MODES OF GOLD OCCURRENCES IN GA'ARA DEPRESSION, WESTERN DESERT, IRAQ

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ABSTRACT

This research deals with gold occurrences in the ferruginous sandstones and ironstones (massive and pisolitic) of the Ga'ara Formation (Permo – Carboniferous). The morphological features of the gold particles suggest that the gold occurrences are multisourced. The gold occurs in two modes namely: mechanical transportation of the gold grains associated with ferruginous sandstones, and chemical mobilization associated with the (massive and pisolitic) ironstones. The most significant primary gold source is the Precambrian Shield of Saudi Arabia after deep weathering and erosion under humid tropical conditions. The other possible source is the supergene ore deposits that are not far from the area. The majority of the gold is transported in a suspended form as scales and gold dust (first mode), or is transported in a colloidal form with the ferric hydroxides (second mode).

أنماط تواجد الذهب في منخفض الگعرة، الصحراء الغربية العراقية

مازن محمد مصطفى و حبيب فرج طوبيا

المستخلص

تم دراسة 25 نموذجا من تكوين الگعرة (من عمر البيرموكاربوني) المتكشف في منخفض الگعرة موزعة على مناطق جبد العبد (8 نماذج) في الجزء الشمالي الغربي من المنخفض، تل العفايف (5 نماذج)، دويخلة (2 نموذج) ووادي أم أيدية (10 نماذج)، وتقع الثلاثة الأخيرة في الجزء الجنوبي والجنوبي الشرقي من المنخفض. جمعت النماذج لتمثل كل أنواع الصخور الحاملة للذهب، إذ تراوحت من الصخور الرملية الحديدية قليلة الصلابة إلى الصخور الحديدية الكتلية الصلبة ناعمة الحبيبات. درست النماذج من خلال الشرائح الرقيقة الصقيلة وكذلك تم دراسة قسم من النماذج بعد إذابة الحديد.

يتركز الذهب في عدة أنواع من الصخور منها: الصخور الرملية الحديدية، الصخور الحديدية الكتلية والصخور الحديدية الحمصية، وتتواجد الصخور الحديدية على شكل عدسات محصورة في الجزء العلوي من التكوين. معدنياً، تتكون النماذج من معدن الكوارتز وكميات مختلفة من الگوثايت والهيماتايت كمادة سمنتية.

يتواجد الذهب في الصخور الرملية الحديدية شبه الهشة (قليلة الصلابة) على شكل حبيبات متناثرة ذات أشكال غير منتظمة ناعمة يتراوح حجمها بين 30 مايكرون إلى 120 مايكرون، أي بحجم الغرين إلى الرمل الناعم.

أما النوع الثاني من الصخور الذي يتركز فيه الذهب، فهي الصخور الحديدية الكتلية خصوصا في عدسات منطقتي جبد العبد وأم أيدية وكلا العدستين لها امتدادات محدودة (حوالي 50 - 100 م) وبسمك (2 – 4) م. هناك تمعدن آخر ضمن الطبقات المتعاقبة للحمصيات (ضمن عدسات الصخور الحديدية الحمصية) وتكون هذه الحمصيات متكسرة وكبيرة الحجم، تتواجد هذه بالقرب من سطح التماس مع تكوين ملصي في الحافة الجنوبية للمنخفض.

ان المصدر المحتمل للذهب في النمط الاول (المرافق للصخور الرملية الحديدية) قد يكون نفس مصدر رسوبيات تكوين الكعرة، اي من صخور الدرع العربي ذات العمر القبلكامبري بعد تعرضها الى تجوية كيميائية شديدة في ظروف استوائية رطبة، اذ نقلت نواتج التجوية بوساطة الانهار والجداول بعد تعرضها الى عدة مراحل من التعرية والترسيب واخيرا ترسبت في البيئات النهرية.

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أما النمط الثاني (المرافق للصخور الحديدية بنوعيها) فقد انتقل مع أكاسيد الحديد المائية على شكل غبار ذات حبيبات ناعمة أو على شكل غرويات مصدرها قد يكون ترسبات الخامات السوبرجينية والتي قد تكون غير بعيدة عن منطقة الكعرة. ان العوامل التي أثرت على تجمع هذه الغرويات قد تكون عوامل كيميائية مثل زيادة القوة الأيونية وتغير الحامضية أو عوامل فيزيائية مثل انخفاض سرعة المياه.

INTRODUCTION

The gold occurs in the ferruginous sandstones and ironstones of the Ga'ara Formation (Permo – Carboniferous) in the Ga'ara Depression, about 65 Km NE of Rutbah town. It lies in the Ga'ara Depression between latitude 33° 25' 00" – 33° 40' 00" N and longitude 40° 03' 00" – 40° 38' 00" E (Fig.1).

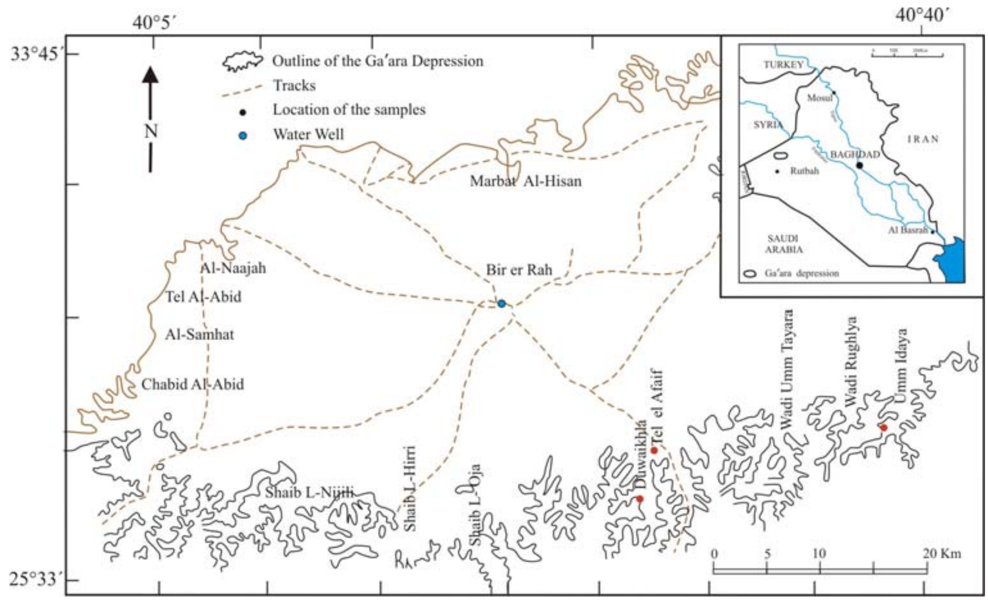

Fig.1: Location map of the samples in Ga'ara Depression, Western Desert, Iraq

MacFayden (1934) was the first to report the gold in Ga'ara sandstone. He mentioned many stories about its presence and concluded that his investigations failed to find any indications of gold in the Ga'ara or in the adjoining areas. Moreover, he claimed that the suggestion of naturally occurring gold in the Ga'ara area "is no more than a myth".

Since that time, efforts have not been renewed to investigate the probability of the presence of gold, until its accidental discovery by Kettanah and Tobia (1984), when their investigations were oriented to study the iron occurrences in Ga'ara Depression. Gold grains were detected during the examination of polished sections of some ferruginous sandstone of Tel el A'faif locality (Fig.1); under ore microscope.

Al-Bassam (1986) collected about 35 samples from the Ga'ara sandstones at Chabid Al-Abid locality (Fig.1). The heavy fraction was analyzed for gold. The results suggest that the possibility of finding commercial gold concentrations in the sands of this locality is rather poor. Also concluded that the mean concentrations of the gold in the studied samples are about 43 ppb, which is close to the usual background level in any normal (unmineralized) sandstone.

Mustafa (1999) collected three samples (S1, S2 and S3) from Chabid Al-Abid locality (Fig.1), he found gold within the massive ironstones, the gold appeared as a bright thin film, and was proved by chemical analysis using atomic absorption technique and fire assay methods. The chemical analysis results are: S_1= 0.08, S_2 = 0.12 and concentrates of S_3 = 198.8 ppm.

Mustafa *et al*. (1999) mentioned that there are fine gold grains (more than 17µm) associated with the ferruginous sandstone facies in Chabid Al-Abid locality (Fig.1).

The aim of this study is to differentiate between the two modes of gold occurrences in various lithofacies of Ga'ara Formation, in Ga'ara Depression, in order to reach a probable source for the gold in each mode.

GEOLOGICAL SETTING

The Western Desert of Iraq is a part of the Stable Shelf of the Arabian Shield. Due to the position of the Western Desert, the regional geology and tectonics have directly influenced the geological history of the area. The regional Rutbah Uplift is the backbone and the main structural element of the Western Desert. The Ga'ara High and Horan Anticlinorium, which accompany its southeastern slope, belong to the uppermost part of the Rutbah Uplift (Jassim *et al*., 1981). The central part of this structure has been eroded to form what is known as Ga'ara Depression (Fig.1). However, the structural contour map drawn by Tamar-Agha *et al*. (1997) on the datum surface shows the absence of the Ga'ara anticline and that the overall structure is gently and uniformly dipping strata toward the south – southeast within the Rutbah Uplift.

Sedimentary formations exposed across the Ga'ara Depression range from Paleozoic (Permo – Carboniferous) to Paleogene (Fig.2). Most of these formations, except the Ga'ara Formation (Permo – Carboniferous) and Rutbah Formation (Late Cretaceous) are composed of carbonates (Buday and Hak, 1980).

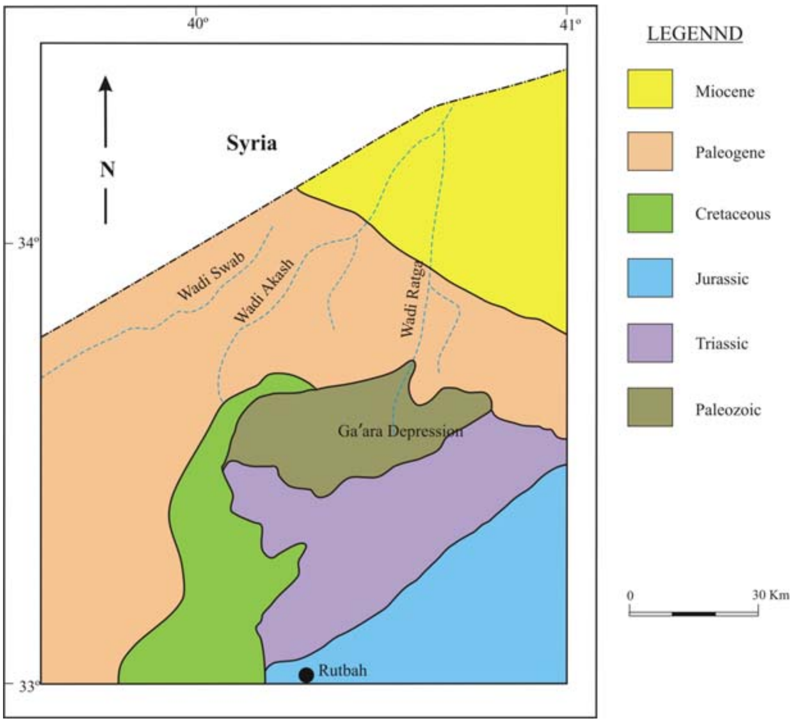

Fig.2: Regional geology of Ga'ara Depression, Western Desert, Iraq
(modified from Al-Bassam, 1986)

The Ga'ara Formation, which occupies the floor and partly the rims of the Ga'ara Depression, is the oldest exposed formation in the Western Desert of Iraq. The thickness of the exposed part of the formation is about 100 m, while probably it extends to a depth of at least 770 m (Buday and Hak, 1980). Lithologically, it consists of repeated, fining upward cycles of sedimentary rocks; each cycle usually starts with sandstone grading upward into siltstone, claystone (mostly kaolinitic) as well as occasional ironstone in the uppermost part of the formation. The goethitic – hematitic ironstones are of four types: sandy, clayey, pisolitic – oolitic and nodular-discontinuous laminated ironstones (Tobia, 1983). In addition, plant remains and thin coal streaks occur in the rocks of the formation.

The Ga'ara Formation is unconformably overlain by the Mulussa Formation of Upper Triassic age, in the southern rim. The Mulussa Formation consists of dolostone, calcareous dolostones and dolomitic limestones. In the northern rim, however, the Ga'ara Formation is overlain by sandstones of Rutbah Formation (Late Cretaceous), as in Chabid Al-Abid locality and by breccia and carbonates of Hartha, Tayarat and Digma formations (Paleogene), as in Al-Na'ajah locality. The sediments of the Ga'ara Formation are believed to have been derived from plutonic – metamorphic complexes of the Arabian Shield, transported by rivers and then deposited in continental, fluviatile and lacustrine environments with possible near shore and wind action contribution (Philip *et al*., 1968; Salman, 1977; Buday, 1980; Radosevic and Lesevic, 1981; Tobia, 1983 and Tamar-Agha, 1993).

The Ga'ara Formation is of special economic importance for its containing ironstones, kaolinites, mudstone deposits and glass sand, which are quarried hitherto.

SAMPLING AND METHODS

Twenty five samples were collected from the Ga'ara Depression, 5 samples from Tel el A'faif locality, 2 samples from Dwaikhla locality, 8 samples from Chabid Al-Abid locality, and 10 samples from Umm Idayya locality (Fig.2). These samples were chosen to represent all types of the gold-bearing rocks, and they range from moderately friable ferruginous sandstone to hard, massive, fine-grained ironstone. All samples were studied by thin polished sections, and five of them were studied after applying the technology of gold lixiviation from ores and concentrates, using hydrochloric acid and extraction from solution by absorption (Olteanu *et al*., 2008).

RESULTS AND DISCUSSION

The Ga'ara Formation consists of repeated fining upward cycles of sedimentary rocks, each cycle starts with sandstone grading upward into siltstone, claystone as well as occasional lenses of ironstone, in the uppermost part of the formation. Gold occurs as scattered fine grains within the ferruginous sandstones and siltstones of Ga'ara Formation. Most ferruginous sandstone beds exposed at Tel el A'faif locality are gold bearing, and exposures in Dwaikhla locality were proved to contain gold too.

The ore microscope examinations show that gold grains are usually located within the limonitic – goethitic cementing materials along side the detrital grains as engulfed within embayment of quartz grains; or trapped in the interstices of quartz grains (Fig.3a).

The gold-bearing sandstones are mostly friable, due to poor cementing by iron oxides; the beds are crossly-bedded and vary in thickness from (1 – 8) m. These beds are channelized reflecting some ancient river channels with sandstones at the bottom grading upward into siltstones and claystones, and sometimes capped by ironstones.

The gold grains are of irregular shapes, i.e. amoeboidal (Fig.3b), porous gold particles, flakey or equate with sharp boundaries. They are golden yellow and yellowish white in color. They range in size from 30 μm up to about 120 μm; i.e. they are of silt to very fine sand size. According to the optical properties (color, reflectance, Vickers micro-hardness), Kettanah and Tobia (1984) concluded that the Ga'ara gold contains certain amount of silver, which increases the reflectivity of the gold, and with probable copper content, due to the higher micro hardness than other natural gold (Table 1).

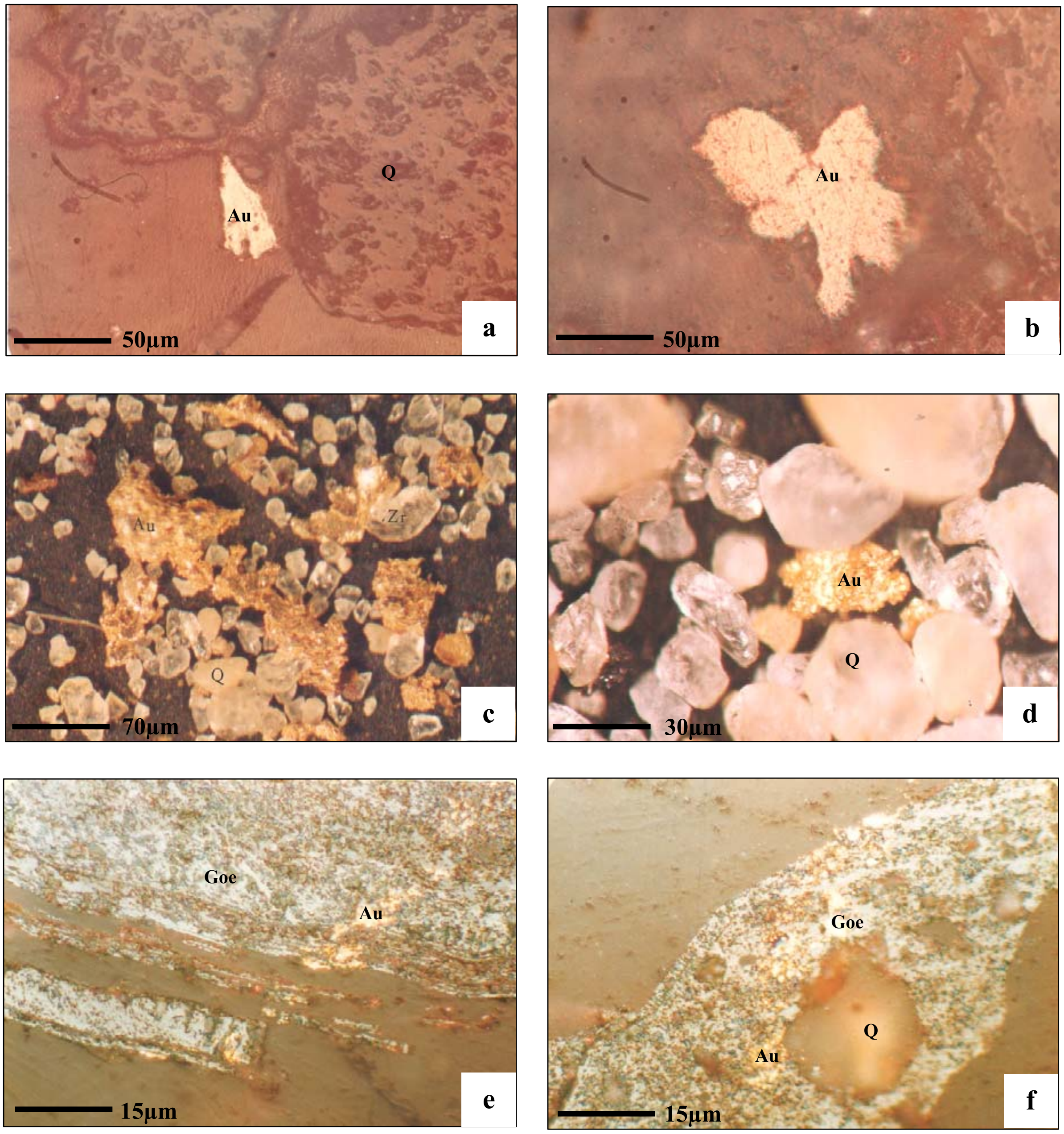

Fig.3: Photomicrographs of the gold from the Ga'ara area, Western Desert, Iraq

a) Gold grain (Au) trapped between three subrounded quartz grains in Ga'ara sandstone, Tel el A'faif, reflected polarized light.

b) Irregular (amoeboidal) gold grain (Au), that rests within the ferruginous cement of sandstone, Tel el A'faif, reflected polarized light.

c) Crisped gold grain (Au) with quartz (Q) and zircon (Zr) grains in extract (lixiviation HCl), Chabid Al-Abid, reflected light.

d) Gold grain (Au) with quartz grains (Q) after treatment with concentrated HCl, Chabid Al-Abid, reflected light.

e and **f)** Gold flakes (Au) scattered in goethite matrix (Goe.), in Chabid Al-Abid locality, reflected polarized light.

Table1: Optical properties of Ga'ara gold, Western Desert (Kettanah and Tobia, 1984) compared with international measurements

Property	Kettanah and Tobia (1984), Plain polarized light	Uytenbogaardt and Burke (1971)
Habit	Irregular: amoeboidal, scaly and platy	Rarely occurs as euhedral crystals, isolated grains
Cleavage	Absent	Absent
Color	Golden yellow and yellowish white	Bright or golden yellow, vary with the admixtures
Bireflection	Absent	Not present
Reflectance: = 498 nm = 551 nm = 584 nm = 644 nm	in air in oil 51.1 41.8 56.2 49.5 80.3 72.4 91.5 79.7	Pure gold 470 nm 35 550 nm 66 590 nm 71 650 nm 82
Polishing hardness	Very soft as evident from numerous polishing scratches and pits	> galena < sphalerite
Vickers microhardness	VHN $_{5-10}$ = 15 – 184; (119 – 136 in average)	VHN $_{10-25}$ = 42 – 88
Anisotropy	Isotropic	Isotropic

The other mode of gold occurrence, in the Ga'ara Depression is its association with the ironstone in Chabid Al-Abid locality (Mustafa, 1999) at the northwestern part of the depression and Umm Idayya locality at the southeastern part of the Ga'ara Depression (Fig.1). The former is overlain by Cretaceous (Rutbah Formation) and the latter by Triassic (Mulussa Formation) rocks. The ironstone lenses are at the uppermost part of the Ga'ara Formation. The two iron bodies have limited extension (about 50 – 100 m) and are about (2 – 4) m thick.

From the field observations, the gold occurs as thin film within the weakness surfaces in the iron bodies. There is another kind of mineralization, which is disseminated within the ironstones, as in Chabid Al-Abid and Umm Idayya localities.

The pisolites of the oolitic – pisolitic ironstone lenses show certain mineralization between the cortexes. These pisolites are large and fractured. The mineralization is clear in the ironstone lenses near the contact with Mulussa Formation, such as in Shaib L-Oja, Shaib L-Agharri and Shaib L-Nijili localities.

Microscopically, the gold shows small grains as crisped particles (aggregates) as in Fig. (3 c and d), or as flakes scattered in goethite matrix (Fig.3 e and f). The flakes may be are formed due to the compaction of the gold dust within the ironstones.

The origin of the second mode of the gold occurrence (within ironstones), is due to enrichment of the gold in the oxidized zone, which is closely associated with iron oxide/ hydroxide matrix and then crystallized. This occurrence supports dissolution and re-precipitation of the gold during weathering. Many studies indicate that a predominantly acidic environment is generated during lateritization, which is conducive to gold mobility (Omana and Santosh, 1996), such state might be suffered little pedogenesis in the latter stages.

Gold might be transported from the source area as suspended form (as a fine grains and gold dust) or as a colloidal phase that can be originated chemically, by the breakdown of complex gold compounds (Wierchowiec, 2002). The colloidal gold could be associated with the iron oxides by strong electrostatic interactions. The poorly ordered iron oxides are highly efficient in trapping gold from solution due to its high surface area (Greffie *et al*., 1996). Mechanically, gold may be abrading because of its softness and high density during transportation through sediment movement resulting in the formation of new colloidal particles (Wierchowiec, 2002).

Adsorption and/ or co precipitation of negatively charged gold complexes and colloids by positively charged gels, such as hydrous ferric oxides, appears to be particularly effective since most iron oxides in or near gold-bearing deposit are generally enriched in gold. In addition, Greffie *et al*. (1996) investigated the interaction of gold complexes with iron oxides (ferrihydrates, goethites) during co-precipitation experiments and they found most of the gold was removed from solution in the presence of iron oxides, whereas gold remained in the reference samples.

The source rocks of the Ga'ara Formation are believed to be from plutonic – metamorphic rock complexes of the Arabian Shield that have been subjected to intense chemical weathering under humid tropical conditions. The weathered products are transported and reworked many times by rivers and streams, to be deposited in continental fluviatile and lacustrine environments (Philip *et al*., 1968; Salman, 1977; Buday, 1980; Buday and Hak, 1980; Tobia, 1983; Tamar-Agha, 1993). This assumption can further be substantiated by the nature of facial distribution of Ga'ara Formation, as it wedges out towards the eastern rim of Ga'ara Depression, and might also wedges out to the north of the Khleisia Uplift, and is most likely open to the south with extensive aerial extent (Buday, 1980).

One of the ultimate origins of the gold is thus, the same as that of the associated sediments (Ga'ara Formation), i.e. the Arabian Shield rocks. The gold is known to exist in Saudi Arabia since old times. It occurs all over the Arabian – Nubian Shield, however, the important gold deposits in the Precambrian Shield of Saudi Arabia are those of Mahd adh Dhahab, Al-Amar and Jabal Ishmas – Wadi Tathlith Fault Zone (Worl, 1980).

Ga'ara gold (especially the mode in ferruginous sandstones) could have been derived from any of the aforementioned major gold deposits or partly all of them, as well as from any other unknown occurrences. However, the optical properties of the Ga'ara gold is comparable to the gold of "Mahd adh Dhahab" and is the nearest to the Ga'ara area (Kettanah and Tobia, 1984). The other mode (in ironstones) may have been transported with hydrous iron oxides as a dust or as colloids from the supergene ore deposits that is not far from the Ga'ara Depression. This can be deposited with the iron oxide, especially with the goethite. The factors that affect the accumulation of these colloids may be due to the chemical factors (increasing of ionic strength, change in pH), or due to the physical factors (reducing water velocity) (Andrade *et al*., 1991).

CONCLUSIONS

- The morphology, surface texture of gold particles and the associated clastics suggest that the gold of the studied occurrences are multisourced.
- The authors believe that the principal sources for the gold most probably are the plutonic – metamorphic rock complexes of Arabian Shield, which are subjected to intensive chemical weathering.
- The majority of the gold is transported presumably in a suspend forms, as flakes, scales, small grains, and gold dust, by rivers and streams; as the results of weathering and erosion of auriferous sediments.

- Gold also could have been dissolved, transported under favorable chemical condition, and reprecipitated (second mode). Some amoeboidal, porous gold particles, without any signs of mechanical abrasion could be formed chemically during diagenesis.
- Gold enrichment has taken place by mechanical followed by diagenesis processes (in ferruginous sandstones) and chemical (in ironstones and pisolites) processes.

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