International Journal of Technical Research and Applications e-ISSN: 2320-8163,
www.ijtra.com Special Issue 19 (June, 2015), PP. 34-38

Study of Alluvial Gold Bearing 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 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 shaking table samples showed the occurrence of placer gold particles in concentrate, middling and tailing. These particles vary in size and morphology. Most of the particles are greater than 70µm, thus amalgamation is very effective for recovery of gold particles larger than 60-70µmwhilecyanidation method is used for the recovery of finer particles. A pilot study is suggested in order to increase the knowledge of the proposed plant and resources.**

***IndexTerms*—Alluvial Gold, Mineralogy**

I. INTRODUCTION

From geographic point of view, Peshawar Basin is 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 Kabul, Swat and Indus Rivers are the main braided rivers of this basin. The study area lies at a distance of approximately a kilometer from the main GT road towards South in the Peshawar Basin, within district Nowshera, South-East of Shaidu town. [1-2]Modern placer deposits have attracted the attention of geologists working in academia as well as those being in search of metals or gemstones. Alluvial and coastal deposits enriched in heavy minerals normally offer easy access to miners and can be worked out by opencast operations since the waste–ore ratio is very low. [3-4]This paper presents the mineralogy, morphology, particle size and chemical study of alluvial gold bearing sediments.

II. PREVIOUS WORK

Researchers 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 half a kilometer wide. These sediments were mainly comprised of less than 40% of gravels cobbles and pebbles and greater than 60% of sand.

The pan concentrate showed visible gold particle and the gold recovery from the pan concentrate was greater than 30 g/ton. [2]

III. DETAIL EXPERIMENTAL WORK

Field Methodology

Fluvial sediments are found in River Kabul near Shaidu area in District Nowshera. Detailed study of this area was conducted to make finds about 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. Most samples were taken from a depth of 2-3 feet so to get the samples representing the area.
The bulk samples collected from each spot were taken in a 20 kg bucket. The material was put in bags and then sent to Mineral Testing Laboratory Peshawar (MTL) for further analysis.

Laboratory Methodology

Samples collected in the field were transported to Mineral Testing Laboratory Peshawar (MTL)
Following is the detail of each method used for extraction of gold in laboratory carried out for successful extraction of gold from the deposit. 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 then divided into three sub samples by *Coning and Quartering* Method and these samples are termed

as Head Samples for chemical, mineralogical analysis and record keeping. These samples were then put into plastic bags and marked accordingly.

Gravity Separation: Gravity separation is the technique used to separate the material on the basis of its specific gravity. Sieved material was passed through shaking table. 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 part relative to concentrate was collected as *middling* and the remaining was collected as *tailing*.

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

Amalgamation: The concentrate of gravity separation contains fine particles of gold and it was treated with mercury to collect gold from it. Mercury was initially in active form so first we deactivated it 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. 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 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 and are trapped in the layer of 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: Then pregnant mercury was 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 evaporated and condensed in a flask which has been linked through a pipe to a motor engine. The pure gold was left behind in the china dish. The gold recovered was in pure form and was checked under microscope for the particle size and the quantity of gold recovered.

Cyanidation Process has been used to recover fine and ultra-fine gold particle from middling and tailing [6]. **F**or silver (Ag) analyses, 30g of sample was treated with 50 ml of Aqua-Regia by heating for about 2 hours on low heat and the solution was diluted to 50 ml with clean water. The solution was directly run through Atomic Absorption for the determination of the silver content.

- *Mineralogical and Morphological Section*

Samples were then analyzed 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).

General morphology of the grains - the description of morphology was done according to Herail (1984) into 8 categories: square, rectangular, circular, oval (and rhombic), spherical, trapezoidal, triangular, elongated.[5] In this process, beside gold and silver other minerals were found, i.e. Rock fragments and gems were identified

IV. RESULTS & DISCUSSION

TABLE I: CONCENTRATION OF GOLD AND SILVER IN DIFFERENT SAMPLES

Sample No.	Metals	Head Sample (ppm)	Concentrate (ppm)	Middling (ppm)	Tail (ppm)
SS-1	Gold	0.17	0.93	0.09	0.09
	Silver	<0.5	<0.5	<0.5	<0.5
SS-2	Gold	0.29	0.89	0.1	0.08
	Silver	<0.5	<0.5	<0.5	<0.5
SS-3	Gold	19	46	14	0.1
	Silver	0.5	0.9	0.6	0.4
SS-4	Gold	13	23	3	0.09
	Silver	0.45	0.23	0.6	0.4
SS-5	Gold	2	6.1	0.10	.07
	Silver	0.93	1.75	0.6	.45
SS-6	Gold	3	19	1.3	0.9
	Silver	0.3	0.5	0.3	0.6
SS-7	Gold	0.3	0.61	0.30	0.09
	Silver	0.6	0.78	0.60	0.43
SS-8	Gold	0.3	1.61	0.30	0.09
	Silver	0.55	0.69	0.30	0.18
SS-9	Gold	0.29	0.89	0.1	0.08
	Silver	0.43	0.75	0.42	0.38
SS-10	Gold	8.0	41	5	0.9
	Silver	0.59	0.70	0.6	0.10

TABLE II: GOLD PARTICLE SIZE, SHAPE AND OTHER MINERALS IN SHAKING TABLE SAMPLES

Sample no.	Different media	Particle Size (mm)	Shape	Other Minerals
SS-1	Head sample			Rock fragments, magnetite, quartz, pyrite, mica, garnet, feldspar, zircon, tourmaline, epidote and pseudo-pyrite (oxidation effect)
	Concentrate			Mostly rock fragments while tracer amount of quartz, garnet pyrite and tourmaline are in small proportion
	Middling			Rock fragments, quartz, epidote, biotite and muscovite with minor amount of and fine magnetite
	Tailing			Fragments are dominant with a little amount of garnet
SS-2	Head sample			Rock fragments, quartz, garnet pyrite and tourmaline are in small proportion
	Concentrate			Mainly composed of quartz, garnet pyrite and tourmaline
	Middling			Rock fragments, quartz, garnet pyrite and tourmaline are in small proportion
	Tailing			Mainly composed of quartz, garnet pyrite and tourmaline
SS-3	Head sample	<0.3	Nearly rounded	Rock fragment, magnetite, quartz, pyrite, mica, garnet, feldspar, zircon, tourmaline, epidote and pseudo-pyrite (oxidation effect)
	Concentrate	0.5 0.3	Rounded to oval and rounded to angular	Mostly rock fragments while tracer amount of quartz, garnet pyrite and tourmaline are in small proportion
	Middling			Rock fragments, quartz, epidote, biotite and muscovite with minor amount of and fine magnetite
	Tailing			Fragments are dominant with a little amount of garnet
SS-4	Head sample	0.5	Nearly circular	Rock fragments, magnetite, quartz, pyrite, mica, garnet, feldspar, zircon, tourmaline, epidote and pseudo-pyrite (oxidation effect)
	Concentrate	0.5 0.3	Elongated to circular	Mostly rock fragments while tracer amount of quartz, garnet pyrite and tourmaline are in small proportion
	Middling			Rock fragments, quartz, epidote, biotite and muscovite with minor amount of and fine magnetite
	Tailing			Fragments are dominant with a little amount of garnet
SS-5	Head sample			Rock fragments, quartz, garnet pyrite and tourmaline are in small proportion
	Concentrate			Mainly composed of quartz, garnet pyrite and tourmaline
	Middling			Rock fragments, quartz, garnet pyrite and tourmaline are in small proportion
	Tailing			Mainly composed of quartz, garnet pyrite and tourmaline
SS-6	Head sample			Rock fragment, magnetite, quartz, pyrite, mica, garnet, feldspar, zircon, tourmaline, epidote and pseudo-pyrite (oxidation effect)
	Concentrate	0.5	Oval to round	Mostly rock fragments while tracer amount of quartz, garnet pyrite and tourmaline are in small proportion
	Middling			Rock fragments, quartz, epidote, biotite and muscovite with minor amount of and fine magnetite
	Tailing			Fragments are dominant with a little amount of garnet
SS-7	Head sample			Rock fragments, quartz, garnet pyrite and tourmaline are in small proportion
	Concentrate			Mainly composed of quartz, garnet pyrite and tourmaline

	Middling			Rock fragments, quartz, garnet pyrite and tourmaline are in small proportion
	Tailing			Mainly composed of quartz, garnet pyrite and tourmaline
SS-8	Head sample			Rock fragments, quartz, garnet pyrite and tourmaline are in small proportion
	Concentrate			Rock fragment, magnetite, quartz, pyrite, mica, garnet, feldspar, zircon, tourmaline, epidote.
	Middling			Rock fragments, quartz, epidote, biotite and muscovite with minor amount of carbonates,malachite and fine magnetite
	Tailing			Little amount of muscovite, garnet and biotite
SS-9	Head sample			Rock fragment, magnetite, quartz, pyrite, mica, garnet, feldspar, zircon, tourmaline, epidote and pseudo-pyrite (oxidation effect)
	Concentrate			Mostly rock fragments while tracer amount of quartz, garnet pyrite and tourmaline are in small proportion
	Middling			Rock fragments, quartz, epidote, biotite and muscovite with minor amount of and fine magnetite
	Tailing			Fragments are dominant with a little amount of garnet
SS-10	Head sample			Rock fragment, magnetite, quartz, pyrite, mica, garnet, feldspar, zircon, tourmaline, epidote and pseudo-pyrite
	Concentrate	>0.5 And 0.25	Oval to butterfly and rounded to angular shape.	Mostly magnetite grains while rock fragments, quartz, garnet pyrite and tourmaline are in small proportion
	Middling			Rock fragments, quartz, epidote, biotite and muscovite with minor amount of carbonates, malachite and fine magnetite
	Tailing			Carbonates & rock fragments are dominant with a little amount of muscovite, garnet and biotite

Beneficiation of placer materials involves the separation of fine gold particles from large quantities of alluvial sediments. Gravity separation is the most commonly used beneficiation method. Water is used in most, if not all steps; initially, to wash gold particles from oversized material and later, to move gold concentrate through the shaking table.

Beneficiation typically involves three general steps: the first is to remove grossly oversized material from the smaller fraction that contains the gold, the second to concentrate the gold, and the third to separate the fine gold from other fine, heavy minerals [7].

The mineralogical study suggested that mineralogy is almost same in head sample, middling and tailing of all samples as shown in Table II. The other minerals associated with gold and silver are rock fragment, magnetite, quartz, pyrite, mica, garnet, feldspar, zircon, tourmaline, epidote and pseudo-pyrite (oxidation effect).The particle sizes were in the range of 0 .25-0.5mm. And these particles were found in head sample and concentrate as in Table II. The shape of gold particles prescribed that it has been transported from a distance of more than hundreds kilometers.

Almost no visible gold particles were found in middling and tailing. But if we look at the results of tailing and middling, it shows the presence of gold and silver particles in these media. Thus it indicates the fine and ultra-fine particles in different media.

The chemical study of the different media of shaking table shows that the gold values are very different. The highest concentration of gold in head samples is 19ppm and lowest is 0.17ppm. Similarly the highest silver grade is 0.93 ppm and lowest value is 0.29ppm.
The highest concentration of gold in concentrate samples is 46ppm and lowest is 0.5ppm. Similarly the highest silver grade is 1.75 ppm and lowest value is 0.5ppm. The highest

concentration of gold in middling samples is 14ppm and lowest is 0.09ppm. Similarly the highest silver grade is 0.6 ppm and lowest value is 0.3ppm.The highest concentration of gold in tailing samples is 0.9ppm and lowest is 0.07ppm. Similarly the highest silver grade is 0.5 ppm and lowest value is 0.1ppm

V. CONCLUSIONS AND RECOMMENDATIONS

It has been concluded that the concentration of gold in alluvial sediments are very random so its grade will vary from sample to sample and place to place as it has been transported from more than 100kms. Gold was associated with other minerals especially magnetite, quartz, pyrite, mica, garnet, feldspar, zircon, tourmaline, epidote and pseudo-pyrite (oxidation effect). Silver presence was a potential source of valuable mineral.

From the particle sizes it was suggested that amalgamation followed by cyanidation is the best method to recover larger, fine and ultra-fine gold particles from all the media while precautionary measures should be taken while using mercury and cyanide.

Gold extraction will require installation of extraction plant. The plant consists of 1) Screening, agitating, and mining unit. 2) Shaking table/gravity separation unit, 3) tumbling unit, 4) furnace unit. Gold particles lost to tailings and middling's could be recovered by employing cyanidation/leaching test on spot by designing a set up that is environmentally friendly.

A pilot study is suggested in order to increase the knowledge of the proposed plant and resources.

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