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# Investigating Optimal Angle of Inclination of a Sluice Box for Improved Artisanal Gold Recovery in Batouri, Cameroon

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**A B S T R A C T**

Artisanal gold mining in Cameroon dates back to 1934 where artisans used rudimentary tools such as pickaxes, spades and pans for gold recovery. The need to maximize gold recovery as well as reduce intensive human labour led to the discovery of sluice boxes. In the design and construction of sluice boxes, many factors like mesh size, feed flow rate, particle size of gold, and the angle of inclination can influence gold recovery efficiency. However, most of these sluice boxes in Batouri are designed and constructed without considering the stated factors. This paper focuses on investigating the optimal angle of inclination of a sluice box on gold recovery in Batouri. Varied angles of inclination were used and 50kg of alluvial material washed at optimal water pressure and mesh size. Gold particles trapped within mesh were washed into a pan and panned. This was done for 4 different angles of inclinations (40, 100, 140, and 180). The gold grains were separated from concentrate via amalgamation. Quantities of gold recovered for each angle were weighed on an electronic balance and recorded (0.15g, 0.33g, 0.20g and 0.4g respectively). From result, the optimal angle for artisanal gold recovery in Batouri was 100 since it yielded the highest amount of recovery. Therefore, artisans will improve gold recovery efficiency if they use angles between 90 and 110 for sluice boxes during sluicing.

**Keywords:** Artisanal Gold Recovery, Angle of Inclination, Sluice Box, Alluvial Material, Batouri

## 1. Introduction

According to Cameroon Mining Code (2016), artisanal mining is mining involved in extracting and concentrating mineral substances by means of manual and less mechanized methods and techniques. Not all mining is done by large companies deep below the ground or with expensive machinery in large open pits. On a global scale, valuable mineral resources from the earth are extracted on a small scale using primitive tools like picks, shovels, and sluice boxes by millions of people. In developing countries like Cameroon, artisanal small scale mining is very important as it plays a crucial role in poverty alleviation and rural development. The workforce of artisanal and small scale miners are commonly itinerant, without much education and training (Noetstaller, 1995). Sluice boxes have been used by artisans for gold recovery over thousand years and is still being used in small scale gold mining operation. Sluice boxes provide much higher concentration ratio than most of the gravity concentrators. They are also reliable and inexpensive and simple to operate (Hamilton, 1988). Placer mining, which involves the extraction of valuable minerals, particularly gold, from alluvial deposits, relies heavily on the efficiency of equipment such as sluice boxes to separate gold particles from concentrate. The angle of inclination, commonly known as the pitch or grade of the sluice box, plays a critical role in the separation process (Alabi and Gbadamosi, 2021). It affects the flow dynamics of water and sediment within the sluice box, influencing the retention and recovery of gold particles. However, the optimal angle of inclination for maximum gold recovery remains uncertain and subject to variation based on factors such as particle size distribution, water flow rate, and sediment characteristics. The lack of a standardized approach to determine the ideal angle of inclination poses significant challenges for placer miners. Operating with suboptimal angles could result in reduced gold recovery rates, increased operational costs, and prolonged processing times. Conversely, employing excessively steep or shallow angles could lead to incomplete separation and loss of valuable gold particles. Vishiti et al. (2015), carried out an investigation on gold grade variation and microchemistry in exploration pits in Batouri gold district but no work has been done on improving gold recovery efficiency through optimal angle of inclination of sluice boxes in Batouri. Hence, there is a critical need to conduct a comprehensive investigation to identify the optimal angle of inclination for sluice boxes in placer mining operations in Batouri, East Cameroon.

### *1.1 Geology and location of the study area*

The study area covers a surface area of 3888 Km$^2$. Batouri town is situated about 90 km northeast of Bertoua and it is accessible through tarred road. The Batouri area is part of the Adamawa-Yadé Domain of the Pan African fold belt in Cameroon. According to Van et al. (2008), the Adamawa-Yade domain extends eastwards from central Cameroon into the Central African Republic where it is known as the Yade massifs. In Cameroun, Adamawa-Yadé domain is bounded to the north by the Tchollire Banyo shear zone and to the south by Sanaga shear zone towards the Yaoundé domain. Inside, the main faults and shear-zones include the Sanaga fault, the Central Cameroon shear zone and the Mayo Nolti shear zone. Particularly, the Central Cameroon shear zone and the Sanaga fault are well investigated in Mayo Dana-West of Tibati and Bafia regions respectively (Ngako et al., 2003). The Adamawa-Yadé Domain is dominated by syn- to late-collisional high-K calc-alkaline granitoids. These granitoids intrude high-grade gneisses that represent a Palaeoproterozoic basement, which was likely dismembered during the Pan-African orogeny (Van et al, 2008). The rocks of the Adamawa-Yadé Domain are classified into three main groups (Toteu et al, 2006): i) large supracrustal blocks of Palaeoproterozoic metasedimentary rocks and orthogneiss with assimilated Archean crust similar to the Ntem Complex; ii) syn- to late-tectonic granitoids of transitional composition and crustal origin, and iii) low- to medium-grade metasedimentary and metavolcaniclastic rocks. The geology of Batouri is particularly dominated by syn- to late tectonic granites locally crosscut by systems of shear zones (Gazel and Gérard, 1954).

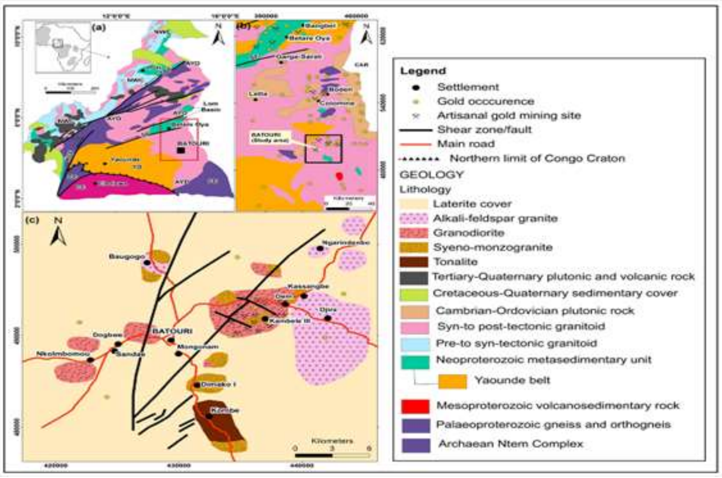


**Figure 1. (a) Geological map of Cameroon (source: Vishiti et al., 2015). ( b ) Regional geological map of south eastern Cameroon (source: Vishiti et al., 2015). (c) Geology of the Batouri gold district (source: Vishiti et al., 2015).**

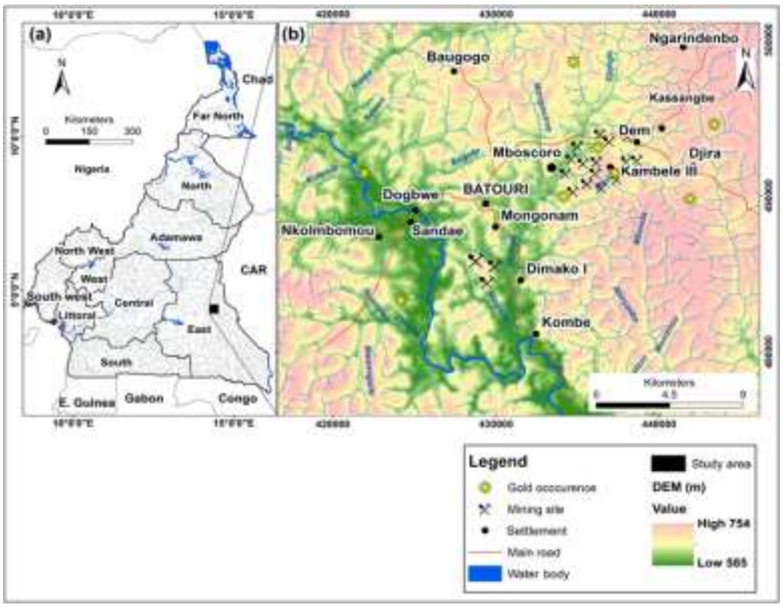


**Fig 2: DEM map of Cameroon and the Batouri gold district (source: Vishiti et al., 2015)**

## 2. Materials and Methods

Alluvia materials were collected from 10 different pits and mixed together with the aid of a spade in order to obtain a uniform mixture. The sluice box was mounted and the angle measured with a compass clinometer. Four different angles of sluice box inclinations were investigated ($4^0$, $10^0$, $14^0$, and $18^0$). The quantity of alluvial material to be washed was measured with a weighing balance. For each experiment, 50kg of alluvial material was weighed and sluiced at a constant water pressure of 2554 Pascal and constant mesh size (16 strands of height 300mm). After sluicing 50kg of material, the mats were removed from the sluice box and washed in a pan. The material was panned to obtain a concentrate made of mostly heavy metals and gold. Gold was separated from heavy metals through the process of mercury amalgamation and the amalgam heated to liberate mercury. The amount of gold recovered was weighed on an electronic balance and the value recorded. For all experiments, the water pressure and mesh size were kept constant while the angle of inclinations of the sluice box were varied. For each angle of inclination, sluicing was done trice and average gold recovery calculated.

## 3. Results and Discussions

### *3.1 Results*

As shown on table 1, 12 different experiments were carried out, 3 for each angle of inclination. For the first angle ($4^0$), the first investigation gave gold recovery of 0.15g, second 0.14g and third 0.16g. The angle $10^0$ gave 0.33g, 0.36g and 0.35g of gold recovery for the first, second and third experiments respectively. As for $14^0$, the first, second and third experiments yielded 0.21g. 0.23g, and 0.24g of gold respectively. For the last angle ($18^0$), gold recoveries were 0.18g, 0.19g and 0.20g for the first, second and third experiments respectively.

**Table 1: Gold recovery**

| Inclination angle ($^0$) | Experiments | Quantity of alluvial (kg) | Gold recovery (g) | Average gold Recovery (g) |
|---|---|---|---|---|
| 4 | 1 | 50 | 0.15 | |
| 4 | 2 | 50 | 0.14 | **0.15** |
| 4 | 3 | 50 | 0.16 | |
| 10 | 1 | 50 | 0.33 | |
| 10 | 2 | 50 | 0.36 | **0.34** |
| 10 | 3 | 50 | 0.35 | |
| 14 | 1 | 50 | 0.21 | |
| 14 | 2 | 50 | 0.23 | **0.22** |
| 14 | 3 | 50 | 0.24 | |
| 18 | 1 | 50 | 0.18 | |
| 18 | 2 | 50 | 0.19 | **0.19** |
| 18 | 3 | 50 | 0.20 | |

### *3.2 Discussions*

At angle $4^0$, average gold recovery was 0.15g. This indicated that the 4° angle did not wash well, resulting in poor gold recovery. Here, poor recovery revealed slow movement of material suggesting the angle was too shallow, and the material was not properly transported along the box, reducing gold recovery efficiency. Also, the $10^0$ angle gave an average gold recovery of 0.34g. This angle allowed the material to flow more smoothly and efficiently, permitting gold grains to settle on the mesh while enhancing the washing away of gangue. Moreover, an average gold recovery for the $14^0$ angle was 0.22g. At this angle, material flow was good but did not yield as much gold recovery as the 10° angle. This indicated that while the 14° angle was effective in transporting the material along the sluice box, it may not have provided the optimal conditions for maximum gold recovery. The investigation showed that using a $14^0$ angle resulted in a greater recovery compared to the $4^0$ and $18^0$ angles. Additionally, the concentrate obtained after sluicing was lesser at $14^0$. This implied that the sluice box performed relatively well, allowing for recovery while minimizing the amount of concentrate produced. It is possible that this angle caused some of the smaller gold particles to be washed away during sluicing. Also, the 18° angle yielded an average gold recovery of 0.19g and did not hold back much material, as well as didn't yield as much gold as the 14° and 10° angles. This suggested that the 18° angle may have been too steep, causing the material to move too quickly through the sluice box. As a result, some gold particles may have been carried away with the excess material, leading to a lower overall gold recovery compared to the other angles. Based on these findings, one can say among the angles investigated, $10^0$ yielded optimal gold recovery. This result is similar to that obtained by Alabi and Gbadamosi (2021) in investigating gold recovery efficiency with the sluice box where 92.36% of gold recovery was achieved while using $10^0$ as angle of inclination.

## 4. Conclusion

As shown on table 1, 12 different experiments were carried out, 3 for each angle of inclination. For the first angle ($4^0$), the first investigation gave gold recovery of 0.15g, second 0.14g and third 0.16g. The angle $10^0$ gave 0.33g, 0.36g and 0.35g of gold recovery for the first, second and third experiments respectively. As for $14^0$, the first, second and third experiments yielded 0.21g. 0.23g, and 0.24g of gold respectively. For the last angle ($18^0$), gold recoveries were 0.18g, 0.19g and 0.20g for the first, second and third experiments respectively. Based on these findings, the angle 10° appears to be the most effective angle of inclination for the sluice box, yielding the highest average amount (0.34 g) of gold recovery at a constant water pressure of 2554 Pascal and constant mesh size (16 strands of height 300mm). However, it is important to note that optimal angle may vary depending on specific conditions, such as water flow rate and particle size distribution of the alluvial material. Also the best angle of inclination cannot be gotten if the other parameters influencing recovery are not changed to have the best of each that operates at a high chance to generate the highest recovery .From result, the optimal angle for artisanal gold recovery in Batouri was $10^0$ since it yielded the highest amount of recovery. Therefore, artisans will improve gold recovery efficiency if they use angles between $9^0$ and $11^0$ for sluice boxes during sluicing.

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