنطقة بئر زلطن بقاعدة بيانات واسعة معدة لكل المعلومات الجيولوجية و المتوفرة لهذه المنطقة وبالتالي يمكن تحديث هذه البيانات في المستقبل عند حدوث أي تطورات جيولوجية.

الكلمات المفتاحية: الاستشعار عن بعد، صورة القمر الصناعي لاندسات، الصور المركبة ذات الألوان الزائفة، التصنيف الخاضع للإشراف، الخريطة الجيولوجية.

Introduction:

Remote sensing techniques are distinguished in their ability to detect natural resources depending on the spectral behavior of these resources in different spectral domains, according to the different land resources, which facilitates detection, investigation and distinction with the least effort, time and money (Melesse et al. 2007).

Satellite images constitute the basic element in remote sensing techniques, and digital processing of remote sensing data is a modern techniques widely used in various fields, including geological studies exploring the earth's mineral resources and determining geological structures (Saibi et al. 2018). Moreover, digital processing using to identify rock units and drawing digital geological maps based on remote sensing data, which are characterized by high accuracy, comprehensiveness and coverage of large areas, as well as, shortens effort, time and expenses (Pour et al. 2018).

The development in software led to diversity and high accuracy in obtaining information through various digital processing of multispectral satellite data to produce digital geological maps. The preparation of high-resolution digital geological maps has become more effective after the availability of other modern data such as digital elevation models, as well as Geographic information system software that used as a basic tool in drawing, processing and spatial analysis and non-spatial analysis data and outputting it in the form of maps, tables, drawings and reports. Furthermore, it can be constantly updated by adding new information (Borie et al. 2019).

Several methods of remote sensing technology has been used in the geology investigation including, but not limited to; T AL-Sayegh and A Daood (2012), used electromagnetic spectroscopy in the laboratory examination of two samples of the dominant rocks in the Sinjar mountain formations, limestone and marl. The spectral range of these rocks was obtained to be 2500–350 nm after that a Landsat 7 multispectral satellite image was applied to create false color composite and 751 and 521 RGB were selected to ensure the corresponding between the tested samples and the results of laboratory tests.

Al-Rawashdeh et al. (2006), examined the usage of Landsat ETM+ and SAR images were used to classify the different geological formations, differentiate the structure and lithology, and specify the zonation of hydrothermal changes in the El Azraq region, which is located in the North East of Jordan. In addition, different image ratios were utilized and 3/1, 4/3, and 5/7 have been chosen as the best. Moreover, principal components analysis was applied and only three components 1, 2, and 3 were chosen in order to distinguish the different types of igneous rocks. The selective principal components analysis utilized bands 1, 3, 4, and 5 were used in mapping iron and iron oxide-bearing minerals, bands 1, 4, 5, and 7 to detect the minerals bearing hydroxyl. Lastly, a hyperspectral technique was used to detect several minerals in the study area.

Al-Azzawi et al. (2018), applied a process of false-color combinations and 741 RGB has been chosen as the best, which is taken as a basis in the classification and mapping of the exposed geological formations in the Gara Barran anticline, which is located in the north of Duhok city, northern Iraq. In addition, different image ratios were utilized and 3/1, 4/3, and 5/7 have been chosen as the best. Besides, principal components analysis was applied and only three components PC3, PC4, and PC5 were chosen in order to distinguish geological formations of the study area.

Saadi et al. (2008), used remote sensing data with Landsat ETM+, surface geological information, and gravity data were utilized to validate the structures on the geological map of the Tarhunah area, northwest Libya. The results indicate that the basin is 39 to 48 km wide towards NE, as well as gradually deepens toward the southwest by using A two-dimensional model with faults of a depth from 2.5 Km to 7.5 km, which produced the volcanic activity of an anticlinal structure is called the Jabal Uplift.

Hassaan (2009), used Post-classification technique with Landsat TM, and Landsat ETM+ data to detect changes in Lake Maryuit, Egypt, and could support the monitoring and management of natural resources over remote sensing techniques from 1984 to 2002. The results indicated that about 4.63 % declined during the past period.

Although some researchers have studied the Bi'r Zaltan area. However, these studies were conventional and limited to small areas and depended on spaced paths in the field, select easy terrain, as well as, consumption of a lot of effort, time and expenses, for an example, the geological work was based on the contract between the Industrial Research Center (Tripoli, Libya) and Strojexport - Geoindustria (Praha, Czechoslovakia), in order to produce regional geological mapping in the central Sirt basin, which include Bi'r Zaltan area.

Therefore, these kind of study need many of images and maps and accordingly, and to solve all these problems, digital processing was used to identify rock units and draw digital geological mapping based on remote sensing data, which is characterized by high accuracy and comprehensiveness, and its coverage of large areas, and its production that shortens effort, time and expenses.

The current study aims to determine the existing and discovered rock units in the Bi'r Zaltan area, using digital processing methods for multispectral satellite images, using special advanced software, such as the ENVI 5.3 software. And the use of the geographic information system program ArcGIS 10 in the process of producing and preparing an accurate digital geological map that resulted from the digital processing of the area mentioned above.

Study area:

The area of the Bi'r Zaltan map sheet is limited by latitudes 28° and 29° N and longitudes19° 30´and 21° 00´E Administratively it belongs to the Maradah municipality. The map covers an area of approximately 16,000.500 square kilometers, it belongs to the northern part of the Libyan Sahara. It covers most part of Jabal Zaltan and the western margin of As Sarir, approximately 200 km

SSE of the Gulf of Sirt, about 500 km west of the Egypt Libya border as shown in figure (1).

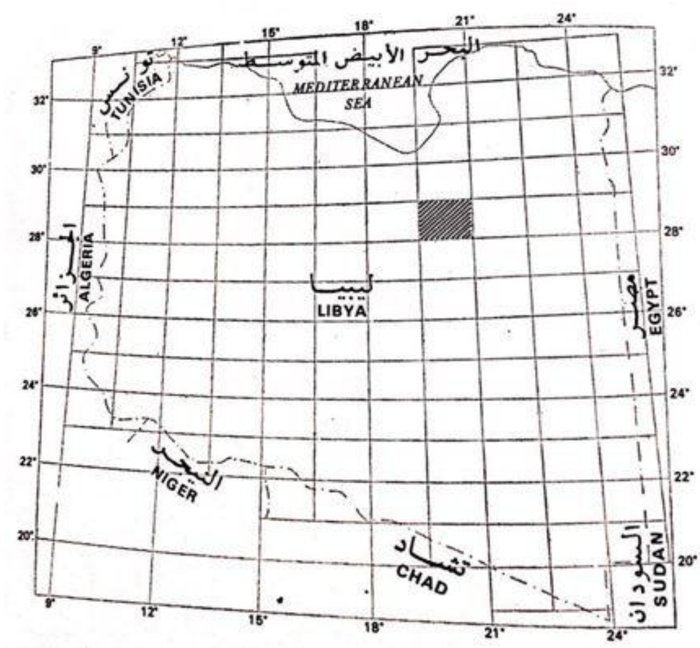

Figure 1: Location of the study area

According to S.P.L.A.J (1985), The Bi’r Zaltan map topography consists of; a) Original Tertiary plains developed in the Jabal Zaltan, in the eastern part of the area; b) Escarpments of the Jabal Zaltan and other residual hills, as high as 150 m; c) Deflation plains were created on more resistant Tertiary strata, such as the plains south and north of Jabal Zaltan, mostly covered with dune fields; d) Sabkhas filling in the depressions below the groundwater table; e) Surface pseudokarstic phenomena on the Jabal Zaltan platform; f) Dune fields of Quaternary age on older deflation plains. In addition to that, the outcropping geological formations in the Bi'r Zaltan area are an integral part of the Sirt basin in which no disjunctive deformation of the type of faults or cracks, or visible folds has developed. On the other hand, the joint system emphasizes the regularities of geological structure and the corresponding force field. In spite of specific local differences, the joint maxima are generally in the NE to N direction and in a direction roughly perpendicular to this, i.e. NW to W. Apart from this, there are also oblique systems, rotated through an angle of approximately 45°. The principal joint directions correspond to the direction of the main faults of the Sirt basin and to directions perpendicular to it.

The stratigraphic subdivision of units building up the area mapped is based on the lithostratigraphic scheme that can be seen in table 1, which determines the ages, geological units, lithological description, and thickness:

Table1: shows the lithological components of the geological formations of the study area

Age	Geological unit	Abbreviations of geological unit	lithological description	Thickness
Oligocene	Continental and transitional marine deposits	Toc	Sand, calcareous, sandstone, quantize conglomerate	Up to 400 m
Lower - Middle Miocene	Maradah Formation:	TmMR		Up to 700 m
Aquitanian - Burdigalian	Qarat Jahannam Member	TmMJ	Sand calcareous, sandstone, calcarenite, siltstone, claystone, dolomite	Up to 500 m
Aquitanian - Serravallian	Ar Rahlah Member: Facies of carbonate rocks Facies of terrigenous clastics	- - -	Limestone, dolomite, calcarenite, marlstone, claystone, siltstone, chalky limestone, coquina Calcareous sandstone, sand, conglomerate , limestone , coquina	Up to 200 m
Miocene-Pleistocene	Duricrust and altered terrestrial sediments	T-Qd	Calcilutite, sandy limestone, dolomite,cherts	0 – 12 m
Pliocene - Pleistocene	Qarat Weddah Formation	Tpl-QU	sandstone, conglomerate	0 – 25 m
Pleistocene	Lacustrine deposits	Qc	Claystone, siltstone, evaporite, chalky limestone	0 – 10 m
Pleistocene - Holocene	Landslides	Ql	Blocks of different rock, slope debris	5 – 30 m
-	Colluvial deposits	Qd	Slope debris, sand	1 – 15 m
-	Fluvioeolian deposits	Qf	Sand and a silty admixture	1 – 5 m
-	Deposits of shallow depressions	Qh	Sand, silts, debris	1 – 5 m
-	Sabkha deposits	Qs	Silt, sand, evaporite	1 – 10 m
-	Wadi deposits	Qw	Gravel, sand	1 – 5 m
-	Eolian deposits	Qe	Sand dunes and sheets	2 – 180 m

Materials and Methods:

In this study, a multispectral satellite image Landsat7 ETM+ captured on (23.04.2022) and with an index (Path183 Row40) was used. Initial processing was performed on this stage (spectral correction and engineering correction) and then configured to the boundary of the study area, Figure (2) shows the sequence of digital processing operations implemented during the current study. Also, several information was collected about the study area represented in literature review and geological maps that will be used later to illustrate the formations and structures that unfold in the study area, as well as to distinguish the boundaries between formations and identify their names.

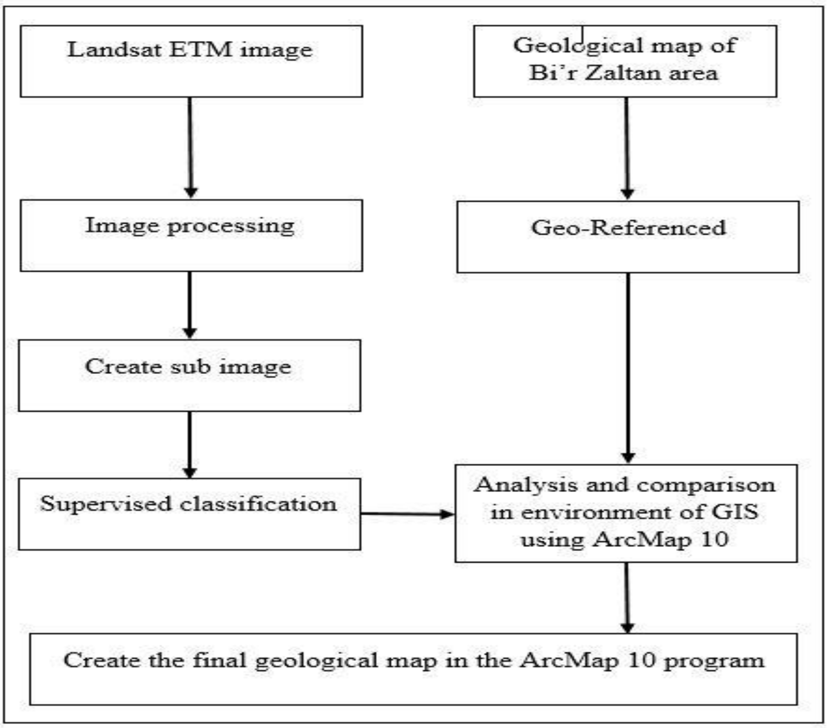

Figure 2: Flowchart of the digital processing sequence

Digital processing of remote sensing data applied for the purpose of visual interpretation in determining the location and extension of different geological formations and their boundaries (Daily 1982). To reach the expected results of this study, first step;

the digital processing was used to create color composite by using several bands, thus, the use of colors in displaying and enhancing digital images is an important concept in the processing of multispectral digital images in order to extract more information from them, the color composite method is consisting of three or more bands (RGB), which are red, green and blue (Lupton et al. 2004). It must be pointed out that it is difficult to analyze the spectrum images with colors composite because of the appearance of the ground materials in other than their true colors, so these images are called false color images (Patra et al. 2006).

Several combination of false color image and all spectral bands were taken for Landsat Enhanced Thematic Mapper ETM+ data and then make observance and emulations by the zooming, link display and geographic linking for digital images that obtained from false color composite, by using the ENVI 5.3 software. The best false color composite was used with band Red, Green and Blue 7, 4, 1 respectively as shown in figure (3), is usually given the largest sequence is red, the middle sequence is green, and the smaller sequence is blue, thus process of interpreting the results on the image is carried out according to color theory (Zha et al. 2003), which is an appropriate for the identification and area estimation, as well as, in determining the extension of most different geological formations and clarify the borders among them (Sgavetti et al. 2006). On the other hand, the importance of this method is due to the ability of the human eye to distinguish color differences and the degree of saturation of each color exceeds its ability to sense the differences in the degree of darkness (Tonal Variation) in the case of black and white images (Toet and Walraven 1996). Next step is to create sub image by extracting a subset of the image Landsat image using a new shape file obtained using the operation polygon feature to determine the boundary of the region and use it to extract by Mask -Area of the raster image in the ArcGis program to obtain an equal and identical image with the a geological map of the region published by the Industrial Research Center- Libya, 1985, as described BI'R ZALTAN NH 34 – 14 as shown in figure (4).

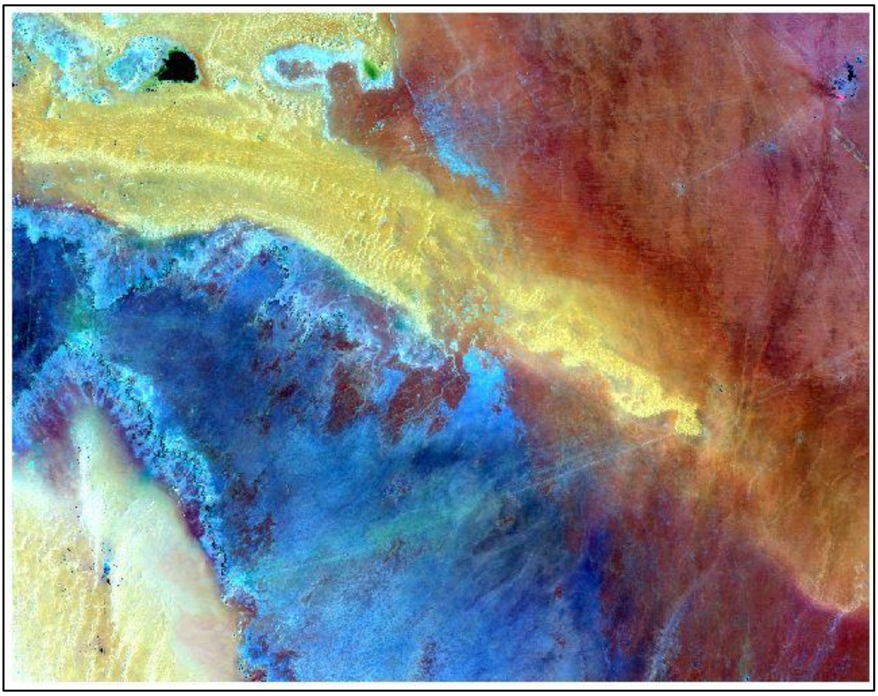

Figure 3: Landsat image composite of false color band 741

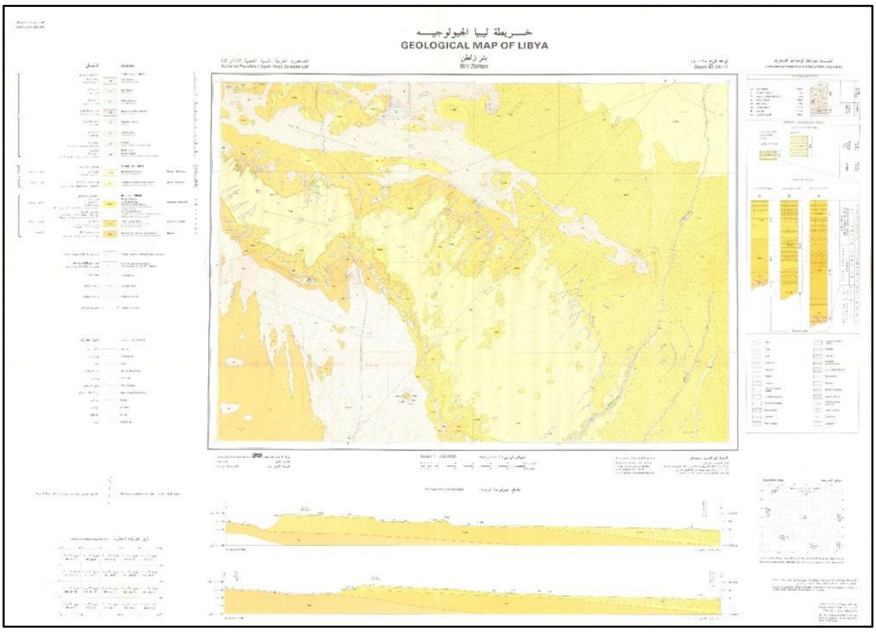

Figure 4: Geological map of study area (Bi'r Zaltan area)

Classification of satellite Image is a process in which the visible image converted into an objective map that carries information about the phenomena in the area pictured , by identifying the terrestrial phenomenon that represented by each unit of optical units (Zha et al. 2003). Therefore, Classification of multispectral images is the most important step in digital processing and it is the final goal of these operations (Alkoffash et al. 2014). Thus, all the information are extracted from the image after all previous corrections and enhancement that has been done.

A supervised classification approach is a classification process based on information about the spectral characteristics of the land cover that is obtained through detailed maps or from the results of digital processing of multispectral remote sensing images. Its purpose is to identify small areas called training samples, in which the information of the items is provided by the computer program, through its direction to complete the classification process (Campbell and Wynne 2011), in other words, the initial information was provided to train the algorithms then utilized to reclassify the remnant of the hybrid approach which means analysts know on the ground where specific features can train at the software in order to look for a very specific reflectance signature (Perumal and Bhaskaran 2010). Through the current study, a supervised classification process was applied to the false color composite image with bands 741 for the Bi’r Zaltan area and to benefit from the results achieved in previous digital processing of remote sensing data to define the training samples based on the extensions of the different geological formations by using the ENVI 5.3 program to complete the classification process, finally obtaining the geological map classified for the Bi’r Zaltan area.

Results and discussion:

The spectral analysis results of all formations in the study area as shown in the geological map, it became clear that all formations have a high ability to reflect the falling rays and in all spectral bands, as this was verified in the false-color image. In addition, the supervisor classification is very important in isolating land features with higher accuracy and less distortion because this type of classification is based on the value of the image units representing the land features, which are separated and isolated according to special algorithms in the programs used in digital processing operations that aim to Improving and interpreting satellite images (Mather and Tso 2016). Finally, geological classified map of the study area was produced based on the principles of visual interpretation by calling the classification map in the GIS environment and through the high capabilities that this technique provides for the cartographic demarcation process, the classification map was matched with the geological map used as a reference (based map) to evaluate and assess the accuracy of classifying Landsat image (supervised classification) by increasing the transparency of the upper layer through the program (ArcGIS 10) to 50% so that the image becomes clear through the display screen, and then match the geological formations with together in both maps, In this case, the geological map available for the study area was used as a base map, where the Ground Truth Points (GTP) were taken on, which are random points for all formations and deposits on the geological map, which number reached more than 20 points for each classification in order to ensure the accuracy and quality of the evaluation, and therefore the total number was 362 distributed over the study area, after using the value to point tool, which takes the value of GTP and reflects it on the shapefile and then adds them as values in a new column opposite to the column values of formations and deposits in the classified image (Raster value) to compare with together, the next step is to use the pivot table tool to calculate the frequency of these points and make statistics for them to obtain the accuracy of the classified map as shown in table 2 as confusion matrix. Thus, the results of this match showed that the overall spatial accuracy of the obtained map was 70% based on 362 ground troth points., which was in agreement with the geological map of the study area. In the end, the digital geological map of the Bi'r Zaltan area can be linked to a wide database that is prepared for all the available geological information about this area, this data can also be updated in the future when any geological developments occur.

Table2: shows the confusion matrix of accuracy of the classified map

	REFERENCE												
CLASSIFIDE	Qe	Qw	Qs	Qh	Qf	Qd	Tpl-QU	T-QD	TmMR	TmMJ	Toc	total	accuracy
Qe	26	0	0	0	0	2	0	0	0	2	3	33	79%
Qw	0	16	0	0	0	0	2	1	0	0	0	19	84%
Qs	0	0	24	0	0	0	0	0	0	0	0	24	100%
Qh	2	0	4	22	25	5	0	2	0	0	0	60	37%
Qf	0	0	0	0	20	0	0	1	0	0	0	21	95%
Qd	0	0	0	0	0	19	0	3	0	0	0	22	86%
Tpl-QU	0	17	0	0	0	0	21	0	2	0	0	40	53%
T-Qd	0	0	0	0	0	4	0	31	1	0	2	38	82%
TmMR	0	3	0	0	2	0	6	1	23	0	0	35	66%
TmMJ	0	0	0	0	0	5	0	4	0	23	1	33	70%
Toc	0	1	0	0	0	0	1	1	4	5	25	37	68%
total	28	37	28	22	47	35	30	44	30	30	31		
accuracy	93%	43%	86%	100%	43%	54%	70%	70%	77%	77%	81%		

Total accurate 250

Overall accuracy 70%

Through the study and analysis of the results of the multiple digital processors implemented on the Landsat 7 image for the Bi’r Zaltan area, were reached to determine the extension of the geological formations and the separating surfaces between them as shown in the figure (5), and thus the production of a geological classification map showing all the formations and depositions for the study area as following:

- Continental and transitional marine deposits
- Maradah Formation
- Qarat Jahannam Member
- Duricrust and altered terrestrial sediments
- Qarat Weddah Formation
- Colluvial deposits
- Fluvioeolian deposits
- Deposits of shallow depressions
- Sabkha deposits
- Wadi deposits
- Eolian deposits

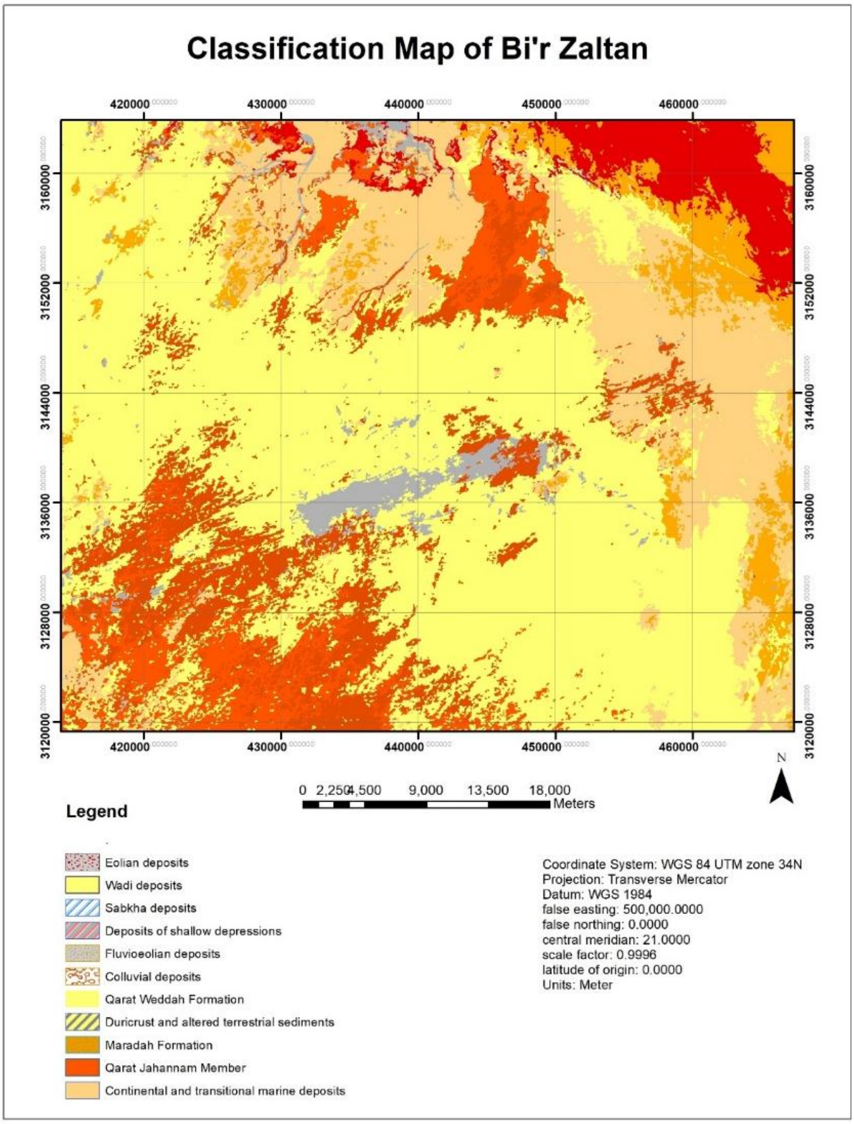

Figure 5: Classification map showing all the geological formations and deposits of the study area

Conclusion:

The current study showed the possibility of benefiting from the outputs of the digital processing operations for multispectral space images to support the creation of digital geological maps based on the high capabilities of remote sensing software and geographic information systems. Moreover, the spectral behavior of formations and deposits obtained from bands 741 RGB are distinguished by their great ability to reflect the radiation falling on them, as well as, the capability of composite false-color images to support and confirm the spectroscopic results. Besides, the ability and efficiency of digital supervisor classification to reach the accuracy required to isolate and distinguish the formations and deposits found in the study area. In addition, the enhancement in the information of geological maps has an additional and net positive value to organizations that can help regarding land use and participate in planning for sustainable development. Furthermore, the principles developed and improved in this study are generally applicable to many other uses of geological map information.

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