International Journal of Technical Research and Applications e-ISSN: 2320-8163,
www.ijtra.com Special Issue 23 (July2015), PP. 77-83

STUDY OF ALLUVIAL GOLD SEDIMENTS OF RIVER KABUL, DISTRICT NOWSHERA (KHYBER PAKHTUNKHWA, PAKISTAN).

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***Abstract*— Shaidu area situated in Peshawar Basin lies in district Nowshera, Khyber Pakhtunkhwa. This area in mainly composed of gravels, sand, silt and cobbles. This area is investigated for the occurrence of placer gold and also to develop an economical, feasible and environmentally safe method. Mineralogical and chemical studies of the collection of samples of the pan concentrates, shaking table showed visible placer gold particles. These particles vary in size and morphology. The gold particles are neither too fine nor coarse. Amalgamation is the most suitable method to recover gold. These sediments show a high concentration of gold. This gold is of high economical grade and values. Its high recoveries can be obtained by constructing the amalgamation plant at the site.**

***Index Terms*— Alluvial Gold, Mineralogy Introduction**

I. INTRODUCTION

I. Introduction

A Peshawar Basic (vast and low-lying depression) situated in the southern margin of Pakistan Himalayas. It is an intermountain basin, which is enclosed by Khyber mountain ranges in the West and North West, Attock-Cherat in the South and Swat in the North West while its southern- eastern side is bordered by Indus River which is open for discharge. The Peshawar Basin is mostly covered with Quaternary sediments, which ranges from Pleistocene to recent age. These sediments vary from piedmont deposits to flood plain and stream channel and loess sediments. [1]

The Kabul, Swat and Indus Rivers are the main braided rivers of this basin which deposit sand, gravels and clay carried away over large distance. The study area lies at a distance of approximately one Km from the main GT road towards south in the Peshawar Basin, within district Nowshera at south east of Shaidu town.

The study area mostly contains the piedmont sediments that are deposited by the Kabul River. These sediments are abundantly comprised of gravels, cobbles, sand and silt of fluvial origin. The above sediments also mix with the local weathered material of the Attock-Cherat ranges and hence are supposed to be as part of Attock-Cherat piedmont deposits. [2]

Many researchers noted the important indicative role of the alluvial autochthonous gold placers for assessment of prospects of the adjacent areas for primary mineralization. [3-4]

II. PREVIOUS WORK

In December, 2005 it was discovered that the locals of Shaidu town panned the sediments for gold. After the preliminary field work in the area, these specific pan concentrated samples were collected for further investigation. The samples were collected from a lenticular deposit of sediments in an area expanding a kilometer long and a half km wide. These sediments were mainly composed of less than 40% of gravels cobbles and pebbles and greater than 60% of sand. [5]

III. DETAIL EXPERIMENTAL WORK

II. *Field Methodology*

Fluvial sediments were found in River Kabul near Shaidu area in District Nowshera. Detail study of this area was conducted to the mineralogy, particle size and other feature to select a feasible and economical method for the extraction of alluvial gold.

For this purpose a proper systemic method was applied for collecting the samples from the fluvial sediments. The latitude and departure were noted, so that we know the exact position from where the samples were collected. A sophisticated way was followed while collecting the sample. With the help of GPS, the latitude and departure was noted before every single collection of the sample. Most samples were taken at a depth of 3 feet so to get the concentrated sample representing the area.

The samples from each spot collected were taken in a 20 kg bucket for screening through a sieve of #7, so to eliminate the oversize particles. The material was weight and then panned by panning method in Shaidu Area.

The visible gold particle were also counted and a considerable amount of gold were found and the heavy mineral concentrate (HMC) were then stored in polythene bag. These polythene bags were systematically marked as S1, S2 and so on. Thus twenty (20) representative pans concentrates were panned and collected from the deposit. The bulk material was also taken from twenty different spot and the material was put in bags for other gravity separators and for chemical analysis as well. These samples were then sent to Mineral Testing Laboratory (MTL) for further mineralogical & chemical analysis.

III. *Laboratory Methodology*

Samples collected in the field were transported to MTL (Mineral Testing Laboratory) Peshawar and ten experiments were carried out in the Processing section of MTL to collect gold from the material. The pan concentrates sample have also studied and processed. Following is the detail of each method used for extraction of gold in laboratory carried out for successful extraction of gold from the deposit.

- *Metallurgical Section:*

In this section, the samples were treated as follows;

Sieving: Bulk samples were first sieved through a sieve of # 10 mesh sizes.

Splitting: The samples were split by the help of a splitter machine after sieving. The material was fed evenly on the top of the splitting machine so that it was randomly split into two equal sizes and fractions on passing through the splitter. Fraction of $1/16^{th}$ of the original sample was produced by repeated application of the procedure. Finally this fraction was riffled out through riffle box. The final fraction were then divided into three sub sample by coning and quartering method and these samples were known as Head Samples of chemical and mineralogical analysis and record keeping. These samples were then put into plastic bags and different sample numbers were given.

Gravity separation: Gravity separation is the technique used to separate the material on the basis of its specific gravity. Sieved material was then passed through shaking table, which works on the principle of gravity separation. Proper supply of water was provided and inclination of the table was adjusted. Material was poured scoop by scoop and processed product was collected. Three types of products were collected from shaking table i.e. 1. Concentrate 2. Middling 3.Tailing

Sampling: The denser part of the sample was collected as concentrate, less dense relative to concentrate were collected as middling and the remaining was collected as tailing.

These three media were then dried in oven and were sampled for further mineralogical and chemical analysis and record keeping. These samples were then put in polythene bags and marked according.

Amalgamation The concentrates of gravity separation contain fine particles of gold and this was treated with mercury to collect gold from it. Mercury was initially in active form so first we deactivate the mercury. Mercury was deactivated using electric current with the help of two wires. For few minutes we did the process and then removed the current. The mercury was deactivated and was ready to be used for amalgamation.

For amalgamation process the concentrate of the shaking table was poured to bottles. Water was then put into the bottle above the level of the concentrate. This mercury was termed as “Deactivated Mercury”. Then the deactivated mercury was put into the bottle and the bottle was placed on bottle rolling machine and the machine was turned on. For 15 to 60 minutes the concentrate was rolled in the bottling on bottle rolling machine. The mechanism followed in the bottle rolling machine for amalgamation was that the deactivated mercury forms a thin layer at the edge of the bottle. The gold particles being heavy than the other particles tends to move toward the edges of the bottle so are trapped in the layer if mercury. The mercury containing gold particles is termed as “Pregnant Mercury”. This pregnant mercury was then collected from the remaining concentrate in a separate dish for further processing.

Heating: The pregnant mercury collected from mercury amalgamation process in bottle rolling machine was then heated in *Assay Furnace* at a temperature of 550˚C for 30 minutes and 650˚C for about 15 minutes till all of the mercury evaporates and condensed in a flask which has been linked through a pipe to a motor engine. The pure gold left behind in the china dish. The furnace was turned off and waited till it cools down and then collected the china dish from it. The gold recovered was in pure form and was checked under microscope for the particle size and the quantity of gold recovered.

- *Chemical section:*

For the chemical analysis, Hubfrt and Chaos Method were performed for absorption & elimination of gold. The pan concentrate samples were stored and weighed and then put in different beakers. Then 50 ml of equa-regia (with ratio 3:1, HCl and HNO_3 respectively) was added & then heated for about 30 minutes. Distil water (30ml) was poured and heated till 50 ml solution left. The material in beakers left was then filtered and wasted by 6NHCl into the test tubes to make 50 ml which is the final volume. The filtrate was ten shifted to 250 ml funnels and the same amount of water was added, and then shaken for about 10 minutes.20 ml of methyl isobutyl Ketone (MIBK) was added to the separate funeral. The lower layer was disposed through the funnels. after this 20ml of 0.2NHCL was added to MIBK in the funnels and shaken for 5 and 10 minutes .The lower layer was discarded again and the MIBK containing extracted gold was stored in a glass bottle for the analysis by electro thermal Perkin Elmer analysis 700, for gold under the standardized condition**.**

For silver (Ag) analyses, 30g of sample was treated with 50 ml of Equa-Regia by heating for about 2 hours on low heat and the solution was made to 50 ml of volume with clean water. The solution was directly run through Atomic Absorption for the determination of the silver.

TABLE I. COMPOSITION OF DIFFERENT MINERALS (IN PERCENTAGE) IN THE SAMPLES CONTAINING VISIBLE GOLD PARTICLE IN THE STUDIED PAN CONCENTRATE

Sample No.	Magnetite	Rock Fragments	Garnet	Zircon	Feldspar	Quartz	Epidote	Tourmaline	Mica	Pseudo-pyrite
S-1	44	36	9	1	1	2	2	2	2	<1
S-6	45	35	12	2	2	2	-	-	1	<1
S-10	40	28	12	3	3	5	1	5	2	<1
S-14	39	30	11	2	3	6	1	5	2	<1
S-16	49	28	12	3	-	2	1	3	1	<1
S-17	47	32	8	2	-	4	2	2	2	<1
S-18	42	30	10	3	2	4	1	6	1	<1
S-19	46	30	12	2	-	3	2	3	1	<1
S-20	48	29	12	3	-	2	2	2	1	<1

- *Mineralogical Section*

Samples were then studied under microscope. Gold grain size was separated and distributed into pieces (greater than 0.3mm) specks (0.3-0.5mm) and color (less than 0.3mm). Morphological studies (i.e. grain size, color & shape) of gold grains were performed. In process, beside gold and silver other minerals were found, i.e. Rock fragments and gems were identified on the basis of percentage amount present in the samples.

IV. RESULTS AND DISCUSSION

The physical & chemical properties of gold show that gold is malleable, ductile and sectile noble metal. It is telluride in nature and occurs as free metal[6] .The placer gold which is released by the weathering from the bed rock is free and coarse. It occurs mostly in fluvial, alluvial and glacio- fluvial sediments. During the gold exploration in such sediments, these concentrates and fine frictions are analyzed for gold concentrations. These concentrates have visible gold. This visible gold as classified as nugget, piece (>0.5mm), specks (0.3-0.5) and color (<0.3mm) (A.S. Joyce, 1984).This gold found confirms the importance of these sediments economically and the size, shape and composition of visible gold also helps in confirming of gold source rock and its direction [7].

The sediments also contain rock fragment, pyrite, quartz, zircon, epidote, biotite tourmaline, mica, garnet and muscovite with minor amount of carbonates, malachite and fine magnetite.

In accordance with the given facts the mineralogy and description of visible gold and the gold concentration in the pan concentrates have been given in tables 1, table 2 and table 3 respectively. Table I. shows that the pan concentrates which are having visible gold, have varying amounts of Rock fragments (28-36%) magnetite (39-49%) garnet (0.16%), Zircon (<3%) feldspar (<3%), Quartz (24%), epidote (<2%), tourmaline (<6%) mica (<2%) and pseudo- pyrite (<1%).

Table II, shows that the gold occurs as pieces, specks and colors. However, no nuggets of gold were found in the studied pan concentrate. The pan concentrates of three samples is S-1, S-6 and S-14 had pieces of gold (>0.5mm) with maximum number of pieces in the sample # S-14. The pieces obtained are mainly irregular to oval shape, they are solid and sub angular to sub rounded and their color varies from yellow to bright yellow.

In the pan concentrates of studied samples, the specks (0.3-0.5 mm) with highest number were found in sample No. S-10 (Table II). The specks were conical, oral, and butterfly in shape to oral, rounded and irregular. The forms were from solid to thick flaky, their roundness varies from sub-invader to sub-round and their color is between light yellow to bright yellow (Table II). The color of gold (<0.3mm) found in the pan concentrate of eight samples(S-6, S-10, S-16, S-17, S-18, S-19 and S-20) with maximum numbers of colors in sample number S-14 as shown in Table II. The various features of visible gold particulars such as size and morphology (flatness, roundness, texture) of the placer gold obtained from the Shaidu area can be evaluated to obtain to proximal or distal nature of gold source. The size and morphology of visible gold with in the pan of the sediments under study showed that their gold has been obtained and carried from the distal source more than few hundred of kilometers up stream either in Afghanistan or Chitral Region of Northern Pakistan where Kabul river played a vital role in the transportation and deposition of the sediments and the host gold particles within the Peshawar Basin .

TABLE II. SHOWING THE DESCRIPTION OF THE GOLD PARTICLES IN THE STUDIED PAN CONCENTRATE

Sample No.	**Particle Size(mm)**	**No.of visible gold particle**	**Shape**	**Form**	**Roundness**	**Color**
S-1	Color(< 0.3)	Nil	……	…….	……	……
	Speck(0.3-0.5)	3	Conical to butterfly	Solid to thick flaky	Sub angular to rounded	Bright yellow
	Piece (>0.5)	2	Almost Rounded	Thin Flaky	Sub rounded to sub angular	Yellow
S-6	Color(< 0.3)	3	Conical to butterfly	Solid to thick flaky	Sub angular to rounded	Bright yellow
	Speck(0.3-0.5)	6	Almost Rounded	Solid to thin flaky	Sub rounded to sub angular	Yellow
	Piece (>0.5)	3	Conical to butterfly	Solid to thick flaky	Sub angular to rounded	Bright yellow
S-10	Color(< 0.3)	5	Conical to butterfly	Solid to thick flaky	Sub angular to rounded	Bright yellow
	Speck(0.3-0.5)	8	Almost Rounded	Solid to thin flaky	Sub rounded to sub angular	Yellow
	Piece (>0.5)	Nil	……	…….	……	……
S-14	Color(< 0.3)	6	Almost Rounded	Thin Flaky	Sub rounded to sub angular	Yellow
	Speck(0.3-0.5)	7	Conical to butterfly	Solid to thick flaky	Sub angular to rounded	Bright yellow
	Piece (>0.5)	7	irregular to oval shape	Thin Flaky	Sub rounded to sub angular	Bright Yellow
S-16	Color(< 0.3)	Nil	……	…….	……	……
	Speck(0.3-0.5)	3	Conical to butterfly	Solid to thick flaky	Sub angular to rounded	Bright yellow
	Piece (>0.5)	Nil	……	…….	……	……
S-17	Color(< 0.3)	Nil	……	…….	……	……
	Speck(0.3-0.5)	3	Conical to butterfly	Solid to thick flaky	Sub angular to rounded	Bright yellow
	Piece (>0.5)	Nil	……	…….	……	……
S-18	Color(< 0.3)	2	……	…….	……	……
	Speck(0.3-0.5)	3	Conical to butterfly	Solid to thick flaky	Sub angular to rounded	Bright yellow
	Piece (>0.5)	Nil	……	…….	……	……

S-19	Color(< 0.3)	Nil	……	…….	……	……
	Speck(0 .3-0.5)	3	Conical to butterfly	Solid to thick flaky	Sub angular to rounded	Bright yellow
	Piece (>0.5)	Nil	……	…….	……	……
S-20	Color(< 0.3)	2	……	…….	……	……
	Speck(0 .3-0.5)	3	Conical to butterfly	Solid to thick flaky	Sub angular to rounded	Bright yellow
	Piece (>0.5)	Nil	……	…….	……	……

Sizes of the gold particles reduce as the distance increases from the source rock [8-9]. But some time the relation between distance and size became complicated as both size and shape of the particles changes as they go downstream. Flakes, become more abundant downstream, and flow or transported easily than sphere [10].

Mercury amalgamation typically recovers in excess of 90% of the gold content of a placer gravel or placer concentrate. Mercury amalgamation is effective only for gold particles larger than 60-70µm [11]. Most of the particle are greater than 70µm, thus amalgamation is very effective method to recover the gold.The concentration of gold in twenty pan concentrate samples is given in Table III. The table shows that the gold concentration is variable and it ranges from 2.1 ppm to 70.0 ppm. The sample S-14 has high concentration of gold (70 mg / kg) or ppm. The samples having visible gold have high concentration of gold than those having no visible gold in the pan concentrates but still had more than 2 mg / kg gold, suggesting the presence if finer gold particles in sediments.

For the total recovery of gold bulk sample obtained, the gold concentration in mg/Kg has been recalculated in grams as shown in table 5.13. It is concluded from the table that 412.6 Kg bulk sample has yielded 10.84434 grams or (26.2g/ton) of gold. As far as the gold extraction methods are concerned, this recovery of gold is very economical. [12-13].

The gold mining from the sediment as placer mining resulting concentrates, middling and tailing while hard rock are mined via open-Pit or underground method. The gold recovery of places is easy, economical and simple than hard rock ore. The extraction of gold is generally done by Gravity Concentration and Amalgamation And Heap Leaching technique. [12-14].

IV. TABLE III. SHOWS THE CONCENTRATION OF GOLD IN THE STUDIED PAN CONCENTRATE SAMPLES AND RECOVERY OF GOLD IN GRAMS FROM ORIGINAL SAMPLE.

Sample No.	Weight of sample (Kg)	Concentration of gold in (mg/Kg) or PPM	Concentration of gold in g/Kg	Weight of gold in original sample in g
S-1	21.2	40.3	0.0403	0.85436
S-2	22.0	5.2	0.0052	0.1144
S-3	19.3	20.3	0.0203	0.39179
S-3	18.9	18.1	0.0181	0.34209
S-5	20.0	8.0	0.008	0.16
S-6	21.3	30	0.03	0.639
S-7	20.7	2.1	0.0021	0.04347
S-8	17.8	17.0	0.017	0.3026
S-9	22.1	20.4	0.0204	0.45084
S-10	20.2	60.0	0.06	1.212
S-11	20.8	22.2	0.0222	0.46176
S-12	18.9	39.1	0.0391	0.73899
S-13	19.7	19.2	0.0192	0.37824
S-14	20.4	70.0	0.07	1.428
S-15	23.0	21.2	0.0212	0.4876

S-16	21.0	12.3	0.0123	0.2583
S-17	20.1	4.4	0.0044	0.08844
S-18	20.4	36.2	0.0362	0.73848
S-19	25.0	38.4	0.0384	0.96
S-20	19.8	40.1	0.0401	0.79398
Total	**412.6**	**524.5**	**0.5245**	**10.84434**

In the first method the gold is obtained in mercury in

pure form after heating, evaporation and condensation of Hg. In heap-leaching gold is dissolved as an Aurocyanide Complex in oxidizing alkaline cyanide solution and is then recovered from cyanide leach solution either by; Merrill-Crowe precipitation, Sodium sulfide precipitation and activated carbon adsorption. [15-16].The mercury

amalgamating and heap latching techniques are applicable for the extraction of gold form the sediment of Shaidu Area. As the major portion of gold is in Free State and coarse thus the heap leaching will not be an effective and feasible method but gold can be extracted by direct amalgamation techniques by building the plant at the site but special consideration must be paid to the effects of mercury before the plant construction.

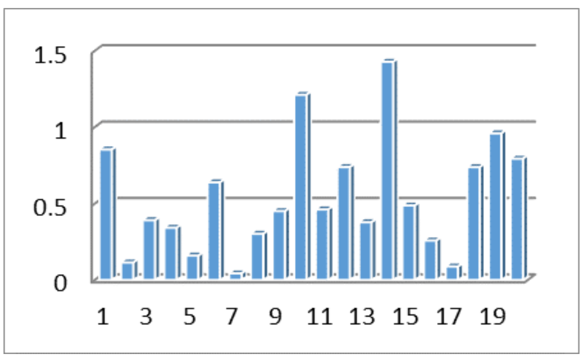

FIGURE 1.SHOWS THE GOLD CONCENTRATION (GRAM/ORIGINAL SAMPLE) IN ALL STUDIED PAN CONCENTRATE SAMPLES.

V. . CONCLUSION:

It is concluded from the particle size and other characteristics that the gold was derived and had been transported from far away source. The average gold recovery 26.27g/ton from the sediment seems economical. Yet, for maximum extraction of gold, detail investigation is needed.

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