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Origin of Ga'ara and Hussainiyat Clays, Iraqi Western Desert

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ABSTRACT

The two Formations Ga'ara and the lower clastic unit of Hussainiyat were deposited in fluvial system of deposition with slight different behaviors like the thickness of fining upward cycles in different times, in addition to, some stratigraphic, structural, paleogeographic and geochemical evidences.

The present work aimed to compare between these formations from sedimentological and geochemical points of view. It has been found that both formations were derived from the same source of the western and southwestern Arabian shield.

أصل أطيان الكعرة والحسينيات - الصحراء الغربية العراقية

الملخص

يمتلك كل من تكويني الكعرة والوحدة الفتاتية السفلى من الحسينيات نظام ترسيبي نهري متشابه تقريباً، مع وجود بعض الأختلافات في السمك ودورات التنعم نحو الأعلى فضلاً عـن بعـض الـشواهد الطباقيـة والتركيبية والمعدنية والجغرافية القديمة والجيوكيميائية.

وتوضح الدراسة الحالية من منظار رسوبي وجيوكيميائي بشكل رئيس بأن كلا التكوينين من المحتمـل انهما مشتقان من نفس صخور المصدر تقريباً والواقعة الى الجهة الغربية والجنوبية الغربية مـن الـصحراء الغربية المتمثلة بالدرع العربي.

INTRODUCTION

The studied area is located in the western desert of Iraq (Fig 1). The Ga'ara Formation is outcropping in the Ga'ara depression, which is located about 50 Km. northwest of the Hussainiyat outcrops.

Many works were carried out on Ga'ara and Hussainiyat Formations dealing particularly with sedimentation and iron ore occurrences. However, there is no one individual study deals with both formations, in order to compare between their origins.

Therefore, most if not all of the previous works declared that the Hussainiyat Formation was derived from the Ga’ara Formation.

Ga’ara Formation is of Permocarboniferous age (Ctyroky, 1973 in Buday and Hak, 1980 and Nader et al.,1993) depending on polenology , and has a thickness of about 750m in borehole (KH 5/1). More than 500 m. of the thickness is buried in Ga’ara depression and about 125 m. in maximum is exposed on the floor of the depression as continuous outcrops appears beneath Mulussa Formation in the southern limb of the depression.

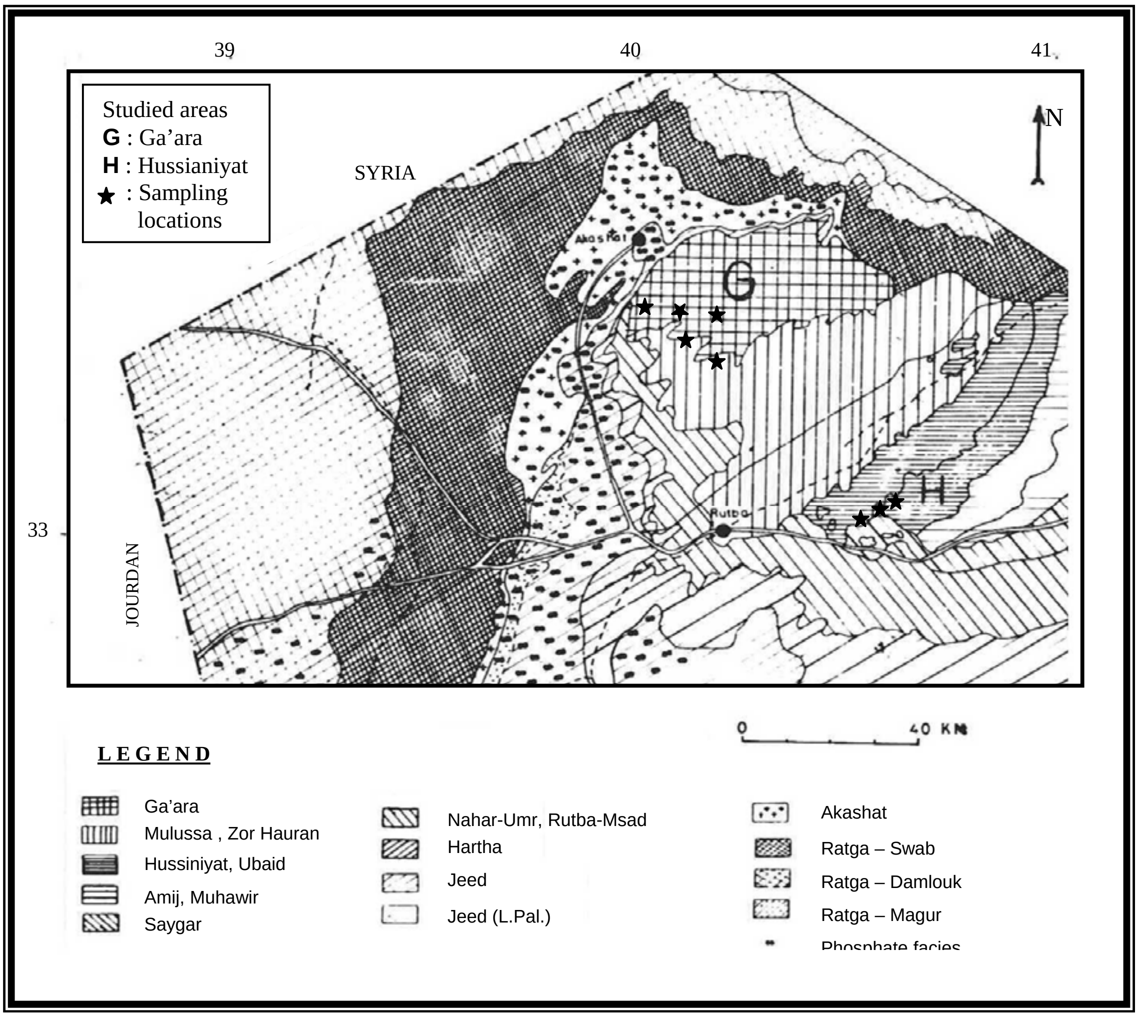

Fig. 1 : Location map of the studied areas (Jassim et al., 1986).

The Ga’ara Formation: is underlain unconformablly by Unit A Ordovician (an individual beds of marl and claystone lay between Al-Sofi and Ga'ara Formations), the Ga'ara Fomation composed of alternation of claystones and sandstones, the later are differ mineralogically and environmentally from Ga’ara sandstones; (Tamer Agha in Al-Mola, 2002), and overlain unconformably by many geological formations of different ages

(Mulussa, M. Triassic; Geed, Hartha , Tayrat , U. Cretaceous; Akashat, Paleocene and Retga, L. Eocene).

The formation constitutes clastic sediments displayed by sandstone, siltstone, silty claystone and claystone beds. These were deposited in fining upward cycles, which range in thickness from about 2m. to more than 25m and most of them are very well developed. The sandstones are dominantly medium to fine grained, whereas coarse-grained sandstones are scarcely occurred. They are characterized by many large -scale sedimentary structures distinctive of fluvial sedimentation. Among them the well-developed channeling and the epsilon type of cross bedding, which may indicate point bar accretion of a river channel (Tamer Agha, 1989).

Some sandstone beds bear iron concretions and others having ferruginous cementing materials, these beds called ferruginous sandstones. The ferruginous sandstones are mostly occurred at the base of the fining upward cycle, where the pervious sandstone, which represents the cycle base, rests directly on the impervious claystone bed which displays the top of the underlying fining upward cycle. In general the sandstone have varied colours and toughness, reflecting the channel and point bar deposits.

The silty claystone have also varied colours. It may alternates with thinly bedded fine-grained sandstones. It is usually tough to medium tough, and may contains iron pisolites in varied amounts and concentrations. Sometimes its thickness exceeds 10m. within individual cycle. Environmentally, the silty claystones may indicate a channel levee sequence within the fluvial system.

Claystones are mostly kaolinitic and characterized by white to greyish white with occasional colour laminations and mottling. Other coloured kaolinitic beds may bear iron in many forms like pisolites, longitudinal and rounded concretions (10 – 20) cm. (Yakta, 1981; Tobia, 1983), pores shape, vermiforms, slabby forms, spots, ferruginous layers (3-6)cm., burrowing shape and mottled layers (Al-Youzbakey, 1989), (Fig. 2).

Hussainiyat Formation: was regarded by Bellen et al., (1959) and Buday and Hak, (1980) as a part of Ubaid Formation (L. Jurassic , Liassic) it is correlated with the so called Milleh Tharthar clastics in the subsurface section in central Iraq, Well Milleh Tharthar No. 1 (Al-Mubarak, 1983 and Hassan, 1985). It is underlain by Ubaid Formation (L. Jurassic, Liassic) age and it is overlain by Amij Formation (Bajocian) (Buday and Hak, 1980, Al-Naqib *et al.*, 1985 and 1986). In Rutba area the extension of the formation to the southeast is unconformably overlaid by Najmah Formation (Upper Jurassic, Malm) and Rutba/Msad Formation (Upper Cretaceous, Upper cenomenian) (Al-Naqib, 1994).

The formation was divided into two main lithological units; the lower is clastic and the upper is carbonate. The present study deals with the lower one only. Detailed

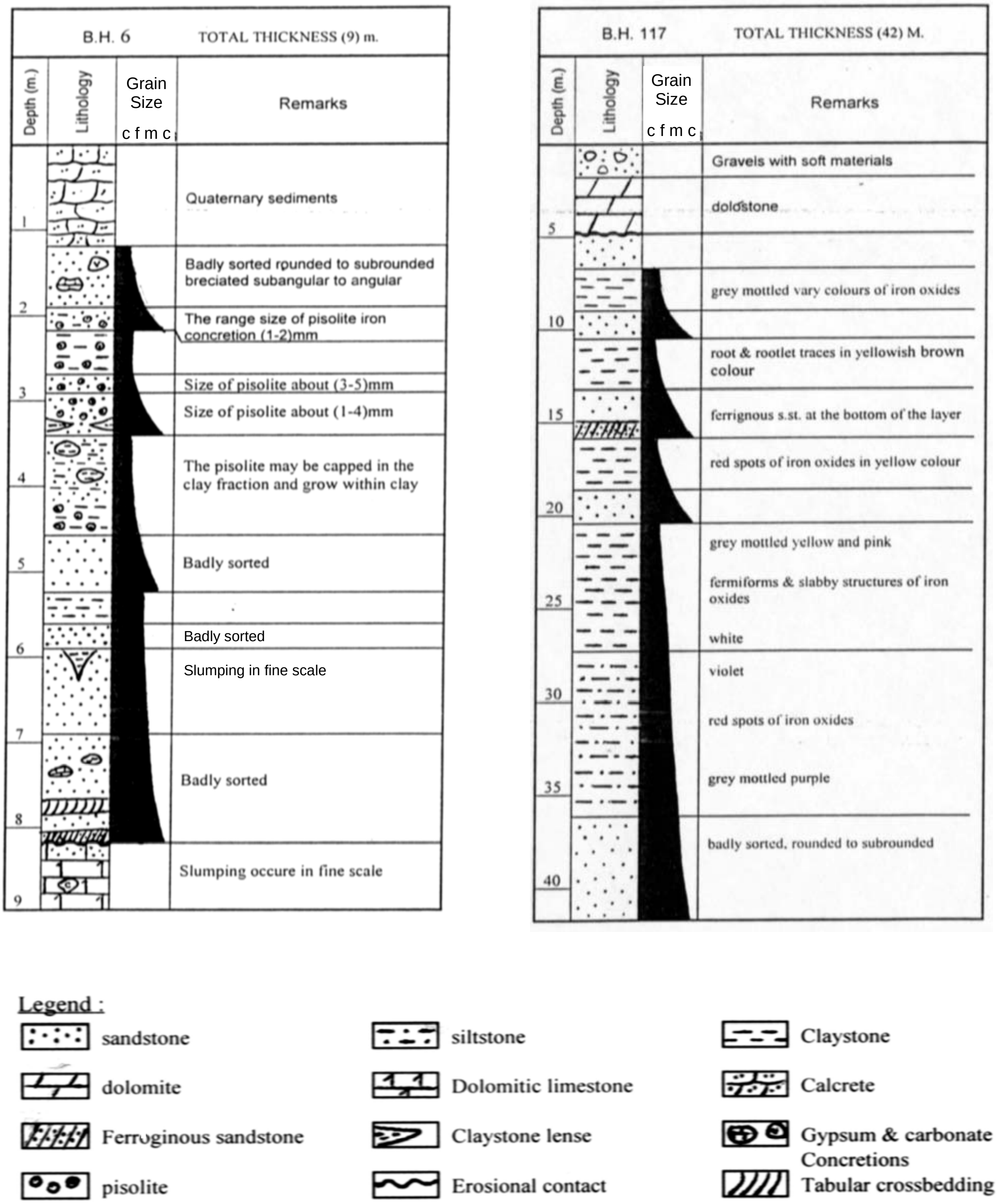
B.H. 6
TOTAL THICKNESS (9) m.
Depth (m.)
Lithology
Grain Size
c f m c
Remarks
Quaternary sediments
Badly sorted rounded to subrounded breciated subangular to angular
The range size of pisolite iron concretion (1-2)mm
Size of pisolite about (3-5)mm
Size of pisolite about (1-4)mm
The pisolite may be capped in the clay fraction and grow within clay
Badly sorted
Badly sorted
Slumping in fine scale
Badly sorted
Slumping occure in fine scale
1
2
3
4
5
6
7
8
9
B.H. 117
TOTAL THICKNESS (42) M.
Depth (m.)
Lithology
Grain Size
c f m c
Remarks
Gravels with soft materials
dolostone
grey mottled vary colours of iron oxides
root & rootlet traces in yellowish brown colour
ferrignous s.st. at the bottom of the layer
red spots of iron oxides in yellow colour
grey mottled yellow and pink
fermiforms & slabby structures of iron oxides
white
violet
red spots of iron oxides
grey mottled purple
badly sorted, rounded to subrounded
5
10
15
20
25
30
35
40
Legend :
sandstone
siltstone
Claystone
dolomite
Dolomitic limestone
Calcrete
Ferroginous sandstone
Claystone lense
Gypsum & carbonate Concretions
pisolite
Erosional contact
Tabular crossbedding

Fig. 2: Lithological sections of (a): Hussainiyat Formation in Rutba area (Al-Naqib et al., 1985) (b): Ga’ara Formations in Ga’ara depression (Tamer Agha, 1989).

sedimentological studies were carried out on Hussainiyat Formation by Al-Naqib et al. (1985 and 1986) and Al-Naqib (1994). These studies showed that the clastic unit of ussainiyat Formation displays by many repetitive fining upward cycles throughout the succession, (Fig. 2). Some cycles are incomplete (missing one or two of their components). Other cycles didn’t begin with pebbly sandstones instead they may begin with coarse – medium grained sandstones. In borehole or outcrop, one to five fining upward cycles have been documented. Cycle thickness is ranging from 2.2 to 14m. (Al-Naqib, 1994). The later divided the clastic unit into five lithofacies relying on lithological changes, grain size and sedimentary structures; they are: claystone, silty claystone and clay siltstone, fine to very fine-grained sandstone, medium to coarse grained and pebbly sandstone.

It is important to discuss the comparison between the Ga’ara iron deposits and the Hussainiyat iron ore with its stratigraphic extension (Rutba iron deposits) from sedimentological and geochemical points of view.

Most if not all the workers; Jassim (1981); Tobia (1983) and Yakta (1984) on Ga’ara and Hussainiyat Formations regarded that, the Hussainiyat iron ore was derived from Ga’ara Formation. In turn, Al-Bassam and Tamer Agha (1998) concluded that the clastics were derived from variety of parent rocks that included low and medium rank of metamorphic, intermediate igneous rocks, and pre-existing sediments of the Nubio – Arabian shield. Al-Atia et al. (1997) suggested that the Hussainiyat clastic sediments and the other Jurassic sediments were most likely derived from two sources: the Ga’ara Formation and the Arabian shield complex rocks. This context has not the fair chance of study, this is nearly all worker has either study Ga’ara iron deposits or Hussainiyat iron ore individually. Only descriptive comparison appeared in few studies e.g Al-Atia et al. (1997).

The present work aimed to determine some sedimentological and geochemical characteristics of the two formations in order to differentiate between them in addition to the field evidences relating structure, stratigraphy, and paleogeography.

METHODOLOGY

twenty seven samples were collected from the base, western and southern flank of the Ga’ara depression. thirty eight samples were collected from Hussainiyat area and its extension (Rutba iron concentrations) toward Rutba city. The samples were analyzed for major oxides and trace elements in the laboratory of Geological Survey and Mineral Investigation – Baghdad.

RESULTS AND DISCUSSIONS

1- Sedimentological characteristics:

On the basis of**:**

a- Grain size; the abundant grain size of the sandstones appear in the Ga’ara Formation is medium-fine , with sparse thinly bedded coarse **-** grained sandstone, on the contrary, the abundant sandstone grain size appear in Hussainiyat Formation is coarse, coarse-medium, with pronounce pebbly quartizitic sandstone beds forming the channel lag deposits. If the sandstone of Hussainiyat Formation was derived from Ga'ara Formation, the grain size of Hussainiyat Formation should be finer than that of Ga'ara Formation or at least has the same size, this is because the distance between the two locations is about 50 Km. and did not affect the grain size in obvious way. The quartz grains found in all fractions in Ga'ara claystones (Al-Youzbakey, 1989), while it is found to be very low or absents in the basal claystone unit in Hussainiyat Formation (Qassim, 1996).

b- Roundness; the quartz roundness of sandstone in the Ga'ara and Hussainiyat Formation have approximately the same degree of roundness with slight variables. This indicates that, the two formations have passed approximately through the same distance of transportation or nearly so, although they have various grain sizes.

c- The main paleocurrent direction of Ga'ara Formation is directed towards the east, whereas the Hussainiyat Formation is directed to the east and southeast. This means that the two formations have slightly different source areas and derived at different ages. It is supported by the paleochannel direction of Ga'ara Formation, made by Tamar Agha (1989) and paleocurrent analysis for Hussainiyat Formation made by Al-Naqib et al. (1986) and Al-Naqib (1994), in addition to paleocurrent direction gained from cross bedding " in particular, the epsilon type" . Thus if Hussainiyat Formation was derived from Ga'ara Formation then the paleocurrent direction of Hussainiyat Formation should be directed to the south and southeast, according to the geographical position of the Hussainiyat Formation related to the position of Ga'ara Formation.

d- Iron amounts and concentrations: It seems that the amount of iron ore in Hussainiyat Formation is much more than that of the exposed part of the Ga'ara Formation in the depression, and the iron concentration of the former one is greater (as average) than the later one. So, the iron-ore of Hussainiyat Formation could not be derived from the Ga'ara Formation.

Another point raised here, that is the iron pisolite of Hussainiyat Formation if transported from Ga'ara Formation, then it should be fragmented, because its major constituents are mostly goethite alternated with clay (kaolinite) and have not the chance of its shape conversion during transportation.

e- The iron concretions and pisolites were made up of clayey iron enriched lamina coating each other. It is pointed that, these lamina haven't the opportunity to transport in fluvial process without destruction (more than 20 Km transporting distance) make the concretions and pisolites more detrital leading to effect on both quantity and quality (Bardossy, 1982).

2- Stratigraphic position:

If the Ga'ara area was the sediments source of the clastic unit of Hussainiyat Formation then, why not other clastic units of the Jurassic system of the western desert like Amij, Muhaiwir and Najmah have the same source area? In addition, paleocurrent direction of the clastic units of the Jurassic system was directed towards north and northeast and northwest directions, respectively (Al-Naqib et al., 1986).

3- Structural characteristics:

Structurally, the Ga’ara Formation is higher than other Triassic and Jurassic formations. The presence of Ga’ara/Mulussa contact, thick pile of sediments of both Triassic and Jurassic formations particularly in the southern limb of the Ga’ara depression and the absence of any marked regional dip, however, suggests that there is no reasonable cause lead to the conclusion that Hussainiyat Formation was derived from Ga’ara Formation.

Inturn, the Cretaceous (Upper Cenomanian) Rutba/Msa’d Formation was derived from the northwestern direction, i.e. Ga’ara area could be part of its source rocks (Al-Naqib, 1994). In addition, field study revealed that there were no any paleogeographic elements like paleovallys or water passages could pointed out that during Lower Jurassic (Lower Liassic), these elements directed from Ga’ara depression towards southeast i.e. Hussainiyat position.

4- Paleogeography:

At Permocarboniferous, Ga’ara Formation was deposited in fluvial sequence forming about 750m. thick, composed of alternations of sandstones, siltstones, silty claystones and claystones. Sandstones forming the base of channels, whereas the claystones (mostly kaolinitic) forming the over bank deposits (Tamar Agha, 1989).

Extensive erosion took place at the end of this age and unconformable contact occurred between the underlying Ga’ara Formation and the overlying M. Triassic Mulussa Formation, where the Lower Triassic age was missed. The above mentioned erosion before the deposition of Mulussa Formation made peneplaination of its upper part. This is quite clear in the field.

After the deposition of Mulussa Formation the regional depositional strike of the Zor Houran Formation (Upper Triassic, Rhiatic) went concordant with the upper part of Mulussa Formation indicated by gradational contact. Environmentally, a transition from subtidal to supratidal environment took place respectively. At the end of Rhiatic time, the Rutba uplift commenced its marked activition leading to regional strike shifting from east–west direction in case of these formations to northeast–southwest direction in case of the succeeding overlying Jurassic Formations. Though, the basin of deposition of the Ubaid Formation runs in northeast–southwest direction and controlled by the Rutba uplift (where the Ga'ara high is part of it) and as a result, confining the Jurassic basin to that direction.

5-Geochemical characteristics:

The great similarity in mineralogical constituents of claystone (Kaolinite, quartz, hematite, goethite, rutile, anatase) of both Ga’ara and Hussainiyat Formations, led the following workers to regard that, Hussainiyat clays were derived from Ga’ara Formation during the Lower Jurassic (Lower Liassic), among them; Jassim (1981), Tobia (1983), Yakta (1984) and Al-Hasso (1990). This fellowship of mineral groups accomplished their geochemical behavior during denudation and hydrolysis of the parent rocks, which were almost made up of igneous & metamorphic rocks. The extensive erosion and leaching gets these mineral groups, which inturn transported and deposited through many sedimentational cycles in slightly acidic oxidizing environment (e.g. meandering river environment). Similar examples are Gorgia (U.S.A), Bohemia (Germany), Cilica (Poland), Kuti (Maxico), Youko Hills (Tanzania) and Ninkeotoki (Japan).

a-The hydrolysis of the igneous rock forming minerals like, mica and feldspar led to the formation of intermediate stages producing kaolinite. This may call it (clay precursors), i.e. the stages producing clay minerals. These were enriched by alumina, silica and iron (Tazaki & Fyfe, 1987). The process needs potassium to remove from mica and feldspar from the crystal structure to the solution (Stock and Sikora, 1976).

However, the proceeding of denudation process in acidic environment led to the initiation of oxides and hydroxides of both iron and aluminum phases, in addition to, the silica (Millott, 1970). Silica is derived from the Hydrolysis of silicate minerals, amorphous silica and from the dissolved silica of the fine quartz (Henderson, 1982). Gibbsite is regarded as the most stable phase among the aluminum hydroxide phases in acidic environment (Gillott, 1968 and Millott, 1970). The access of silica presence prevents gibbsite formation, where it will react with gibbsite to form kaolinite due to the –ve gibbs free energy (Chesworth, 1975) through the silicification process (Kittrick, 1969 and Van Olphen and Veniale, 1981). Consequently, the precipitates become enriched by kaolinite , quartz and iron oxides, and the aluminum hydroxide phase has not the chance to stay in solution. So that the Ga’ara Formation has excess silica. It is thought that the presence of the little amount of aluminum hydroxide in Hussainiyat claystones was the product of the sever denudation of the igneous source rocks, in humid climate during Jurassic time (Al-Atia, 2002), as well as, the pedogenic bauxites and laterites.

b- The low concentration of potassium (1 – 2)% reflects the presence of illite in claystones. It indicates that the transformation to kaolinite was immature (Michailids and Tsrambides, 1986), and represent the later intermediate stages of leaching (Henderson, 1982). The continuous process of leaching will remove potassium from crystal structure and form kaolinite (Stoch and Sikora, 1976). If the sever denudation which the Ga’ara Formation was suffered produced kaolinite hydrolysis, logically, the illite which accompanied the kaolinite must be dissolved. Though potassium must leave the crystal structure and stays in the solution.

As potassium is regarded as a mobile element, therefore it can not be expected to enter the structure of the newly formed clay minerals of Hussainiyat formation with the same concentration. Table (1) shows the potassium distribution with both studied formations. Consequently, there was no difference in potassium concentration, which reflected by the illite. Briefly, the illite accompanied the kaolinite during transportation from the parent rock of Ga’ara formation and not derived from Ga’ara Formation itself.

c- It is evident that the presence of Mn in the claystones was associated with iron oxides minerals in Ga'ara (Al-Youzbakey, 1989) and Hussainiyat formations (Tobia, 2005). The low concentration (ppm) of Mn can be attributed to its high oxidizing potential against iron (Millott, 1970). However, the iron precipitated as oxides and hydroxides leaving Mn in solution except the very low Mn concentration, which associated with the iron precipitation.

The latest literatures on Hussainiyat Formation (e.g. Tobia (2005)) didn’t argue any phase of Mn within any minerals.

Table 1: Chemical analysis of Ga’ara and Hussainiyat mudstones.

Oxides & Elements	Ga’ara Formation			Hussainiyat Formation		
	Present Study	Zainal 1980	Tobia 1983	Present Study	Al-Hasso 1990	Qassim 1996
SiO_2 (%)	49.99	51.30	55.74	43.20	45.79	31.00
TiO_2	1.04	1.03	1.26	1.57	1.40	1.10
Al_2O_3	22.62	26.61	22.73	16.62	22.75	20.7
Fe_2O_3	12.34	5.70	5.90	19.51	15.94	14.75
MgO	0.22	0.25	0.06	0.90	0.72	n.a
CaO	0.35	0.50	0.33	5.57	1.28	1.81
K_2O	0.59	0.88	0.44	0.63	0.58	0.65
Na_2O	0.54	1.05	0.48	0.15	0.17	0.18
Ni (ppm)	62	48	40	238	52	113
Co	30	47	7	n.a	78	106
Cu	20	15	10	21	8	11
Zr	563	222	459	597	645	360
Cr	149	364	116	244	151	302
Mn	57	88	13	251	131	n.a
Pb	32	17	8	15	11	n.a
V	256	96	80	355	277	291
Sr	65	n.a	125	n.a	n.a	17
Zn	39	n.a	<10	40	n.a	25
Ga	n.a	n.a	n.a	51	32	24

n.a = not analyzed

Table (1) revealed the Mn concentration in both formations, it has 57ppm in Ga’ara and 250ppm in Hussainiyat claystones (as average). If the previous hypotheses were true, the hydrolysis conditions of the iron oxides and hydroxides must set the Mn out to the solution which can not be precipitated within iron precipitation in Hussainiyat Formation. This is may be due to its high oxidizing potential. Conclusively, the Hussainiyat iron must not be derived from Ga’ara iron.

d- Aluminum replaced the Fe^{+3} in iron oxides and hydroxides (e.g. Hematite and goethite). The Al mol percent in hematite and goethite (as average) are 3 and 8 in Ga’ara iron respectively (Al-Youzbakey, 1994), while it is 9 and 11 in Hussainiyat iron (Qassim, 1996).

The fragments which suffer from hydrolysis and reprecipitation did not take much more aluminum. As a result the solution has not excess alumina in dissolution conditions of ferric oxides and hydroxides. Though, it can't be expected for aluminum substitution in Hussainiyat iron to occur.

e- During heavy minerals study of both Formations, the zircon and rutil are regarded as the highest weathering resistance minerals. The two minerals within Ga'ara Formation have euhedral and subrounded form (Ismail, 1989), whereas in Hussainiyat Formation the zircon was subrounded to rounded (Qassim, 1996). Consequently, the zircon of Hussainiyat Formation has relatively transported longer distance than the zircon of Ga'ara Formation. Thus, the 50 Kms hypothetical distance between the two Formations was not enough to change the roundness from euhedral - subrounded (in Ga'ara) to rounded (in Hussainiyat). This mean that the source rocks of Hussainiyat clays and irons are far away than the source rock of Ga'ara, although the two have the same direction relative to the geographical locations of the two formations.

f- iron oxides and hydroxides phases in both formations were hematite and goethite. In Ga'ara Formation the iron phase of goethite is more than the iron phase of hematite (Al-Youzbakey, 1989), in turn hematite is the dominant iron phase in Hussainiyat Formation (Al-Naqib et al., 1986). Although hematite represent the stable phase in comparison with goethite but it is very slow transformation (i.e. long geological time) from hematite to goethite (Koch,1986). As well as, the presence of goethite reflected humid climate while hematite reflected semi-arid climate (Millott, 1970). However, the climate clues of Hussainiyat claystone pointed to humid climate (Al-Atia, 2002). From the above mentioned discussion it is difficult to transform all the Ga'ara goethite to hematite in Hussainiyat.

g- The structure of pisolites in Ga'ara formation indicated that it was formed from nuclei of detrital fragments composed of quartz or goethite surrounded by radial thick layer of goethite altered with film of kaolinite (Al-Youzbakey, 1989). Intern, pisolites in Hussainiyat Formation were forming insitu and composed of hematite without nucleous. This indicates that the process of forming pisolite was differ in both environments of the two formations.

h- Table (1) generally, shows that the trace element concentrations are close in both formations and tend to increase in Hussainiyat. This closing doesn't indicate that Hussainiyat claystones and associated iron oxides were derived from Ga'ara. This is in general, because of the ability of kaolinite, illite (Koppelman and Dillard, 1977) and iron oxides (Mason, 1966) to adsorbed elements on their surfaces in different places are the same (Millott, 1970).

If the denudation processes on Ga'ara claystones took place and then reprecipitation in Hussainiyat have occurred, the concentration of trace elements must be decrease due to the colloidal kaolinite and iron oxides sever depleting to adsorbed these elements through the acidic solution (Bear, 1965).

Some elements like Ni, Co, Cr, Cu and V were move as soluble ions in acidic solutions. Cobalt for example, usually found in claystones < 10 ppm (Millott, 1970), but the high concentrations recorded in both formations are due to its adsorbing on iron oxide phases. Through the leaching process, cobalt form hydrated cobaltic oxides associated with iron in oxidizing conditions e.g. latrites (Mason, 1966; Kopplelman and Dillard, 1977). Cobalt adsorbed especially on pisolites which found in Hussainiyat more than Ga’ara. Intern the transportation of pisolite from Ga'ara to Hussainiyat through acid oxidizing conditions will decrease cobalt to the solution, so its concentration must be less than in Ga’ara. The cobalt concentration in both formations depends on the conditions of denudation and sedimentation from source rocks to Ga’ara and Hussainiyat areas. The above behavior was almost similar for other above elements.

CONCLUSIONS

The similarity of the associated mineral assemblages is due to their similar geochemical behavior through the hydrolyses process on the parent rocks. This included intermediate igneous and low – medium rank metamorphic and pre-existing sediments of the Nubio – Arabian shield. The suffered leaching process on the parent rocks form these mineral assemblages which transported by a complex system of meandering rivers and deposited through many cycles in acidic and oxidizing environments as any other places in the world. The climate, humid and semi-arid seasons and the oscilation of water table played an important role in the redistribution of iron in both channels and flood plain local environments.

The differences in some sedimentological and geochemical features were due to the different in the transported paths of eroded parent rocks, cycles of sedimentation and pedognesis in the environment of two formations. Paleocurrent analysis indicates the similar direction to the east and north from the same source area. Many cycles of sedimentation and pedognesis process play an important role in the redistribution of lithofacies and iron oxide structures under different climate conditions.

So, sedimentologically; it is obvious from the above mentioned evidences that both formations were derived from the same position source area or nearly so during various geological times.

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