LITHOLOGICAL MAP OF IRAQ, COMPILED USING GIS TECHNIQUES

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Received: 26/ 2/ 2012, Accepted: 3/ 5/ 2012
Key words: Lithological units, Sedimentary rocks, Quaternary sediments, ArcGIS, Iraq

ABSTRACT

The Iraqi territory is covered mainly by sedimentary rocks, Quaternary sediments and very rare igneous and metamorphic rocks. The sedimentary rocks are represented mainly by carbonates and clastics, with subordinate gypsum, marl and shale. The igneous rocks are represented mainly by gabbros, whereas the metamorphic rocks are represented mainly by serpentines.

In order to compile the lithological map of Iraq, the 89 exposed geological formations and units, and 18 types of Quaternary sediments are classified into 14 lithological units, depending on the main constituent of each geological formation and different types of Quaternary sediments, which appear on the Geological Map of Iraq at scale of 1: 100 000. Each lithological unit is given a certain color depending on its main lithological constituent.

Using GIS techniques, the exposed geological formations and Quaternary sediments that are presented on the Geological Map of Iraq at scale of 1: 1000 000 are assigned to 14 lithological units. However, on the Geological Map of Iraq, many formations are grouped together, age wise, due to scale limitation. This case is found only in the northern and northeastern parts of Iraq, which are mountainous areas, with intensely folded and thrusted strata, besides to the wide age range of the exposed formations, which extends from Precambrian to Pleistocene. In such cases, the lithology of the most predominant geological formation in the group is taken in consideration for assigning the group to a certain lithological unit. Moreover, the coverage area of each lithological unit is determined, also using ArcGIS software.

توليف الخريطة الصخارية للعراق باستخدام تقنية نظم المعلومات الجغرافية

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المستخلص

تغطي الصخور الرسوبية وترسبات العصر الرباعي بشكل عام معظم مساحة العراق، مع وجود بعض الصخور النارية والمتحولة. إن الصخور الرسوبية تتمثل بالصخور الكاربوناتية والفتاتية، مع القليل من الصخور الجبسية والطفل والصلصال. بينما تتمثل الصخور النارية بشكل عام بأنواع الگابرو، أما الصخور المتحولة فتتمثل بصخور السرپنتين.

لغرض توليف الخريطة الصخارية للعراق، فقد تم تصنيف التكوينات الجيولوجية المتكشفة (89 تكوين ووحدة جيولوجية) وترسبات العصر الرباعي (18 نوع) والبالغ عددها معاً 107 وحدة إلى 14 وحدة صخارية، اعتماداً على المكونات الصخرية الرئيسية لكل تكوين جيولوجي وترسبات العصر الرباعي، وكما تظهر على الخريطة الجيولوجية للعراق من مقياس 1: 000 1000. وأعطيت لكل وحدة صخرية لون خاص واعتماداً على المكون الصخري الرئيسي للوحدة.

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باستخدام تقنية نظم المعلومات الجغرافية، فقد تم تنسيب التكوينات الجيولوجية المتكشفة وترسبات العصر الرباعي، وكما تظهر على الخريطة الجيولوجية للعراق من مقياس 1: 000 1000، إلى أربعة عشر وحدة صخرية. ولكن على الخريطة الجيولوجية للعراق فقد تم دمج العديد من التكوينات الجيولوجية اعتماداً على العمر وذلك لمحددات مقياس الخريطة. ومثل هذه الحالات ظهرت فقط في المناطق الشمالية الشرقية والشمالية من العراق، لكونها مناطق جبلية ومتأثرة بالطي الشديد والفوالق العكسية، إضافةً إلى تكشف تكوينات جيولوجية ومن أعمار مختلفة تمتد من ما قبل الكامبيري والى البلايستوسين. وفي مثل هذه الحالات، فان صخارية التكوين الجيولوجي الأكثر شيوعا في المجموعة المدمجة قد أخذت بنظر الاعتبار عند تنسيب المجموعة الى وحدة صخارية معينة. وقد وصفت خطوات إعداد الخريطة الصخارية للعراق بشكل خطوات متسلسلة. وكذلك أعطيت نماذج مختارة من مناطق مختلفة من العراق، حيث تمت مقارنة الخريطة الجيولوجية مع الخريطة الصخارية لتلك المناطق المختارة. وكذلك تم احتساب المساحة السطحية لكل وحدة صخارية عن طريق استخدام برنامج ArcGIS.

INTRODUCTION

The Iraqi territory is covered mainly by sedimentary rocks and Quaternary sediments, except very small parts, in the northeastern parts, which are covered by igneous and metamorphic rocks. The main types of the sedimentary rocks are carbonates and fine clastics, with subordinate gypsum, shale, marl, phosphorites and conglomerate. The main types of igneous rocks are different types of gabbros, whereas the main types of metamorphic rocks are serpentines. The Quaternary sediments cover considerable parts in Iraq, especially in the central part; they are represented by different types of alluvial sediments of the Tigris and Euphrates Rivers flood plains, and their tributaries. They form the main Mesopotamian Land. The sediments are mainly of silt, clay, sand with subordinate gravels. Moreover, gypcrete and sand dunes also cover considerable parts of the Iraqi Territory.

▪ Aim and Location

The aim of this study is to compile a Lithological Map for Iraq, using ArcGIS techniques. Such map can be used for different applications, such as economic potential, civil constructions, deducing some types of geological hazards, and looking for agricultural lands.

▪ Previous Works

Few similar works have been performed, as the Iraqi territory is concerned, but all of them are beyond the scope of this study. Hereinafter is the main performed works.

- Muradian *et al*. (1985) compiled the Economic – Geological Map of Iraq at scale of 1: 1000 000 and used a generalized lithological map, using rasters and colors as a base map for the compiled map, in order to deduce the relation of the presented quarries and existing raw materials with the lithology.
- Araim (1990) compiled the Hydrogeological Map of Iraq at scale of 1: 1000 000 and used a generalized lithological map, using rasters and colors as a base map for the hydrogeological map, in order to deduce the lithology of the aquifers, which partly shows the exposed rocks.
- Hamza (1997) compiled the Geomorphological Map of Iraq at scale of 1: 1000 000 and used a generalized lithological map, using rasters and colors as a base map for the geomorphological map, in order to deduce the relation of the presented geomorphological units with the lithology.
- Sissakian and Abdul Jabbar (2002) compiled a special map that shows the distribution of gypsum in the Iraqi Territory, within a special study, which dealt with the gypsum problems on engineering structures.

- Barwary *et al*. (2003) compiled the Quaternary Sediments Map of Iraq at scale of 1: 1000 000. They differentiated the Quaternary sediments age wise, beside the generalized constituents of each type of the sediments, in which the type of the sediments is differentiated lithology wise.
- Sissakian and Ibrahim (2005) compiled the Geological Hazards Map of Iraq at scale of 1: 1000 000 and used rasters and colors in order to deduce some geological hazards, which are related to lithology, such as gypsum induced hazards; in which areas covered by gypsum are presented, sand dunes, gypcrete, expansive clays, flood plains, in the last four types of geological hazards, the sediments type is concerned.
- Al-Bassam (2007) compiled the Minerogenic Map of Iraq at scale of 1: 1000 000 using rasters and colors. In order to classify the Minerogenic Zones, he used the main lithology of some exposed formations in deducing some zones.

In all aforementioned maps, the presented lithological units were deduced by simplifying the covered areas within each lithological unit. The units were drawn approximately; therefore, the coverage area of each lithological unit does not represent the true coverage area of the involved unit, which is out of the scope of this study.

Moreover, some workers compiled special maps dealing with the distribution of some raw materials in Iraq, like distribution of gypsum, limestone, gypcrete. All those maps are beyond the scope of the presently compiled map, because they dealt only with a certain lithological type.

MATERIALS USED AND METHODOLOGY

▪ Materials Used

In order to compile the Lithological Map of Iraq, the geological maps of Iraq (Sissakian, 2000 and Sissakian and Fouad, 2012) were used as a base map to indicate the exposed geological formations and the existing Quaternary sediments, which are presented on the map. Other geological maps and reports were used as data base to indicate the constituent(s) of the exposed geological formations. ArcGIS programs and extensions were used for digitization of the geological map of Iraq, and then to compile the present lithological map.

▪ Methodology

In order to compile the present lithological map of Iraq, the exposed 89 geological formations and units, and the 18 types of Quaternary sediments were grouped in 14 lithological units (Table 1), and each lithological unit is defined by certain lithological constituent(s) (Table 2), taking in consideration the main lithological types, which form the exposed geological formations and Quaternary sediments, in Iraq.

After defining the 14 lithological units (Table 1), each geological formation, and each type of Quaternary sediments, which are presented on the Geological Map of Iraq (Sissakian, 2000 and Sissakian and Fouad, 2012), is assigned to a certain lithological unit, among the defined 14 lithological units (Table 1). The main constituent of each geological formation (Table 3) and each type of the Quaternary sediments is indicated from the best available data, especially Bellen *et al*. (1959), which defines the type section of each geological formation, hence the lithology is indicated too. Moreover, data presented by Buday (1980), Jassim *et al*. (1984), Sissakian (2000) and Jassim and Goff (2006) were used too to indicate the main lithology of each geological formation and each type of Quaternary sediments (Table 3).

Table 1: Main lithological constituents of the exposed geological formations and Quaternary sediments

LITHOLOGICAL UNITS

FORMATIONS and QUATERNARY SEDIMENTS

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Anah	Aaliji	Bedu	Akashat	Amij	Kata Rash	Dibdibba	Bai Hassan	Chalki Volcanics	Fatha	Intrusive Complex	Fluvial Sediments (9 types)	Gypcrete	Sand Dunes
Aqra – Bekhme	Balamo	Chia Gara	Ratga	Garagu	Naopurdan	Ga'ara	Hab'bariyah Gravels	Khabour	Dhiban	Shalair	Polygenetic Sediments	Sabkhas (3 types)	
Avana	Baluti	Gulneri		Ghar	Perispiki Red Beds	Gercus	Hauran Gravels						
Avroman	Chia Zari	Harur		Hussainiyat	Qandil	Injana	Dokan Conglomerate						
Azkand	Dammam	Kura China		Kiasta	Shalair	Kolosh							
Baba	Digma	Mirga Mir		Muhaiwir	Suwais Red Beds	Mukdadiya							
Bajwan	Euphrates	Naokelekan		Qulqula	Walash	Nahr Umr							
Barsarin	Geli Khana	Ora		Tayarat		Rutbah							
Dokan	Hadiena	Sargelu		Zahra		Tanjero							
Govanda	Hartha	Sarki											
Khurmala	Jaddala												
Kometan	Jill												
Mergi	Mauddud												
Ms'ad	Najmah												
Mulussa	Nfayil												
Palani	Sarmord												
Pila Spi	Shiranish												
Piran	Zor Hauran												
Qamchuqaa													
Sehkaniyan													
Serikagni													
Sheikh Alas													
Shurau													
Sinjar													
Tarjil													
Umm Er Radhuma													
Ubaid													

Table 2: Main lithological constituents of the 14 defined lithological units

Unit No.	Lithology	Unit No.	Lithology
1	Carbonates	8	Conglomerate
2	Carbonates and Marl	9	Clastics, with Igneous and Metamorphic rocks
3	Carbonates and Shale	10	Marl, Limestone and Gypsum
4	Carbonates and Phosphorite	11	Igneous and Metamorphic rocks
5	Carbonates and Clastics	12	Fluvial sediments
6	Carbonates, Igneous and Metamorphic rocks	13	Evaporates
7	Clastics	14	Aeolian Sand dunes

Table 3: Lithological characteristics of the exposed geological formations (after Sissakian, 2000)

No	Formation	Lithology	No	Formation	Lithology	No	Formation	Lithology
1	Aaliji		30	Ghar		59	Ora	
2	Akashat		31	Govanda		60	Palani	
3	Amij		32	Gulneri		61	Pila Spi	
4	Anah		33	Hadiena		62	Piran	
5	Aqra –Bekhme		34	Hartha		63	Pirispiki Red Beds	
6	Avana		35	Harur		64	Qamchuqa	
7	Avroman		36	Hussainiyat		65	Qandil	
8	Azkand		37	Injana		66	Qulqula	
9	Baba		38	Jaddala		67	Ratga	
10	Bai Hassan		39	Jill		68	Rutba	
11	Bajwan		40	Kaista		69	Sargelu	
12	Balambo		41	Kata Rash		70	Sarki	
13	Baluti		42	Khurmala		71	Sarmord	
14	Barsarin		43	Khabour		72	Sehkaniyan	
15	Bedu		44	Kolosh		73	Serikagni	
16	Chia Gara		45	Kometan		74	Shalair	
17	Chia Zairi		46	Kura China		75	Sheikh Alas	
18	Chalki Volcanics		47	Mauddud		76	Shiranish	
19	Dammam		48	Mergi		77	Shurau	
20	Dhiban		49	Mirga Mir		78	Sinjar	
21	Dibdibba		50	Msad		79	Suwais Red Beds	
22	Digma		51	Muhaiwir		80	Tanjero	
23	Dokan		52	Mukdadiya		81	Tarjil	
24	Euphrates		53	Mulussa		82	Tayarat	
25	Fatha		54	Nahr Umr		83	Ubaid	
26	Ga'ara		55	Najmah		84	Umm Er Radhuma	
27	Garagu		56	Naokelekan		85	Walash	
28	Geli Khana		57	Naopurdan		86	Zahra	
29	Gercus		58	Nfayil		87	Zor Horan	

Lithological Legend

Carbonates	Claystone	Siltstone	Phosphorite
Marl	Conglomerate	Gypsum and /or Anhydrite	Igneous rocks
	Sandstone	Shale	Metamorphic rocks

▪ **GIS Applications**

The GIS is an integrated and modern system, which has the ability of storing and retrieving of the data, and to analyze and present the data in different forms (Ormsby *et al*., 2004; Allen, 2009 and Gorr and Kurland, 2009). In order to compile the lithological map of Iraq, ArcGIS software was used in 10 steps; as follows:

– Step 1: Performing the geodata base of the geological map of Iraq, in form of layers, using ArcCatalog and ArcMap programmes. A folder was created, which can be opened by means of "Open Attribute Data" order.

– Step 2: The data of the geological map of Iraq was presented in order to create new layers concerning the lithology in form of 14 layers.

– Step 3: The first performed layer was the Carbonate, Unit 1 in Table (2); it includes 27 formations (Table 1). A new selection was created.

– Step 4: After creating of the Carbonate layer, the same steps were repeated, to create the other layers, for the remaining 13 lithological units

– Step 5: In the contents raw, a new layer for the Carbonates can be observed; it was derived from the data of the geological formations layer (from the geodata base).

– Step 6: The created data bank for the Carbonate Unit was checked to be sure that the stored data equal to the number of the geological formations assigned to the Carbonate Unit (Table 1). Moreover, the data of each geological formation was checked (Table 3) to be sure that the lithology of the assigned formations to the Carbonate Unit coincides with the lithology of the Carbonate Unit.

– Step 7: The steps 2 – 6 were repeated for the other remaining lithological units (Table 1), which attains 13.

– Step 8: The created lithological data are displayed only in the lithological raw, for storing them as data bank.

– Step 9: The Lithological Unit No.8 (Conglomerate, in Table 2) includes data of geological formations and data of Quaternary sediments. Hence, two categories of input datasets were selected to obtain the output as a new layer, which includes the involved geological formations and the Quaternary sediments. This was done by means of using advanced level for analyzing and dressing of data.

– Step 10: After, creating the data of all 14 Lithological Units (Table 2), they were displayed and sorted by colors and symbols. Meanwhile, they were checked as a final check for the compiled Lithological Map of Iraq (Fig.1).

STATISTICAL DATA

After compilation of the Lithological Map of Iraq (Fig.1), the coverage area of each lithological unit, among the 14 units, was determined using ArcGIS software, ArcMap and ArcTool box, as corrected to the least kilometer. The acquired data are mentioned in Table (4). However, the mentioned coverage area did not represent precisely the coverage area of each lithology within the coverage area of the Iraqi territory. This is attributed to the fact that the mentioned lithology of each unit does not indicate the exact lithological constituent of each unit. Because within each unit (Table 1), there are subordinate lithologies, which are not included, and this is due to the existence of different subordinate lithologies within each exposed geological formation (Table 3), beside the Quaternary sediments.

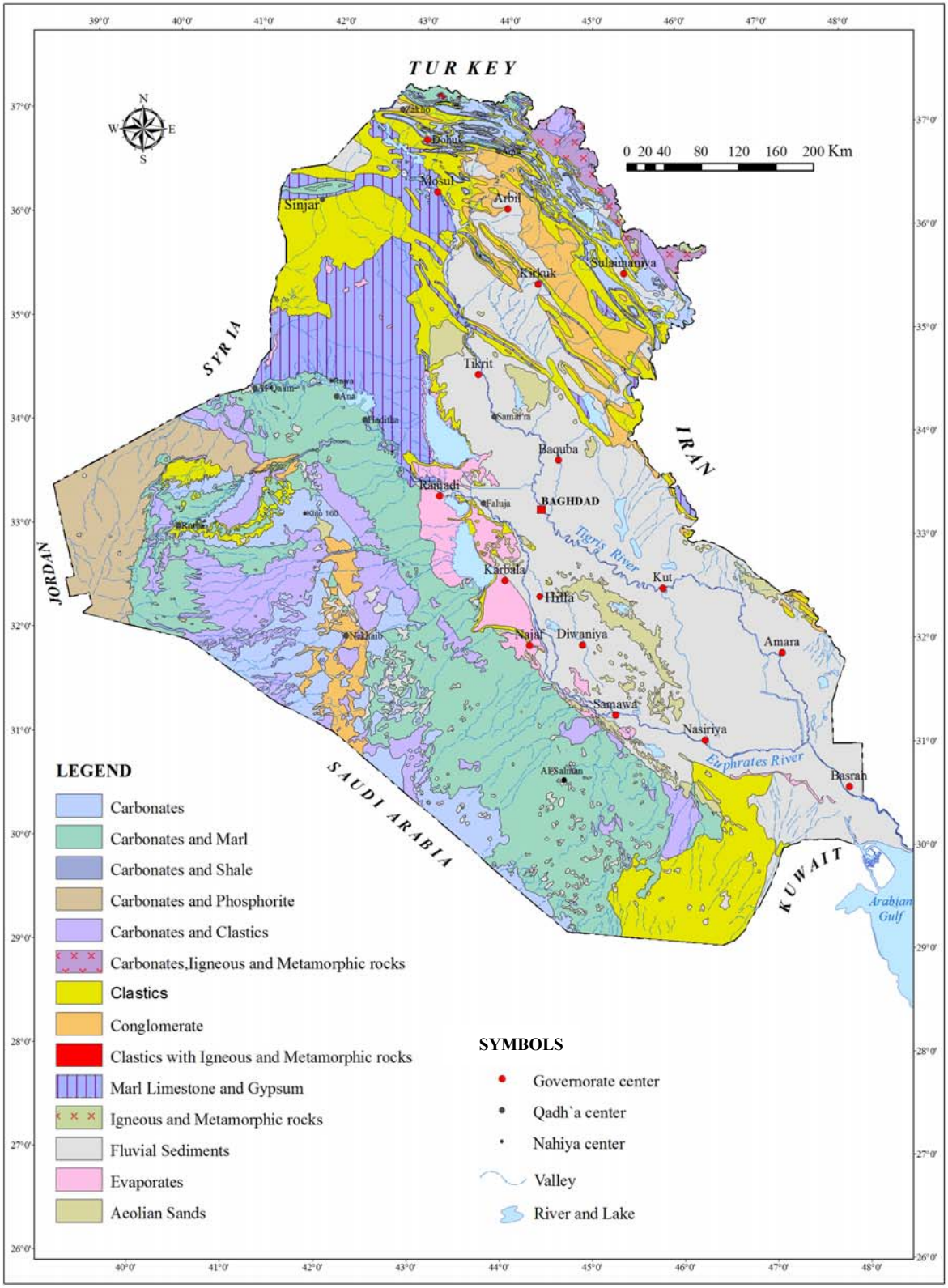


Fig.8: Lithological Map of Iraq (present work)

Table 4: Coverage areas of the 14 lithological units, within the Iraqi Territory

Unit No.	Coverage area (Km^2)	Unit No.	Coverage area (Km^2)
1	3315	**8**	19233
2	90889	**9**	29
3	895	**10**	32276
4	17892	**11**	918
5	31225	**12**	132702
6	4075	**13**	11094
7	57500	**14**	10151

The total coverage area of the 14 Lithological Units is 412194 Km^2, which represents the coverage area of the Iraqi Territory, excluding the coverage areas of water bodies. It is worth mentioning that the coverage area of the Iraqi Territory is about 443 500 Km^2. Table (5) shows the percentage of the coverage area of each lithological unit, as corrected to two decimals.

Table 5: Percentages of the coverage areas of the 14 Lithological Units

Unit No.	Coverage area (%)	Unit No.	Coverage area (%)
1	0.80	**8**	4.66
2	22.05	**9**	0.01
3	0.22	**10**	7.83
4	4.34	**11**	0.22
5	7.57	**12**	32.19
6	0.99	**13**	2.69
7	13.95	**14**	2.46

The Quaternary sediments represented by Lithological Units 12, 13 and 14, and part of Unit 8 (Table 1) cover areas of 153947 Km^2, which means 37.35% of the total coverage area of the Iraqi Territory, excluding the coverage areas of the water bodies. But, when adding 30% of the coverage areas of Lithological Unit 8, which includes Bai Hassan Formation, Hab'bariyah, Hauran Gravels and Dokan Conglomerate (Table 1), then the total coverage area of the Quaternary sediments will be 160358 Km^2, with percentage of 38.9% from the area of the Iraqi Territory. Only 30% of the coverage area of the Lithological Unit 8 is added, because Bai Hassan Formation represents about 70% of the coverage area of this unit.

The igneous and metamorphic rocks with their associated sedimentary rocks represented by Lithological Units 6, 9 and 11 (Table 1) cover areas of 5022 Km^2, which means 1.22% of the total coverage area of the Iraqi Territory, excluding the coverage area of the water bodies.

The clastic rocks, represented by Lithological Unit 7 (Table 1) cover areas of 57500 Km^2, which means 13.95% of the total coverage area of the Iraqi Territory, excluding the coverage area of the water bodies. However, when adding the coverage areas of the Bai Hassan Formation (Tables 1 and 4), then the area will be 70322 Km^2, which means 17.06% of the total coverage area of the Iraqi Territory, excluding the coverage area of the water bodies.

The carbonate rocks with their associated sedimentary rocks represented by Lithological Units 1, 2, 3, 4 and 5 (Table 1) cover areas of 144216 Km^2, which means 34.98% of the total coverage area of the Iraq Territory, excluding the coverage area of the water bodies.

RESULTS

The Lithological Map of Iraq is compiled using ArcGIS techniques. The used base map is the Geological Map of Iraq (Sissakian, 2000 and Sissakian and Fouad, 2012). In order to compile the lithological map, 14 lithological units are defined (Table 1), each unit is presented by a certain color, in some units rasters are added with the color. Each exposed geological formation and/ or Quaternary sediment, which is presented on the Geological Map of Iraq, at scale of 1: 1000 000, is assigned to one of the 14 lithological units. This was performed depending on the main lithology of the exposed formations and/ or Quaternary sediments.

The coverage areas of each lithological unit is determined, using ArcMap and ArcTool box programmes (Table 4), after changing the compiled map (Fig.1) to UTM coordinates, in order to calculate the coverage areas of each unit. Otherwise, the coverage areas cannot be calculated. The determined coverage areas, however, did not present the precise coverage area for each lithological type.

DISCUSSION

The ArcGIS techniques were used to compile the Lithological Map of Iraq (Fig.1), based on the Geological Map of Iraq (Sissakian, 2000 and Sissakian and Fouad, 2012). The described Steps (2 – 10) were performed by the co-author, in the Information Technology Department, in Iraq Geological Survey. The steps were performed regularly, except when some difficulties were met, how to assign certain formation(s) to a certain lithological unit, among the established 14 units (Table 1), especially when more than one geological formation are grouped together in the geological map. The following action was performed to overcome the aforementioned difficulty. On the geological map of Iraq (Sissakian, 2000 and Sissakian and Fouad, 2012) some of the geological formations are grouped together, age wise due to the scale limitations, especially in the northeastern and northern parts of Iraq. This was performed because those parts are mountainous areas, highly folded and thrusted, which make the geological formations to be exposed in very small areas, consequently cover small areas on the geological map at scale of 1: 1000 000. Whereas, in the western, southern, eastern, and central parts of Iraq, each geological formation is presented separately on the geological map, because those areas are either not folded or very gently folded, therefore, each geological formation covers considerable areas. In the former cases, the assigning of a group of geological formations, as they appear in the geological map, to a certain lithological unit is almost impossible, because the grouped formations have usually different lithologies (Table 1). In such cases, the lithology of the most prominent formation in the group is considered; when assigning of the grouped formations to a certain lithological unit. However, this action had caused the appearance of certain formation(s), in the complied Lithological Map of Iraq within a certain lithological unit, which did not include the lithology of the formation. This can be checked from comparison of the geological map and the compiled lithological map. Figures (2, 3 and 4) are examples of such cases. Moreover, enlarged parts of the compiled lithological map can be viewed too, in those figures, moreover, both maps could be compared, concerning the areal distribution of a certain lithological map (Figs.2A, 3A and 4A) with their assigned geological formations and/ or Quaternary sediments (Figs.2B, 3B and 4B).

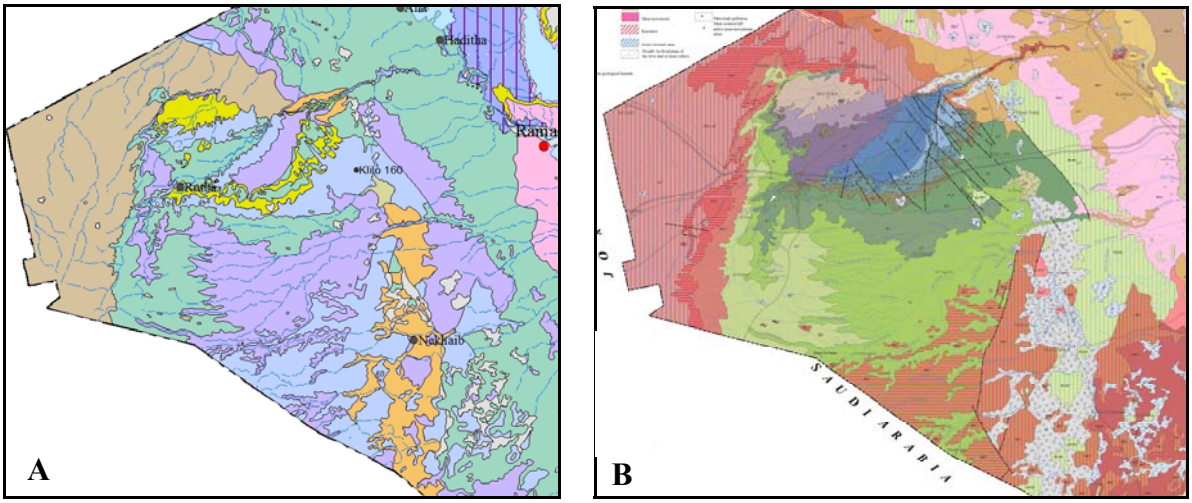
Another difficulty was met when a certain lithological unit includes geological formations and Quaternary sediments, because in the established geodata base of the Geological Map of Iraq (Sissakian, 2000 and Sissakian and Fouad, 2012) the geological formations and Quaternary sediments are saved in different layers. Therefore, the following action was performed to overcome this difficulty. When a certain lithological unit includes geological formations and Quaternary sediments (Table 1), then the Step 9 was performed to overcome this difficulty. This is because the presented geological formations and Quaternary sediments on the Geological Map of Iraq have different geodata bases. Therefore, they cannot be treated directly, unless the mentioned special action (Step 9) is performed.

The coverage area of each lithological unit was determined, using ArcGIS software (Table 4). However, the determined coverage area of each unit within the Lithological Map of Iraq (Fig.1) does not necessarily represent the precise lithological coverage areas. This is attributed to the fact that the exposed 89 geological formations and units (Table 3) and 18 types of Quaternary sediments include subordinate lithologies, which are not considered when the formations were assigned to the 14 Lithological Units. It is almost impossible to consider the subordinate lithologies within the exposed geological formations and/ or Quaternary sediment, during assigning them to certain lithological unit. However, the percentage of the ignored subordinate lithologies has no significant effect on the main lithology (or lithologies) of the 14 lithological units, considering the scale of the map. A good example is the Pila Spi Formation (Table 1), which is assigned to Unit 1 (Carbonate Unit) (Table 1), although it includes subordinate marl (Table 3). The percentage of the marl within the main constituent (carbonate) of the formation is negligible, therefore, it is assigned to Unit 1, and when indicating the coverage area of the Carbonate Unit (3315 Km^2), then certainly the determined coverage area does not refer to carbonates only. Many such examples occur within other lithological units. No relevant solution did occur to overcome such difficulties, except working with more detailed scale maps.

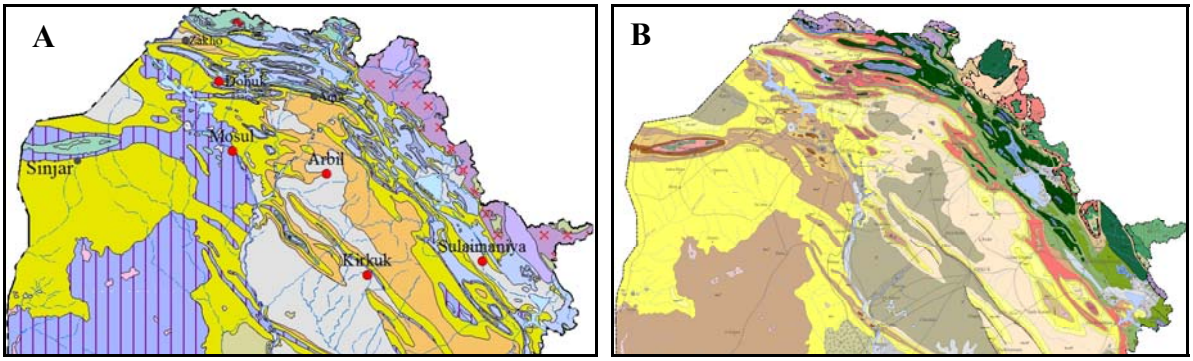
In reviewing Table (6), it could be obviously seen that the number of geological formations and Quaternary sediments within a certain lithological unit is not a function of the coverage area of that lithological unit. For example Unit 1 (Carbonates) includes 27 geological formations (Table 6) with coverage areas of 3315 Km^2 (Table 4), whereas Unit 2 (Carbonates and marls) includes 18 geological formations (Table 6) with coverage areas of 90889 Km^2 (Table 4). Such differences are attributed to the following aspects: **1)** Thickness of each formation and/ or Quaternary sediments, **2)** Whether the rocks are folded or not and **3)** Dip amount; when folded. The dip amount plays an important role in the coverage area of the involved geological unit, consequently the coverage area of the assigned lithological unit.

Table 6: Number of geological units within each lithological unit

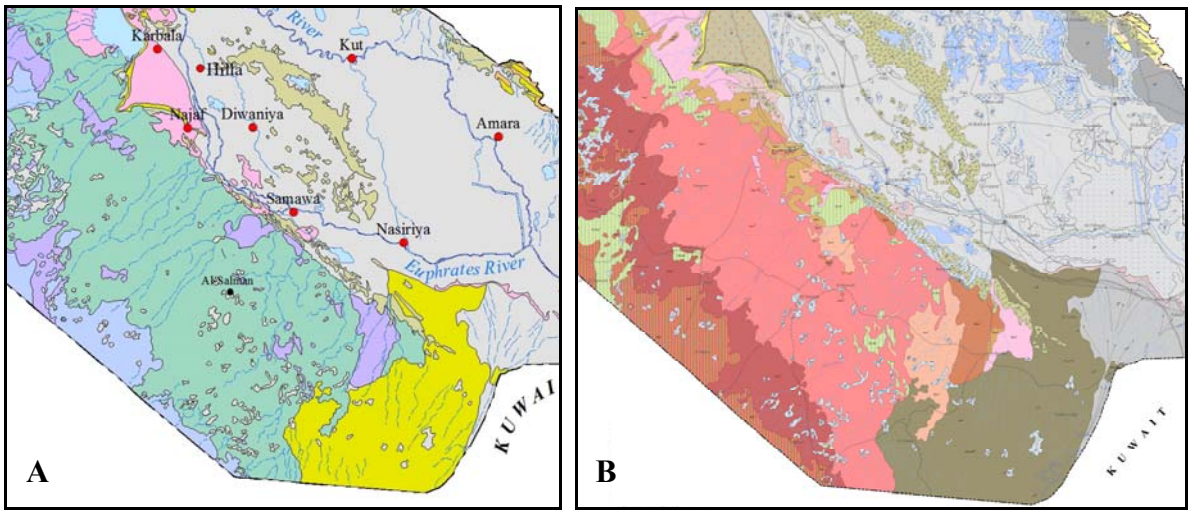
Unit No.	Number of geological units	Unit No.	Number of geological units
1	27	**8**	4
2	18	**9**	2
3	10	**10**	2
4	2	**11**	2
5	9	**12**	10
6	7	**13**	4
7	9	**14**	1



2.1



2.2



2.3

Fig.2: Three examples of different parts of the compiled Lithological Map of Iraq (**A**) as compared with the same parts of the Geological Map of Iraq (**B**)
2.1) Western part, 2.2) Northern part and 2.3) Southern part

The only determined representative coverage area within the total coverage area of the Iraqi territory is that of the Aeolian sand dunes, Unit 14 (Table 3), which has coverage areas of 10151 Km^2 (Table 4) and percentage of 2.46% (Table 5). This is because it is the only lithological unit, which includes only one lithology. However, Unit 10 (Marl, limestone and gypsum) (Table 2), which includes only two geological formations (Fatha and Dhiban) (Tables 1 and 6) with coverage areas of 32276 Km^2 (Table 4) and percentage of 7.83% (Table 5) is also a representative for this lithological unit. Because the coverage area of Dhiban Formation is almost negligible; when compared with that of the Fatha Formation, beside the fact that the Dhiban Formation does not include marl and limestone, but it was assigned to this lithological unit, because it is the most relevant lithological unit among the established 14 Lithological Units (Tables 1, 2 and 3).

CONCLUSIONS

The following could be concluded from this study:

- ArcGIS techniques, using ArcCatalog, ArcMap and ArcTool box software was performed successfully to compile the Lithological Map of Iraq, from the available geodata base of the digitized Geological Map of Iraq, at scale of 1: 1000 000.
- The used GIS techniques enable the prepared geodata base to display the map in any required scales, very easily.
- The used GIS techniques enable the prepared geodata base to display any lithological unit of the presented 14 lithological units.
- From the compiled Lithological Map, the lithotypes of the exposed rocks and/ or Quaternary sediments; in any part of Iraq can be established.
- The coverage areas of each lithological unit is determined. The larger (Unit 2) and smaller (Unit 18) unit within the rocks is 90889 Km^2 and 29 Km^2, respectively. The former is represented by Carbonate and Marl Unit and includes 18 geological formations, whereas the latter is represented by Clastics with Igneous and Metamorphic rocks Unit and includes only two geological formations. Whereas, within the Quaternary sediments, the largest one is 132702 Km^2, which is Unit 12, and is represented by Fluvial sediments.

ACKNOWLEDGEMENTS

The authors would like to express their sincere thanks to Mr. Sabah Y. Yacoub, for his critical comments, concerning the used GIS techniques, which have amended the article. Thanks are also forwarded to Mr. Hayder H. Taha, for arranging the tables and figures in the article. Thanks are also extended to the staff of GIS Division, in the Iraq Geological Survey, those who were involved in digitizing of the Geological Map of Iraq.

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