Gold Anomaly in the Quaternary Sediments of Peshawar Basin, Shaidu Area, District Nowshera, NWFP, Pakistan

M. T. SHAH, L. ALI AND S. A. KHATTAK
National Centre of Excellence in Geology, University of Peshawar, Peshawar, Pakistan.

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Summary: Shaidu area, a part of the district Nowshera, NWFP, lies within the Peshawar Basin. It is dominantly composed of fluvial sediments (*i.e.*, gravels, cobbles, sand and silt) deposited by the Kabul river. The area has for the first time been investigated for the occurrence of placer gold by collecting representative samples of pan concentrates. These samples were subjected to mineralogical and chemical studies. These studies suggest that visible placer gold particles are present in variable size and morphology and also have high concentration (up to 170 mg/ kg) of gold in the studied sediments. This gold is of economical grade and its high recovery (> 30 g/ ton) can be obtained by erecting the mercury amalgamation plant at the site.

Introduction

Peshawar Basin (a broad, low-lying depression) is an intermountain basin lying at the southern margin of the Pakistani Himalayas. It is surrounded by mountain ranges of Khyber in the west and north-west, Attock-Cherat in the south and Swat in the north-east, while its south-eastern side is bordered by the Indus River and is open for discharge (Fig. 1). The major portion of Peshawar Basin is covered with Quaternary sediments ranging from Pleistocene to Recent age. These sediments are classified as piedmont deposits, flood plain and stream channel and lacustrine / loess sediments [1-7].

The Kabul, Swat and Indus rivers are the main braided rivers of the basin, which deposit sand, gravels and clay transported over a greater distance. However, in the piedmont deposits, occurring near the mountains, these are mixed with weathered material, transported for shorter distance.

The study area is located south-east of the Shaidu town in District Nowshera within the Peshawar Basin (Fig. 1) at a distance of about one kilometer from the main GT road toward south. The area of study is dominantly comprised of piedmont sediments of gravels, cobbles, sand and silt of fluvial origin, deposited by the Kabul river. These sediments also incorporate the local weathered material of the Attock-Cherat ranges and are, therefore considered as a part of the Attock-Cherat piedmont deposits [7].

In December 2005, one of the authors came to know that the local people of the Shaidu town are panned the sediments of the area for gold. Soon after that a preliminary fieldwork was conducted in the area and the representative pan concentrate samples were collected for further investigations in this regard. The samples were collected from a lenticular deposit of sediments, being about a kilometer long and half a kilometer wide. The sediments were composed of < 40 % of gravels, cobbles and pebbles of varied and > 60 % of sand. This paper was the result of the data obtained during this study.

Results and Discussion

The physical and chemical characterizations of gold suggest that it is a ductile, malleable and sectile noble metal found as a free metal and is telluride in nature [8]. Therefore, the placer gold, which is liberated by weathering from the bedrock is free and fairly coarse and occurs mainly in the fluvial, alluvial and glacio-fluvial sediments. During exploration of gold in these kinds of sediments, the pan concentrates and fine-fractions of the sediments are generally analyzed for gold concentration. The pan concentrates generally have visible gold, which has been classified as nugget, piece (> 0.5 mm), specks (0.3-0.5 mm) and color (< 0.3 mm) [9]. The occurrence of visible gold not only confirms the economical importance of the sediments but also the particle size, shape and composition of visible gold grains can be used to constrain the distance and direction of source rock [10]. This gold can be extracted by various techniques if found in economical concentration.

Keeping in view the above-mentioned facts, the mineralogy, the description of visible gold and

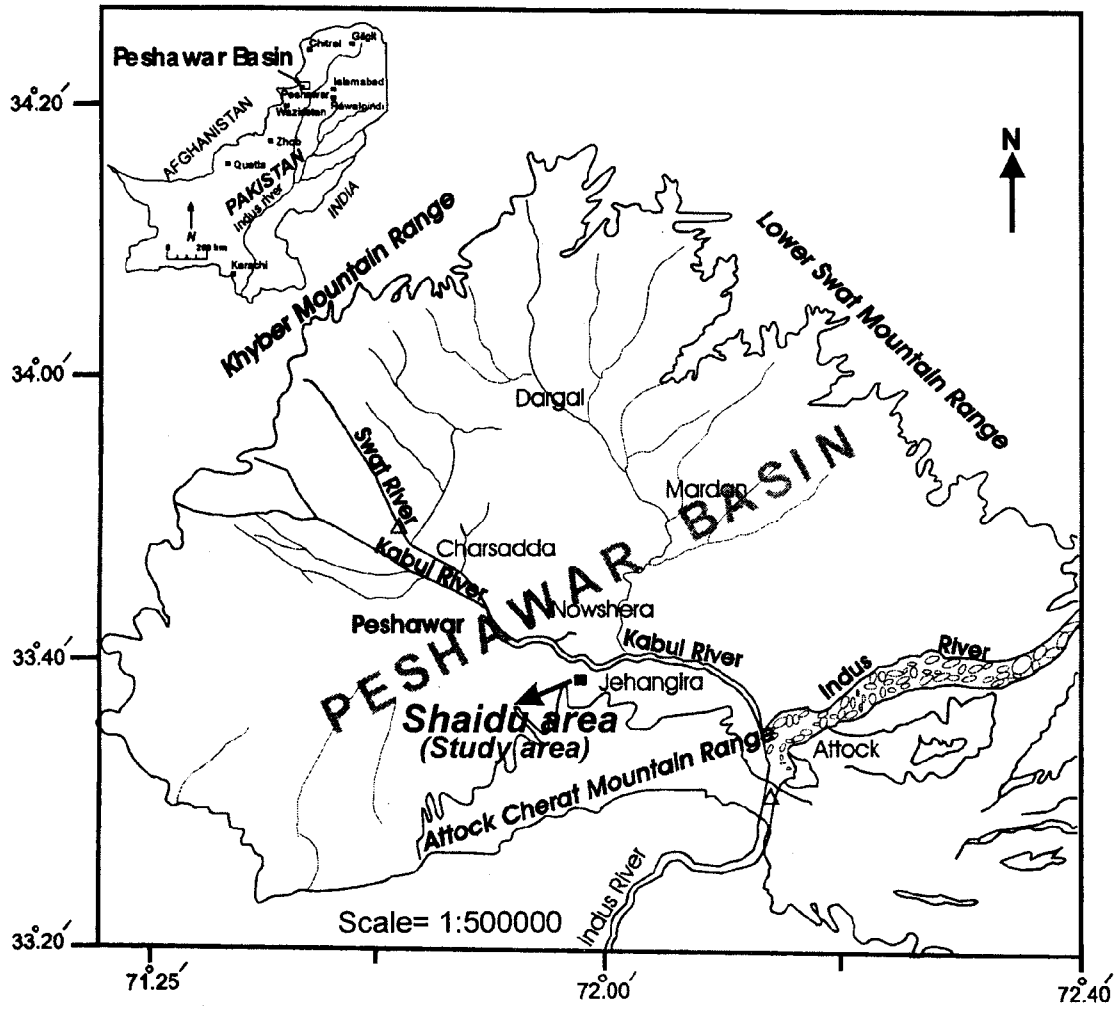

Fig. 1. Map showing the location of the study area in the Peshawar basin.

the concentration of gold in the pan concentrates have been presented in Tables 1, 2 and 3, respectively. It is clear from Table-1 that the pan concentrates, having visible gold, have variable amounts of rock fragments (27-35 %), magnetite (40-50 %, garnet (8-15 %), zircon (< 3 %), feldspar (< 3 %), quartz (< 5 %), epidote (< 2 %), tourmaline (< 5 %), mica (< 2 %) and pseudo-pyrite (< 1 %). Table-2 shows that the visible gold occurs as pieces, specks and colors. However, no nugget of gold could be found in the studied pan concentrates. The pan concentrates of three samples (i.e., SH-7, SH-12 and SH-14) possessed the pieces of gold (> 0.5 mm) with maximum number of pieces in the sample No. SH-12. The pieces are generally irregular to nearly oval in shape, solid in form and sub-angular to sub-rounded in roundness and yellow to bright yellow in color (Table-2). The specks of gold (0.3–0.5 mm) were present in the pan concentrates of studied samples with maximum numbers of specks in sample No. SH-12 (Table-2). The specks very in shape

Table-1. Modal mineral composition (in percent) of the studied Panned concentrate samples containing visible gold.

Sample. No.	SH-2	SH-4	SH-7	SH-9	SH-11	SH-12	SH-14
Rock Fragments	30	27	30	35	30	32	30
Magnetite	50	50	45	45	45	47	40
Garnet	10	12	15	12	10	8	10
Zircon	3	3	2	2	3	2	3
Feldspar	-	-	-	2	-	-	3
Quartz	2	2	5	2	5	5	5
Epidote	2	1	1	-	1	1	1
Tourmaline	2	3	-	-	3	2	5
Mica	1	1	1	1	2	2	2
Pseudo-pyrite	<1	<1	<1	<1	<1	<1	<1

Table- 2: Description of visible gold grains in the studied pan concentrate samples

	Sample No.	SH-2	SH-4	SH-7	SH-9	SH-11	SH-12	SH-14
Piece		Nil	Nil	(1)	Nil	Nil	(13)	(2)
(>0.5mm)	Shape	-----	-----	Almost square	-----	-----	Irregular to nearly oval	Irregular to nearly oval
	Form	-----	-----	Solid	-----	-----	Solid	Thick solid
	Roundness	-----	-----	Sub-angular	-----	-----	Sub-angular to sub-rounded	Sub-angular to sub-rounded
	Color	-----	-----	Yellow	-----	-----	Yellow to bright yellow	Yellow to bright yellow
Speck		(2)	(3)	(4)	(4)	(4)	(14)	(1)
(0.3-0.5mm)	Shape	Conical to butterfly	Oval to butterfly	Oval to rounded	Irregular to oval	Rectangular to oval	Irregular to oval	Oval to rounded
	Form	Solid to thick flaky	Thin to thick flaky	Thick solid	Solid to thin flaky	Solid to thick flaky	Solid to thick flaky	Thick solid
	Roundness	Sub-rounded to rounded	Sub-angular to sub-rounded	Sub-angular to rounded	Sub-angular to sub-rounded	Sub-angular to sub-rounded	Sub-angular to sub-rounded	Sub-angular to rounded
	Color	Bright yellow	Dark yellow to brassy yellow	Light yellow to dark yellow	Dark yellow to bright yellow	Dark yellow to bright yellow	Dark yellow to bright yellow	Light yellow to dark yellow
Color		Nil	Nil	(1)	Nil	(2)	(4)	(1)
(<0.3mm)	Shape	-----	-----	Almost rounded	-----	Cylindrical to oval	Oval to butterfly	Cylindrical to oval
	Form	-----	-----	Thin flaky	-----	Thin flaky	Thick flaky	Thin flaky
	Roundness	-----	-----	Rounded	-----	Sub-rounded	Rounded to sub-rounded	Sub-rounded
	Color	-----	-----	Dark yellow	-----	Bright yellow	Light yellow to yellow	Bright yellow

Number of gold grains is given in parentheses

between conical and oval to butter fly, oval to rounded and irregular to rounded; the form varies from solid to thick flaky; the roundness varies from sub-angular to sub-rounded and the color is light-yellow to bright-yellow (Table-2). The color of gold (< 0.3 mm) occurs in the pan concentrates of four samples (SH-7, SH-11, SH-12 and SH-14) with maximum numbers of colors in sample No. SH-12 (Table 2).

The characteristics of visible gold particles such as size and morphology (including flatness, surface texture and roundness) of the placer gold from the sediments of the Shaidu area can be evaluated to understand the proximal or distal nature of gold source. The size and morphology (sub-angular to rounded and solid to flaky) of visible gold particles within the pan concentrates of the studied sediments suggest that the gold in these sediments had been derived and transported from a distal source at least more than few hundreds of kilometer up stream either in the Afghanistan or Chitral region of northern Pakistan where Kabul river played an important role in the transportation and deposition of the studied sediments and the host gold particles within the Peshawar Basin.

The concentrations of gold in mg/ kg in fifteen pan concentrates have been given in Table 3. It is clear that the concentration of gold is highly variable and ranges from 1.6 mg/ kg to 169.54 mg/ kg. The concentration of gold in mg/ kg is in consistence with the amount of visible gold particles in these samples (Tables-2 and 3). Those samples having visible gold (i.e., SH-2, SH-4, SH-7, SH-11, SH-12 and SH-14) in the pan concentrates had high concentration of gold (18.5-169.54 mg/ kg) but those having no visible gold in the pan concentrates still had more than 2 mg/ kg gold, suggesting the occurrence of finer gold particles in these sediments.

Table-3:. The concentration of gold in the studied pan concentrate samples recalculated to total gold recovered in grams

Sample No.	Weight of the original sample in kg	Concentration of gold in mg /kg	Concentration of gold converted to g/ kg	Weight of gold in grams in original sample
SH-1	18.9	3.15	0.0032	0.060
SH-2	20.21	18.5	0.0185	0.374
SH-3	19.78	2.25	0.0023	0.045
SH-4	20.78	42.5	0.0425	0.883
SH-5	22.75	2.15	0.0022	0.049
SH-6	17.9	1.60	0.0016	0.029
SH-7	19.67	63.00	0.0630	1.239
SH-8	20.23	2.85	0.0029	0.058
SH-9	20.65	39.00	0.0390	0.805
SH-10	17.45	4.10	0.0041	0.072
SH-11	18.54	43.50	0.0435	0.806
SH-12	20.34	169.54	0.1695	3.448
SH-13	17.56	3.80	0.0038	0.067
SH-14	18.43	62.50	0.0625	1.152
SH-15	18.67	3.45	0.0035	0.064
Total	291.86			9.150

In order to calculate the total recovery of gold the bulk samples obtained during field, the concentration of gold in mg/ kg had been recalculated in grams and the results are given in Table 3. It is clear from this table that all the samples, having total weight of 291.86 kg, yielded 9.15 grams of gold. If it is converted to gram per ton, then 31.35 gram per ton of gold can be recovered from the sediments of the study area. This recovery is very economical as far as the placer gold by various gold extraction techniques is concerned [11-15].

The gold extraction or recovery from its ore may require a combination of mineral processing,

hydrometallurgical and pyrometallurgical processes to be performed on the ore. Gold mining from the sediments can be achieved by placer mining resulting in a concentrate while the hard rock ores are typically mined via open pit or sub-surface mining technique, which is relatively more expensive and time consuming. Therefore, the recovery of placer gold from the sediments is more economical as compared to that of the hard rock ore. The extraction of gold is mainly done by 1) gravity concentration and mercury amalgamation and 2) heap-leaching techniques [11-18]. In the mercury amalgamation technique, the gold is recovered in the mercury as pure gold after heating, evaporation and condensation of mercury. During heap-leaching, the gold is dissolved as an aurocyanide complex in oxidizing alkaline cyanide solutions and is then recovered from the pregnant cyanide leach solution either by 1) Merrill-Crowe precipitation, 2) sodium sulfide precipitation and 3) activated carbon adsorption [12, 14, 19].

Both mercury amalgamation and heap-leaching techniques can be applied to the recovery of gold from the studied sediments. However, as the major portion of gold is in free state and fairly coarse in the studied sediments, the heap-leaching in fact will not be very effective but the gold can be recovered from the studied sediments by direct amalgamation technique by erecting the gold extraction plant at the site. However, environmental effects of mercury should be fully evaluated before the erection of extraction plant.

Experimental

Field Methodology

A systematic technique was adopted to collect samples from the studied fluvial sediments through a random pattern. The sample at each spot was taken in a 20 kg bucket so that the oversized particles were screened out through a sieve of # 7 mesh size and the sieved material was put in a bucket until it was filled. This material, after weighing, was panned to about 100 grams by panning techniques and was stored in the polythene bag. In this way, fifteen representative pan concentrates were collected from the whole deposit during filling. These samples were then transferred to the laboratory for mineralogical and chemical studies.

Laboratory Methodology

Pan concentrate samples were mineralogically studied under the stereomicroscope. Gold grain-size was identified and classified into piece (> 0.5 mm), speck (0.3–0.5 mm) and color (< 0.3 mm) (Table-2). Morphological studies (*i.e.,* grain-size, shape and color) of gold grains were carried out in each sample (Table-2). Besides gold, other minerals and rock fragments were also identified (Table-1).

For the chemical analysis, the method of Hubfrt and Chao [20] was adopted for the digestion and extraction of gold. Each pan concentrate sample stored for chemical analysis was weighed in total and put in different beakers. 50 ml of equa regia (HCl and HNO_3 in the ratio of 3:1 respectively) was added and heated for 30 minutes. 30 ml of distilled water was added and heated until approximately 50 ml solution was left in the beakers. The contents of the beakers were then filtered and washed by 6N HCl into the test tubes to make the final volume of 50 ml. The filtrate was then transferred to 250ml separatory funnels and same amount of distilled water was added to it. 20 ml of Methyl Isobutyl Ketone (MIBK) was added to the separatory funnels. The funnels were shaken for 10 minutes. The lower layer was discarded through the separatory funnels. Then, 20 ml of 0.2N HCl was added to the MIBK in the separatory funnels and was shaken again for 5 minutes. The lower layer was again discarded and the MIBK containing extracted gold was stored in a glass bottle for the analysis by electro-thermal Perkin Elmer AAnalyst 700, for gold under the standardized conditions [21] in the Geochemistry Laboratory of the NCE in Geology, University of Peshawar.

Conclusions

The particle size and morphological characteristics of the visible gold in the pan concentrates of the fluvial sediments of the Shaidu area suggest that the gold had been derived and transported from a distal source. The gold concentration in these sediments seemed to be economical. However, further detailed investigation should be carried out in order to have the better extraction of gold through mercury amalgamation technique.

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References

1. J. R. L. Allen, *Geol. Bull. Univ. Peshawar*, **2** (1964).
2. D. W. Burbank, R. A. K. Tahirkheli, *Geol. Soc. Am. Bull.*, **96**:539 (1985).
3. K. P. Pogue, A. Hussain, *Information Release*, **135**,15 (1986).
4. K. Cornwell, S. Hamidullah, *Geol. Bull. Univ. Peshawar*, **24**, 113 (1992).
5. Nizam-Din, M. Yoshida, *The Quaternary Research*, **36**, 43 (1997).
6. A. Husain, R. S. Yeats, K. R. Pogue, Geol. Bull. Univ. Peshawar, 22, 45 (1989)
7. S. Tariq, Unpublished Ph.D. thesis. University of Peshawar (2001).
8. R. W. Boyle, *Geol. Surv. Canada*, (1974).
9. A. S. Joyce, Geochemical exploration, Australian Mineral Foundation, (1984).
10. J.S. Leon, *Explor. Mining. Geol.*, **4**(4), 335 (1995).
11. N. L. Weiss, SME Mineral Processing Handbook. New York. Soc. Mining Engin., (1985).
12. J. Yannopoulus, The Extractive Metallurgy of Gold. New York, Van Nostrand Reinhold (1991).
13. W. T. Ruhmer, Handbook of the Estimation of Metallurgical Process Costs. Randburg, Mintek (1992).
14. J. Marsden, I. House, The Chemistry of Gold Extraction. New York. Ellis Horwood (1992).
15. H. Mason, *Circular*, **52** (1995).
16. R. Beard, *Circular*, **27** (1987).
17. F. F. Linns, M. M. Monte, C. R. Hamelmann, *CETEM. EPD Congress*, 193 (1994).
18. L. B. Moses, F. W. Petersen, *Miner. Engin.*, **13**(3) 255 (2000).
19. C. K. Gupta, T. K. Mukkerjee, Hydrometallurgy in extraction processes. CRC Press. Inc. Florida, USA (1990).
20. A. E. Hubfrt, T. T. Chao, *Talanta*, **32**(7) 568 (1985).
21. Perkin Elmer, Analytical methods for the atomic absorption spectrometry, Perkin Elmer Instruments Inc (2000).