# GOLD GRAIN SIZE OF OFFIN PLACER DEPOSIT AND ITS EFFECT ON DREDGE RECOVERY

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ABSTRACT: Gold in the Offin placer deposit at Dunkwa-on-Offin, Ghana, occurs freely. Gravity concentration methods such as jigging and sluicing are employed to recover the gold. These methods are most efficient within specific size ranges of the gold grains.

This paper conducts mineralogical, sieve and microscopic analyses to establish the gold grain size and its distribution along the Offin River. The results of the size analyses are used as a basis to evaluate the effectiveness of the dredge treatment plants at Dunkwa Goldfields Ltd. in gold recovery.

The analyses take into consideration three operational zones: Upper, Middle and Lower Offin. In each operational zone, size analyses are carried out on the gold grains in the deposit, gold grains recovered by the treatment plant, and those lost by the treatment plant.

The particle sizes are grouped into three main classes:

(i) Upper range: + 440 μm
(ii) Middle range: - 440 μm to + 120 μm
(iii) Lower range: - 120 μm

The analyses show that within the deposit, the gold grain size reduces generally from the Upper to Lower Offin. The percentage of the upper size range reduces from the Upper to Lower Offin. The percentage of the lower size range increases while that of the middle size range is fairly constant.

The results of the analyses of the gold grain in the tailings indicate that the performance of the dredges located in the Upper and Middle Offin is satisfactory. The dredge in the Lower Offin is inadequately efficient. Its relative poor performance can be attributed to the inability of the jig to recover the gold grain in the lower size range; it is suggested that a Knelson concentrator could be a better choice.

The mineralogical analysis is conducted only for the samples from the in-situ material. The results show that the main constituent minerals, have specific gravities such that the minerals have no significant effect on gold recovery.

RESUMÉ: L'or dans le dépôt alluvionaire de Dunkwa-on-Offin, Ghana, se trouve sous forme libre. Les méthodes de concentration par gravité comme le jig et le sluice sont employées pour récupérer l'or. Ces méthodes sont les plus efficaces pour des gammes de grosseurs spécifiques des grains d'or.

Cet article présente les analyses minéralogiques, par tamisage, et au microscope pour établir la taille des grains d'or et leur distribution au long de la rivière Offin. Les résultats des analyses granulométriques sont utilisés comme base pour évaluer l'efficacité de l'installation du traitement de la drague à Dunkwa Goldfields Ltd.

Les analyses prennent en considération trois zones opérationnelles dans le dépôt alluvionaire: Offin supérieur, moyen et inférieur. Dans chaque zone, l'analyse granulométrique est réalisée pour établir la taille des grains d'or dans le dépôt, dans le matériel récupéré et traité et dans le matériel perdu dans le rejet de la drague.

Les tailles des grains sont groupées en trois classes granulométriques:
(i) La classe supérieure: plus de 440 μm
(ii) La classe intermédiaire: de 440 μm à 120 μm
(iii) La classe inférieure: moins de 120 μm

Les analyses montrent que la grosseur des grains d'or diminue généralement entre le Offin supérieur et le Offin inférieur. Le pourcentage de la classe supérieure diminue entre le Offin supérieur et le Offin inférieur. Le pourcentage de la classe inférieure augmente alors que celui de la classe intermédiaire reste assez constant.

Le résultat des analyses granulométriques du matériel rejeté indique que la performance des dragues situées en Offin supérieur et Offin moyen est satisfaisante. La performance de la drague en Offin inférieur n'est pas assez efficace. On peut attribuer cette mauvaise performance relative à l'incapacité de la drague de récupérer les grains d'or dans la classe granulométrique inférieure; il est suggeré qu'un concentrateur *Knelson* sera un meilleur choix.

L'analyse minéralogique est faite uniquement pour les échantillons du dépôt in-situ. Les résultats montrent que les densités des minéraux essentiels constitutifs du dépôt sont telles qu'elles n'ont aucun effet significatif sur la récupération de l'or par gravité.

## 1. INTRODUCTION

The Offin Placer deposit belongs to the Dunkwa Goldfields Ltd. (DGL), a subsidiary of the State Gold Mining Corporation (SGMC). It is located at Dunkwa-On-Offin, some 150 km southwest of Kumasi, the second largest city in Ghana.

The company's dredging concession stretches from the Upper Offin through the Middle Offin to the Lower Offin (fig. 1). The concession extends about 1.6 km on either side of the Offin River and some 60 km upstream. It also covers the Jimi River and its valley, from the confluence with the Offin River northwards to the concession boundary of the Ashanti Goldfields Corporation (Gh) Ltd. DGL employs five bucket ladder dredges to mine the placer deposit of the Offin River.

Gold in the Offin placer deposit occurs freely and the method of treatment of the placer material is by gravity concentration, jigging and sluicing. The efficient recovery of gold by these processes depends to a large extent on the size of the gold grains (Taggart, 1944).

The main objective of this paper is to establish the size range of gold grain in the Offin placer deposit so as to be able to determine how effective the treatment plant operates.

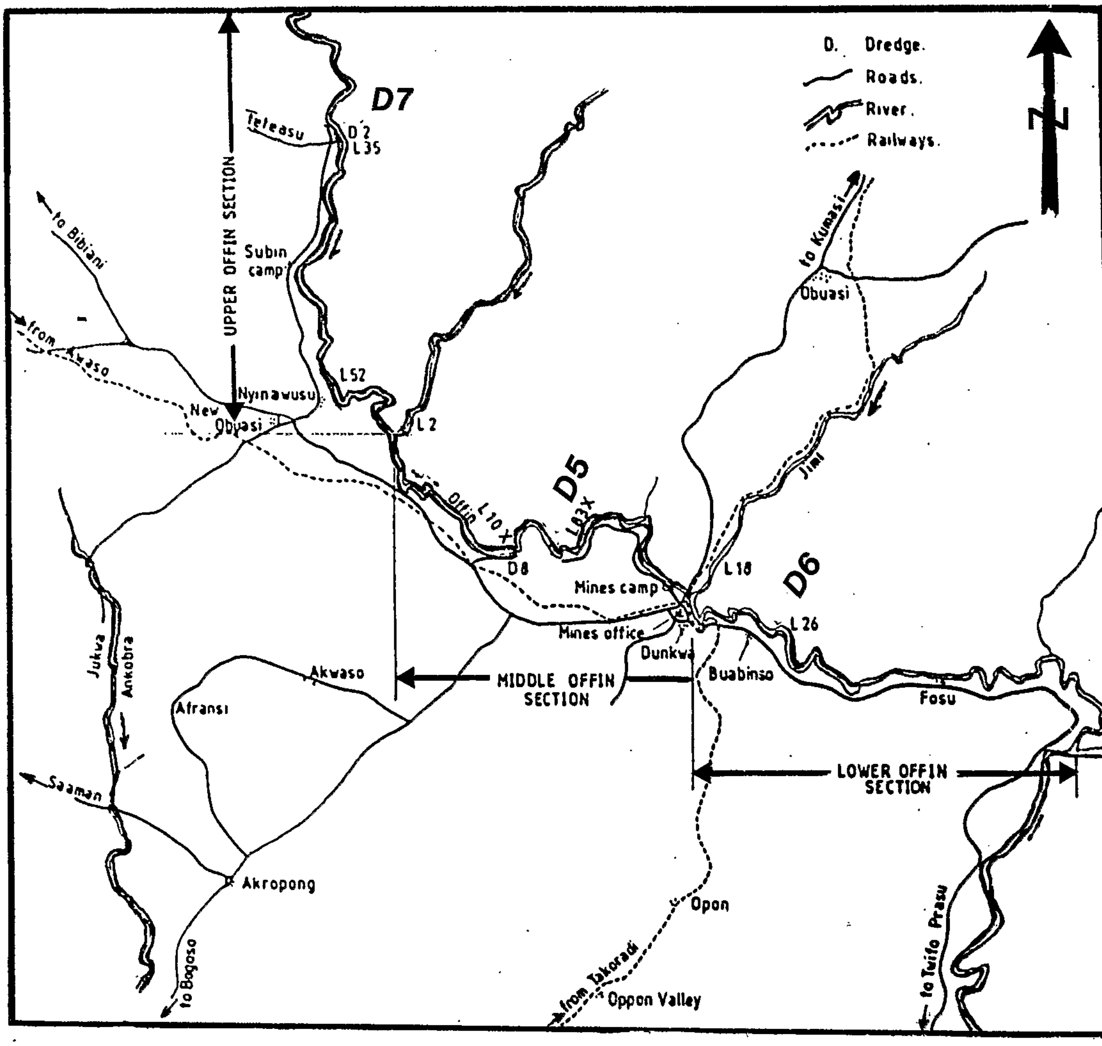


Fig. 1: Map showing the three operational zones of DGL.

The work is centered on three dredges namely: dredges D/5, D/6 and D/7 which are located in the Middle, Lower and Upper Offin respectively. It entails size analyses of (i) the gold grains in the deposit, (ii) gold grains recovered by the treatment plant, and (iii) gold grains lost by the treatment plant. The samples were taken from dredge buckets (representing grains in the deposit), secondary jig underflows and screen (recovered grains) and primary and secondary jig overflows (representing lost grains). This made it possible to study the gold grains in the deposit as well as those which are recovered and lost by the treatment plant.

## 2. THE OFFIN PLACER DEPOSIT

The alluvial gold deposits of DGL form part of the placer deposits associated with the Birimian and Tarkwaian rock systems. These two rock systems are Precambrian in age but the latter is younger. The area is traversed by the Anum, Offin, Jimi, Ankobra, and Oda Rivers. The distribution of alluvial gold in the Birimian and Tarkwaian rock systems is dependent basically on the general trend of the Birimian gold reefs and the Tarkwaian banket series from which the gold is derived. Most of these reefs and the banket series trend in a North-East to South-West direction. The streams and rivers which cut across these reefs also run in the same direction and are made up of silty clay and sandy gravels. Consequently, the deposit material in the Offin placer is also made up of silty clay overburden overlying sandy river gravels on a soft decomposed green bedrock.

Gold distribution in the deposit is erratic both along and across the alluvial flats but it has been observed that the top half of the gravels contains about 15% of gold while the bottom half contains 85%. The last 0.7 - 1.0 m of the gravels just above the bedrock has been observed to have high gold values. The Offin placer gold is generally very fine-grained and of relatively high fineness.

## 3. SUMMARY OF OPERATION

### 3.1. DREDGING

The mode of operation of the dredge involves excavation of the placer deposit (both underwater and river bank) and transporting the excavated material to the sizing trommel by a bucket ladder. Treatment of the washed material is carried out on the dredge and waste is disposed of at the rear end of the dredge. Movement of the dredge on the river is by an array of five winch ropes controlled from a central winch room.

### 3.2. TREATMENT OF ORE

The method of treatment involves screening to get rid of the coarse pebbles, gravity concentration and amalgamation. Figure 2 shows the flow-sheet of a typical treatment plant. As can be seen from this flow-sheet the treatment plants on the dredges basically consist of:

- (i) Trommel
- (ii) Primary jigs
- (iii) Sluice
- (iv) Hydrocyclone
- (v) Secondary jigs
- (vi) Tertiary jigs
- (vii) Silver trap

The trommel is the first stage of the treatment plant where washing and sizing takes place. It consists of a screen of size 9.5 mm to allow screen/ stacker splits of 60%/40% feed proportion (Annon, 1989). The inner periphery is provided with lifters to cascade the material for washing and loosening. Along the length is a 0.3 m diameter pipe which delivers high pressure waterjets through several 15.9 mm spigots for the washing process as the screen revolves. Washed oversize gravels and clay are delivered to waste. Gravel sizes of -0.9 mm pass through the screen and washes into a primary concentrate sump that feeds the primary jig via a hydrocyclone. The primary jig has three cells of dimensions of 14.5 m by 12.7 m. These cells have stroke lengths of 19.1 mm to 12.7 mm. The underflow from the primary jig is fed into a secondary concentrate sump and then to a cyclone (basically a de-sliming device) via a 102 mm pump, where particles are separated according to size and specific gravity. The overflow from the cyclone is delivered to the secondary concentrate sump and the underflow to the secondary jigs for further concentration.

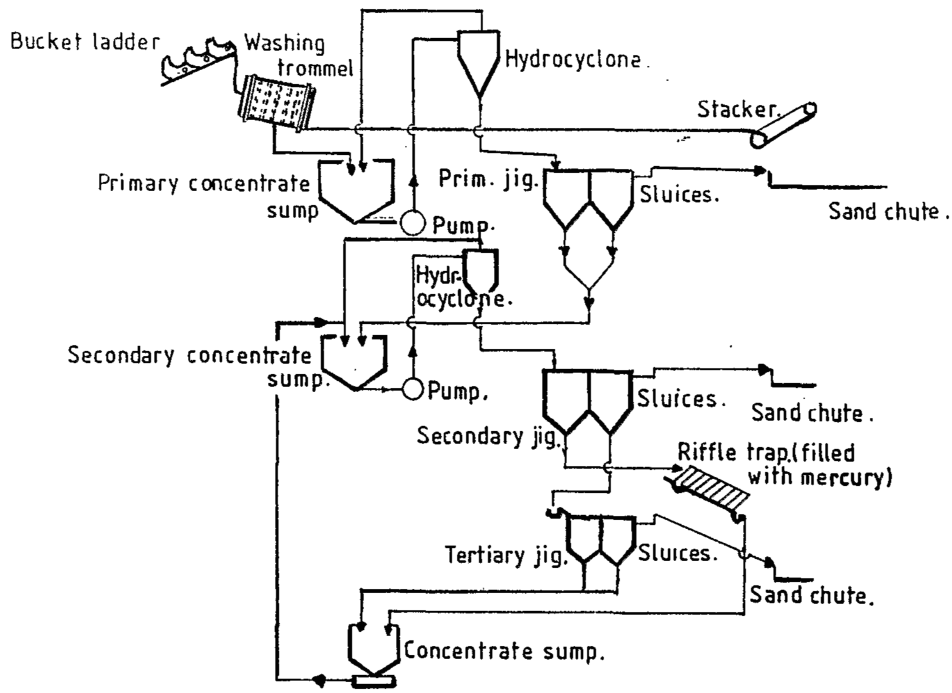


Fig. 2: Flowsheet of a typical treatment plant at DGL

The secondary jig consists of two cells, each with a stroke length of 12.7 mm. The underflow of cell one feeds the mercury trap, while that of cell two feeds the tertiary jig and the overflow discarded. The tertiary jig further concentrates the impoverished feed (from secondary jig) by further jigging and its underflow goes back to the secondary concentrate sump and the overflow discarded. All jig overflows run across sluices lined with coconut mats, which are intended to concentrate any gold that might have been lost to the jigs.

As stated earlier, the underflow from cell one of the secondary jig feeds the mercury trap - a device for forming the amalgam. It consists of an arrangement of several units of wooden boards on which are rolls of drilled slots of 25.4 mm by 15.9 mm deep, at a pitch distance of 25.4 mm in a staggered pattern filled with mercury. Between the rolls of slots are metal strips or riffles which create ripples in the cross-flow.

The fourth unit is the stacker. This is a 42.3 m conveyor system used for the disposal of waste (washed gravel and overburden). Trough idlers are spaced 0.6 m and the return idlers 1.2 m. The belt runs in a superstructure inclined at about 150 to the horizontal and is suspended by tension ropes.

## 4. GRAVITY CONCENTRATION

Gravity concentration is essentially a mineral separation method which effects the separation of particles by differential specific gravities and their relative motion in reaction to gravity and some other forces such as flow resistance in a viscous fluid. The efficiency and effectiveness of any gravity separation depends on the difference in density between the particles in the material being treated and particle sizes. It should be emphasized that the process is also limited by the mineralogy of the ore. It is to be observed that, in general, the more pronounced the difference in gravity between the particles on one hand and the fluid medium on the other, the more efficient the separation would be. This assertion is verified by the concentration criterion $C$ (Taggart, 1944), which mathematically may be stated as:

$$C = \frac{D_h - D_f}{D_1 - D_f}$$

where $D_h$ = specific gravity of the heavy mineral
$D_f$ = specific gravity of the fluid medium
$D_1$ = specific gravity of the light mineral

The significance of $C$ according to Wills, 1985, is as follows:

(i) if $|C| > 2.5$, then gravity concentration method is possible for all sizes,

(ii) if $|C| < 2.5$, then gravity concentration is generally not commercially feasible.

The other variable influencing the efficiency of gravity separation is the particle size. The effect of the particle size becomes more pronounced when $1.25 < |C| < 2.5$. The object of all mineral processing, irrespective of the method used, is to separate the minerals into concentrate on one hand and gangue in the tailings on the other. As most often is the case, some valuable mineral particles mix with the gangue minerals to form a third group normally termed as 'middlings'. This becomes quite serious when very fine particles (slimes) are being treated. Gravity concentration techniques are so sensitive to slimes (ultra-fine particles) that they become unacceptably inefficient (Wills, 1985). To achieve an efficient gravity separation, it is imperative that the feed is prepared carefully. It is not uncommon in some gravity concentrators to de-slime the feed as a way of good feed preparation. Figure 3 shows the performance of gravity and centrifugal concentration devices at different feed sizes.

The method of separation also affects the effectiveness of the treatment plant. Pryor, 1978, classified the separation methods into three categories namely:

(i) vertical current separation: e.g. jigging

(ii) streaming current separation: e.g. sluicing, spiralling, tabling

(iii) quiet pool of dense media: e.g. dense media separation

At DGL, jigging (vertical current separation) is predominant although sluicing assists in the separation process. A jig basically is a mechanical concentrator that accomplishes separation of heavy particles from light ones by employing the differences in specific gravity. In practice, jigs are found to perform well in the -12 mm and +75 μm size range (fig. 3).

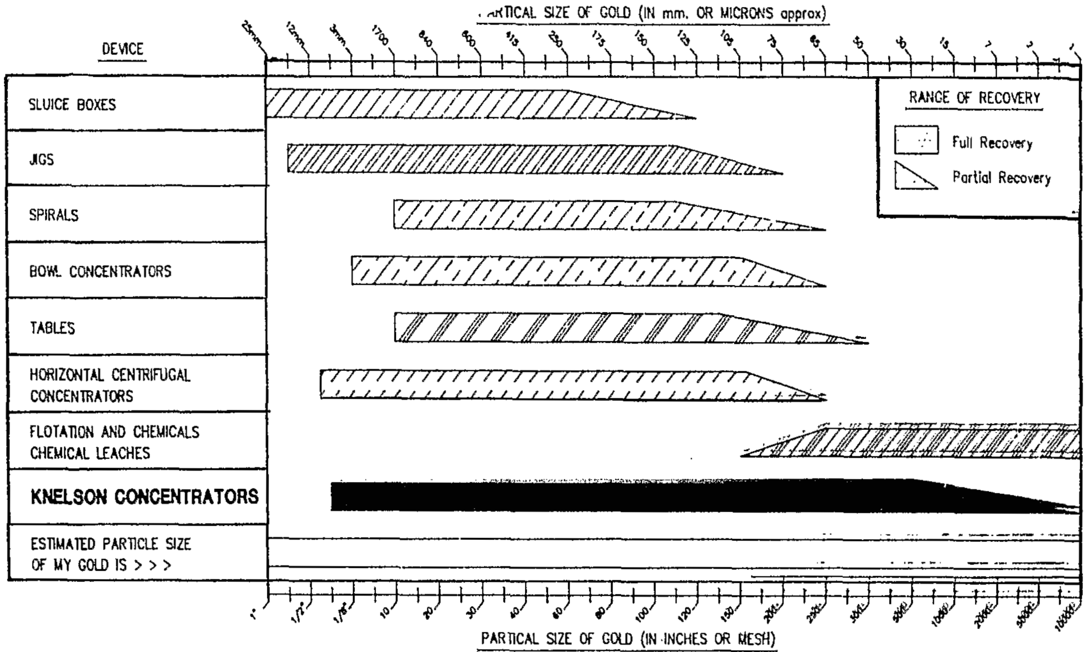


Fig. 3: Performance of gravity and centrifugal concentration devices at different feed sizes (after Anon, 1978)

## 5. SAMPLING PROCEDURE

The sampling programme was designed to evaluate the size ranges of gold in the Offin placer deposit with the view to establishing the effectiveness of the treatment plant on dredges D/5, D/6 and D/7. These three dredges were chosen because they are in the Upper, Middle and the Lower Offin, which are the main operational zones along the Offin River.

Samples were taken from strategic points on each dredge, points which would reflect gold grains in the deposit (i.e. in situ) as well as those reflecting recovered and lost grains by the treatment plants. These points were the bucket for the gold grains in the deposit, the secondary jig spigot for the recovered gold grains, and the overflows and screen tailings to represent the gold lost by the treatment plant. The sampling procedure at each sampling point is discussed below.

(a) Bucket samples: Samples were taken by means of a tube of 50.8 mm diameter slanting at one end. The tube was speared into a moving bucket and sample volume at each time was about 0.05 $m^3$. Samples were washed in a 19.5 mm perforated headpan and the undersize transferred into a sample bucket, hand-panned to the "black" and bagged as a final sample. In all, 300 samples amounting to some 15 $m^3$ were taken.

(b) Secondary jig underflow: Samples were obtained by means of a 25.4 mm diameter hose of about 3.0 m length which was connected to the spigot of the secondary jig and the concentrate was delivered into a basin for a period of 20 seconds. Sampling was carried out in 2-minute intervals and about 0.18 $m^3$ of concentrate was collected after a 2-hour period. This sample was panned and bagged. A total of 300 samples were analyzed.

(c) Overflow samples:

(i) Primary jig overflow:

A sample bucket was passed across the full width of a chute at the tail board of the dredge at an even speed for about 10 seconds. After the 10 seconds period, the sample was transferred into a basin. This was repeated for a total test period of 2 hours. The sample in the basin was panned and bagged. A total of 500 samples were taken.

(ii) Secondary jig overflow:

Samples were collected just as described in (i) above. In all, 500 samples were taken.

(iii) Screen tailings:

The conveyor was stopped every 10 minutes for samples to be taken. All material on a 60 cm section on the conveyor was cleaned out into a measuring box. This sample was washed through a screen and the undersize panned and bagged. A total of 500 samples were recorded.

## 5.1. SAMPLE TREATMENT

### 5.1.1. Microscopic sizing

This sizing procedure involved comparing the projected area of a particle with the areas of reference circles. The particles were viewed by transmission microscopy where the areas of the magnified images are compared with the areas of the reference circles of known sizes. In the procedure, some quantity of gold grains (out of a batch) was put onto a glass slide and viewed under a microscope. The quantity taken each time was such that all the gold grains were counted within a test period. The process was repeated until a whole batch had been sized. The relative number of particles were determined in each series of size classes. All gold grains from the various sample points for the three dredges were similarly analyzed.

### 5.1.2. Test sieving

This type of test is one of the oldest and most widely methods of particle size analysis. It is achieved by passing a known weight of sample material through a nest of sieves of various sizes (usually the coarsest at the top and finest below) and weighing the amount collected on each sieve to determine the percentage weight of each size fraction. The effectiveness of sieve test depends on the charge (i.e. the amount of material fed onto the sieve) and the type of movement imparted to the sieve. All the samples were analyzed, employing the wet sieving techniques to approximate the continuous flow method as used at DGL.

The objectives of this test were two-fold:

(i) to compare this result with that of the microscopic analysis and

(ii) to examine the gold grains sizes in the under 120 µm size range, which was taken as the lower limit in the microscopic analysis.

### 5.1.3. Mineralogical analysis

As has been stated in Section 4. of this work, gravity separation is most efficient when the mineral and gangue in the mineral mixtures differ appreciably in specific gravity. The objective of this analysis was therefore to find out the accessory minerals that exist in the Offin placer (in-situ material) in order to assess those most likely to affect gold recovery at DGL. The samples were prepared into polished sections. Each section was analyzed in plane and crossed polars and mineral identification was by the degree of reflection technique.

## 6. DISCUSSION OF RESULTS

The discussion focuses attention on the gold grain size and its distribution in the Offin placer deposit (i.e. in-situ), in the recovered concentrate (i.e. jig underflow), and in the tailings (i.e. jig and screen overflows). The aim of the analysis was to determine the optimal size of gold grains that are recovered effectively by the treatment plants, and to determine the size range at which possible losses might be occuring in the plant so that they may be reduced. The mineralogical analysis should establish the various gangue minerals. The specific gravity of the gangue minerals would indicate whether they adversely affect gold recovery by gravity separation.

### 6.1. GOLD GRAIN SIZES IN THE OFFIN PLACER DEPOSIT

Figure 4 shows histograms of the gold grain size for the various sections of the Offin for the microscopic test.

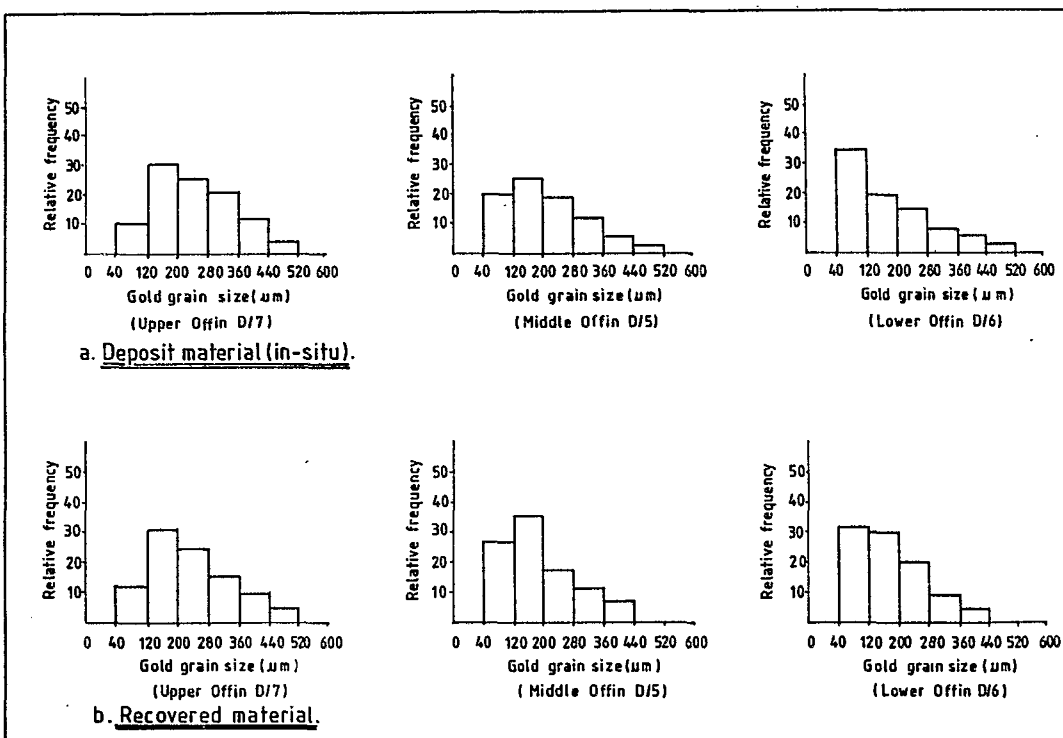


Fig. 4: Histogram of gold grain size (microscopic test).

Plots of log values of the upper class size versus cumulative frequency on an arithmetic probability paper (fig. 5) showed straight lines indicating that the gold grain sizes are lognormally distributed.

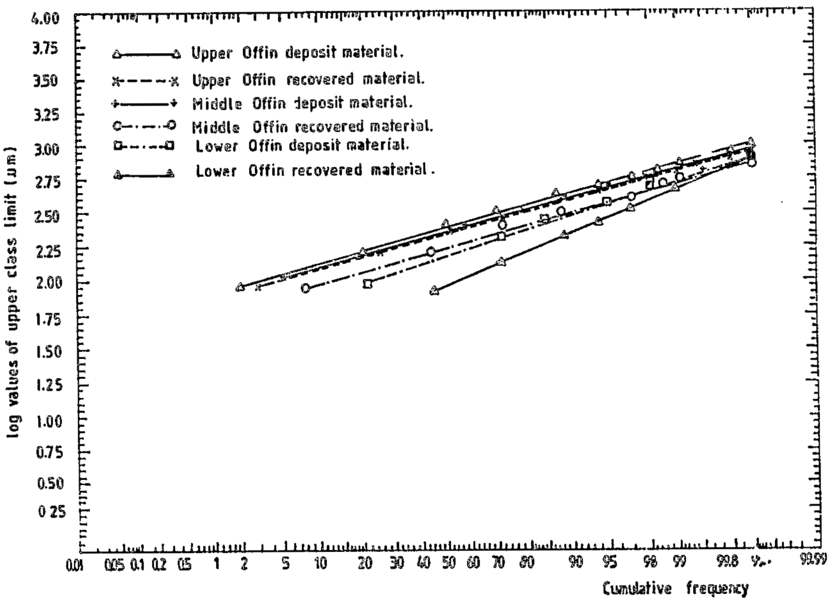


Fig. 5: Log of upper class limit versus cumulative frequency.

The estimated mean values are shown in Table 1. In figure 6 are histograms showing the weight percentage of the gold grain size for the sieve test. Weight percentage had been used for the sieve test as against relative frequency due to the observations made by Allen, 1981.
Graphs of cumulative percentage of gold grains against upper class size for both deposit and recovered material of both tests are shown in Figure 7. For practical purposes, the size ranges of +440 µm (upper range), -440 µm to +120 µm (middle range), and -120 µm (lower range) have been used for the analysis.

Table 1: Mean gold grain sizes for the Upper, Middle and Lower Offin.

| | In-situ material | | Recovered material | | Lost material | |
|---|---|---|---|---|---|---|
| DEPOSIT | No. of grains | Mean size (µm) | No. of grains | Mean size (µm) | No. of grains | Mean size (µm) |
| Upper Offin | 1732 | 250 | 524 | 230 | 37 | 85 |
| Middle Offin | 681 | 240 | 673 | 185 | 54 | 85 |
| Lower Offin | 836 | 185 | 647 | 95 | 200 | 95 |

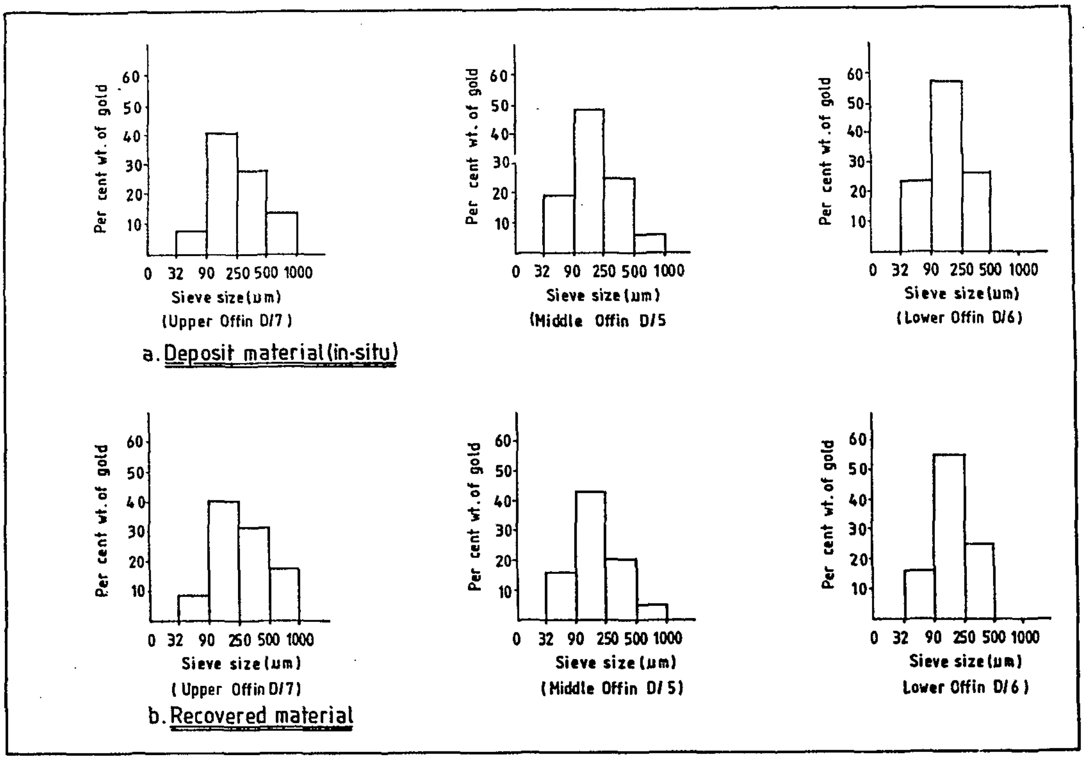


Fig. 6: Histograms showing weight percentage of gold grain size.

The following observations can be made:

(i) In the Upper Offin, the microscopic test showed that the gold grain size in the deposit (i.e. in-situ) have about 15% of the grains in the upper range (i.e. +440 μm) size, 73% in the middle range (-440 μm to +120 μm) size and 12% in the lower range (i.e. -120 μm) size. The sieve test showed 7%, 53% and 40% respectively. These two tests produce an average of 11%, 63% and 26% respectively.

(ii) In the case of the Middle Offin, the two tests produce an average of 7% (upper size range), 64% (middle size range) and 29% (lower size range).

(iii) The Lower Offin had an average of 3%, 63% and 34% respectively.

The deductions that could be made from these observations are that:

1. More than 60% of the gold grains in the Offin placer deposit are found in the middle size range (-440 μm and +120 μm).
2. The trend in size distribution of gold grains in the Offin placer deposit is such that gold grains become finer from the Upper Offin to the Lower Offin i.e. the percentage of the under 120 μm increases.

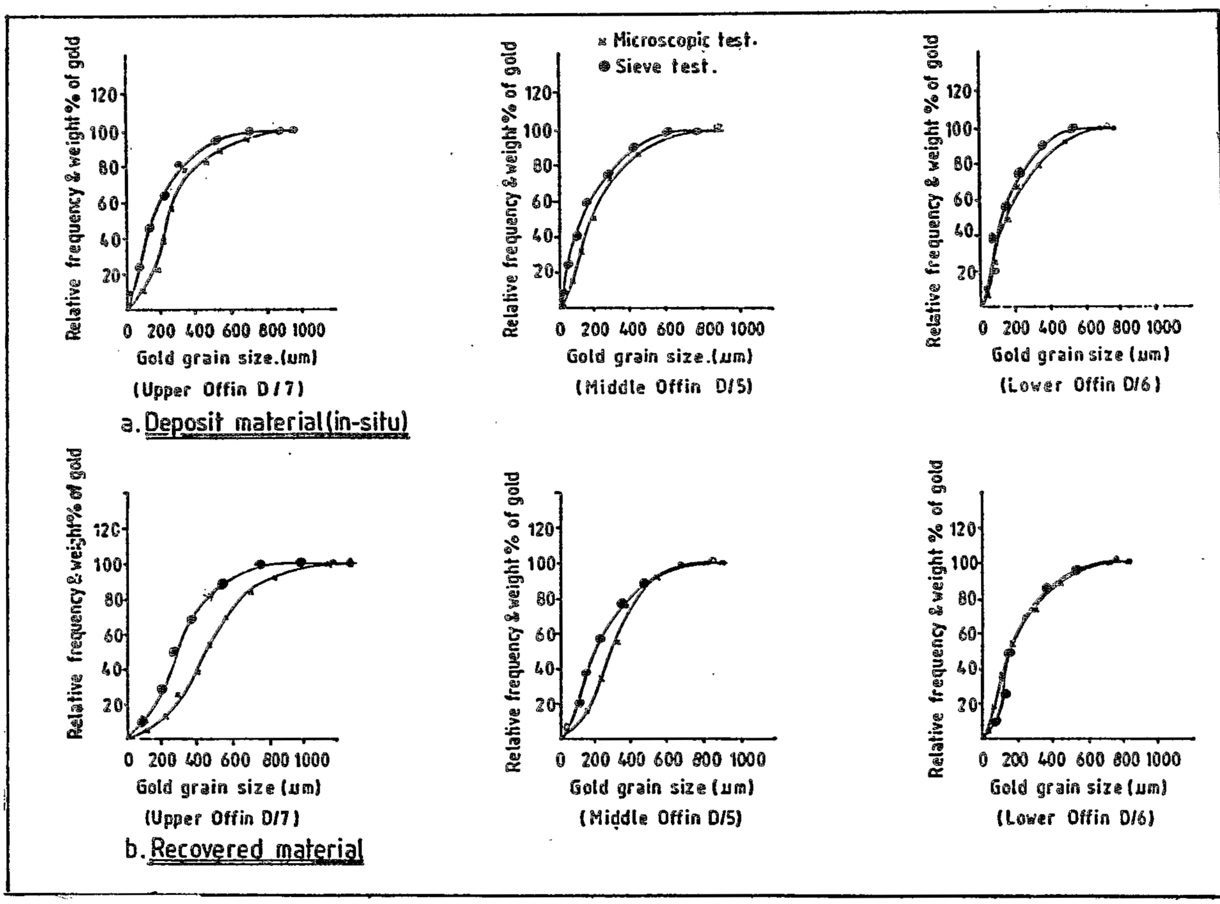


Fig. 7: Cumulative weight percent and relative frequency of gold.

## 6.2. EVALUATION OF TREATMENT PLANT

In order to evaluate the effectiveness of the dredges with respect to the size of gold grains and its recovery in the Offin placer, the correlation between the gold grains in the deposit and that recovered by the treatment plant was statistically estimated. The results are shown in Table 2.

The results indicate that for Upper Offin, the correlation between gold grain sizes in the deposit (i.e. in-situ) and that recovered by the treatment plant is 0.98 for the microscopic test, while that for the sieve test is 0.95. The two results average out to 0.96. Similarly, the averages for the Middle and Lower Offin are 0.92 and 0.47 respectively. It could be concluded therefore that the dredges D/7 (Upper Offin) and D/5 (Middle Offin) are performing reasonably well at their present locations. The performance of D/6 is relatively poor.

Table 2: Correlation between gold grains in the deposit and that recovered by the treatment plants for the Microscopic and Sieve analyses.

| | Correlation coefficient | |
|---|---|---|
| | Microscopic | Sieve |
| **Upper Offin (D/7)** | 0.98 | 0.95 |
| **Middle Offin (D/5)** | 0.93 | 0.90 |
| **Lower Offin (D/6)** | 0.45 | 0.48 |

## 6.3. MINERALOGICAL ANALYSIS

A summary of the results from this analysis is as presented in Table 3.

Table 3: Summary of accessory minerals in Offin placer deposit.

| Gangue mineral | % in specimen | Specific gravity* |
|---|---|---|
| Quartz | 40 - 50 | 2.65 |
| Pyrite | 10 | 4.8 - 5.1 |
| Magnetite | 10 | 5.18 |
| Ilmenite | 2 | 4.5 - 5.0 |
| Marcasite | 2 | 4.9 |
| Goethite | 20 - 30 | 4.0 - 4.4 |
| Rutile | 2 | 4.2 |
| Zircon | <2 | 4.7 |

* *Source: Blyth and de Freitas, 1977*

It could be seen from the mineralogical test that quartz, goethite, pyrite and magnetite with specific gravities of 2.65, 4.0 - 4.4, 4.8 - 5.1, and 5.18 respectively constitute over 80% of the samples. The only property of these minerals which will have any significant effect on the recovery of gold in a gravity concentration method is specific gravity. With gold being 19.6 far above those listed, it most unlikely that these minerals would have any major effect on the recovery of gold from the Offin Placer deposit.

# 7. CONCLUSION AND RECOMMENDATIONS

The results obtained in this study have shown that the mean gold grain sizes in the Offin placer deposit decrease systematically from the Upper to the Lower Offin. Generally, more than

60% of the gold grains for the three operational zones are between the -440 μm and +120 μm range and about 25% under 120 μm. The remaining constitute the over 440 μm.

In the case of the gold grain sizes recovered by the treatment plant, results indicate that the concentration size range of dredges D/7 (Upper Offin) and D/5 (Middle Offin) fall within the effective concentration range of jigs i.e. 12 mm to 75 μm. For D/6 (Lower Offin) more than 50% of the gold grains recovered from the tailings were of sizes less than 120 μm indicating more gold loss in this range.

The correlation coefficients indicate that dredges D/5 and D/7 are most suitable for the sizes of gold grains being mined at DGL. D/6 is however not likely to recover all the gold grains especially below the -120 μm range. On this basis, D/6 is considered not to be suitable enough for the Lower Offin. A possible solution could be the use of a Knelson concentrator (fig. 3).

The main associated gangue minerals are quartz, goethite and pyrites. These minerals are considered not likely to affect the concentration of gold on the basis of their specific gravities.

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