Geol. Bull. Univ. Peshawar, Vol. 37, pp. 27-40, 2004

Exploration and extraction of placer gold in the terraces of Bagrot valley, Gilgit, northern Pakistan

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ABSTRACT: *The upper reaches of Chitral, Gilgit and the Indus river, in northern parts of Pakistan, are well known for the placer gold occurrences. The extraction of gold by gold-washers, using primitive tools, has been practiced since long period in the region. Due to the recent advancement in technology, there has been a rapid growth in gold production from placer deposits world over. However, mining of placer gold in Pakistan has not been given due consideration so far. The study of the placer deposit of Bagrot valley has, therefore, been carried out to determine the mineralogy of these placer deposits, which could help in investigating the source rock for gold and also to design methods for the extraction of placer gold in more economic manner.*

The placer deposits of the Bagrot valley are mainly composed of glacio-fluvial and fluvial sediments in the form of terraces of various sizes. Representative samples of the sediments from each terrace in Chirah, Farfooh and Bulchi villages of the Bagrot valley were collected during fieldwork.

The glacio-fluvial and fluvial terraces of the study area have similar mineralogy with only difference in the size and shape of the gold particles in concentrates. The gold particles of the fluvial terraces have smaller size and more roundness in shape as compared to those of glacio-fluvial terraces. The sediment load in both types of terraces is mainly composed of rock fragments, magnetite, quartz, biotite, muscovite, chlorite and epidote. Garnet, tourmaline, amphibole, pyroxene, olivine, pyrite and chalcopyrite are present in lesser amounts while zircon and sphene occur in traces. Chemically, maximum gold and silver have been noticed in the concentrates while rest of the media (middling and Tail) have negligible gold and silver. Both mineralogical and chemical studies suggest that gold in the source rock is present as coarse-grained native form and, therefore, the gravity separation method is the most appropriate method for the extraction of placer gold in the area.

The size and morphology of gold in the concentrates of both glacio-fluvial and fluvial terraces of the study area have been evaluated to understand the proximal or distal nature of the gold source. The general characteristics of studied gold particles suggest that gold in glacio-fluvial and fluvial terraces has been derived and transported from a distal source at least more than a few tens of kilometers, up-stream.

INTRODUCTION

Bagrot Valley, partly covering toposheet Nos. 42L/5 and 42L/9, is located at a distance of about 30 km NE of Gilgit City (Fig. 1) and is surrounded by three Peaks i.e., Rakaposhi

(7788 m), Belchair Dubani (6134 m) and Diran (7273 m). Among these, Dubani and Diran Peak is situated between Bagrot and Haramosh Valley. The Bagrot Valley consists of seven small villages with a population of about 14000 inhabitants. However, the study area comprises of only three villages, which are Chirah, Bulchi and Farfooh (Fig. 2). The area is easily accessible through every kind of transportation from Gilgit, by a matelled road up to Oshikhan Das. From Oshikhan Das a 16km un-metaled road leads to Chirah Village, which is the last settlement in the Bagrot Valley. Chirah village is very close to the snout of the Hinarchane Glacier, which feeds regular material to the Bagrot river. Jeep services throughout the year are operating from Gilgit to all the villages of the Bagrot Valley. Bagrot Valley is surrounded by High Mountains and has only one exit for water discharge into the Gilgit river. The annual rainfall is few inches because the Mount Belchair Dubani works as a barrier for the monsoon to the northeast of Bagrot Valley. However, monsoon dropped appreciable precipitation around the Haramosh and Bagrot Valleys, which are close to the Naga Parbat area. As a result these two valleys have more vegetation in the entire Karakuram Region.

The occurrence of placer gold in the upper reaches of the Chitral and Gilgit and along the Indus River in Northern Areas of Pakistan have been reported by Austromineral in 1976 and 1978. The occurrence of placer gold has been proved through drilling and panning along the Indus and Gilgit river in northern areas of Pakistan (Austromineral, 1978). These placer deposits, generally recent in age, occur as thin pockets of heavy mineral concentrate.

Gold washing has been a practice since a long period along the Indus and Gilgit rivers in northern areas of Pakistan. Presently, there are more then 200 families who are directly involved in this job. However; only few families have adopted this profession as a part time activity. These gold washers use primitive tools for extraction of gold from the Indus sands. Therefore, in spite of working hard throughout the year, their income is few thousand rupees annually. They use panning and mercury for the extraction of course gold while fine, ultra-fine and invisible gold is thrown into the river along with other residual material containing high amount of mercury and other heavy metals. It is causing pollution in our main rivers, which is certainly destroying the environment.

Detail geological work has been carried out in the Northern part of Pakistan including the sampling area (Bard et al., 1980; Butler & Prior, 1988; 1989; Chamberlain et al., 1991; Coward et al., 1982; 1986; 1987; Hanson, 1989; Kazmi & Jan, 1997; Khan, 1988; Khan et al., 1989; 1994; 1983; Searl, 1991; Sear et al., 1996; Shah & Shervais, 1999; Tahirkheli, 1982; Tahirkheli & Jan, 1979; 1996; Zeitler et al., 1989; 1993; Zeitler & Chamberlain, 1991). However, no work has been done so far on the terrace of the Bagrot valley in regard to the mineralogy of heavy mineral concentrates and placer gold and silver extraction. However, the following work has been done in regard to mineral exploration in the northern region of Pakistan. Tahirkheli (1974) worked on alluvial gold prospects in the Chitral and Gilgit areas and along the Indus river in the northern parts of Pakistan. Investigation of placer mineral deposits along the Indus, Gilgit,Hunza and Chitral rivers have been conducted by workers from the geological survey of Pakistan (Ahmad et al., 1976). The Austromineral (1975 & 1978) also did some work on the placer gold in the northern parts of Pakistan including the area around Bagrot valley.

Gold exploration, and mineral analysis project has been conducted on the geochemical survey of stream sediments in the Chitral, Gilgit and Skardu regions of the northern Pakistan under the auspicious of Australian Agency for International Development (AIDAB) in collaboration with Sarhad Development Authority (SDA) and Pakistan Mineral Development Corporation (PMDC) of Pakistan (Sweatman et al., 1995). Halfpenny and Mazzucchelli (1999) have carried out reconnaissance survey by conducting the regional multi-element drainage geochemistry in the Himalayan Mountain, northern Pakistan.

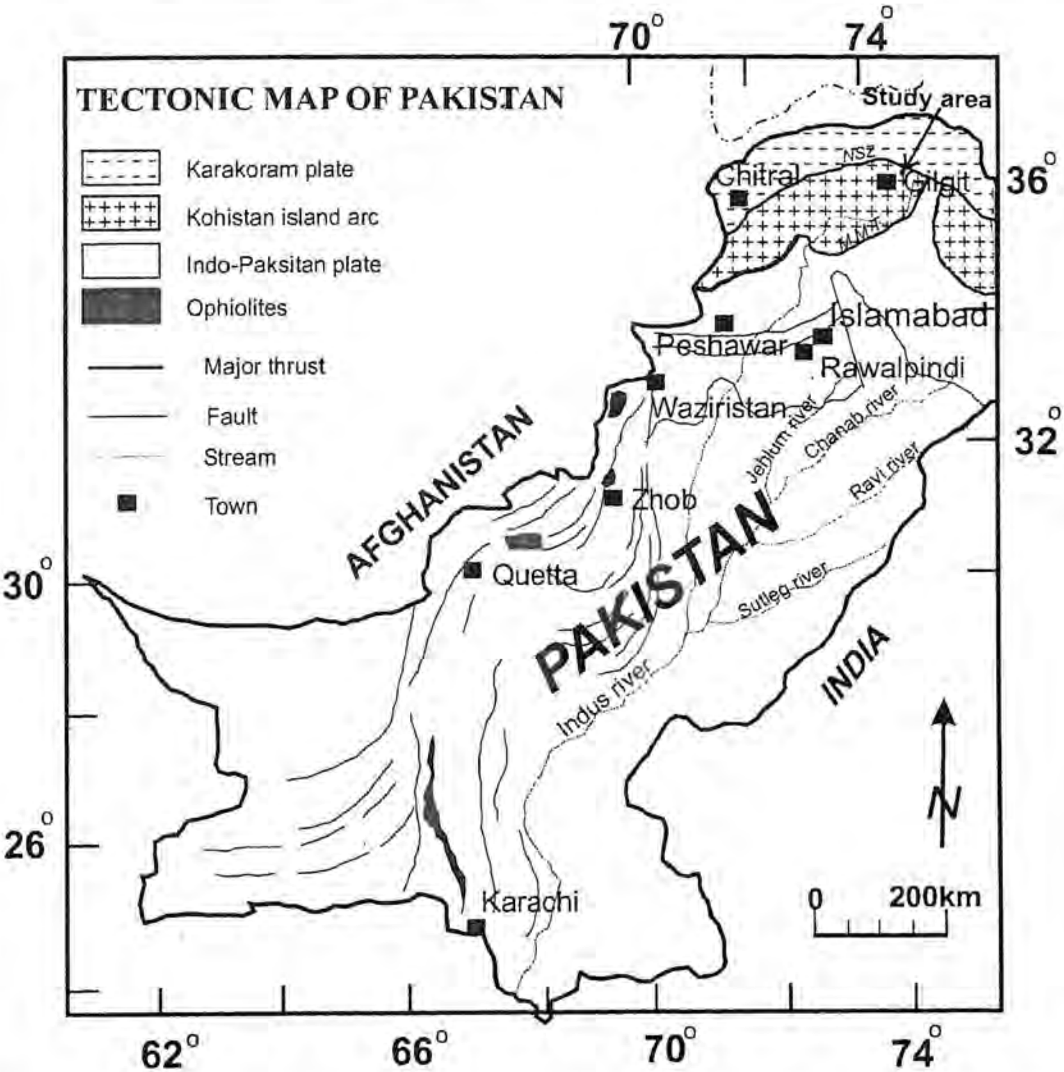

Fig. 1. Tectonic map of Pakistan showing the location of the study area (modified after Asrarullah et al., 1979).

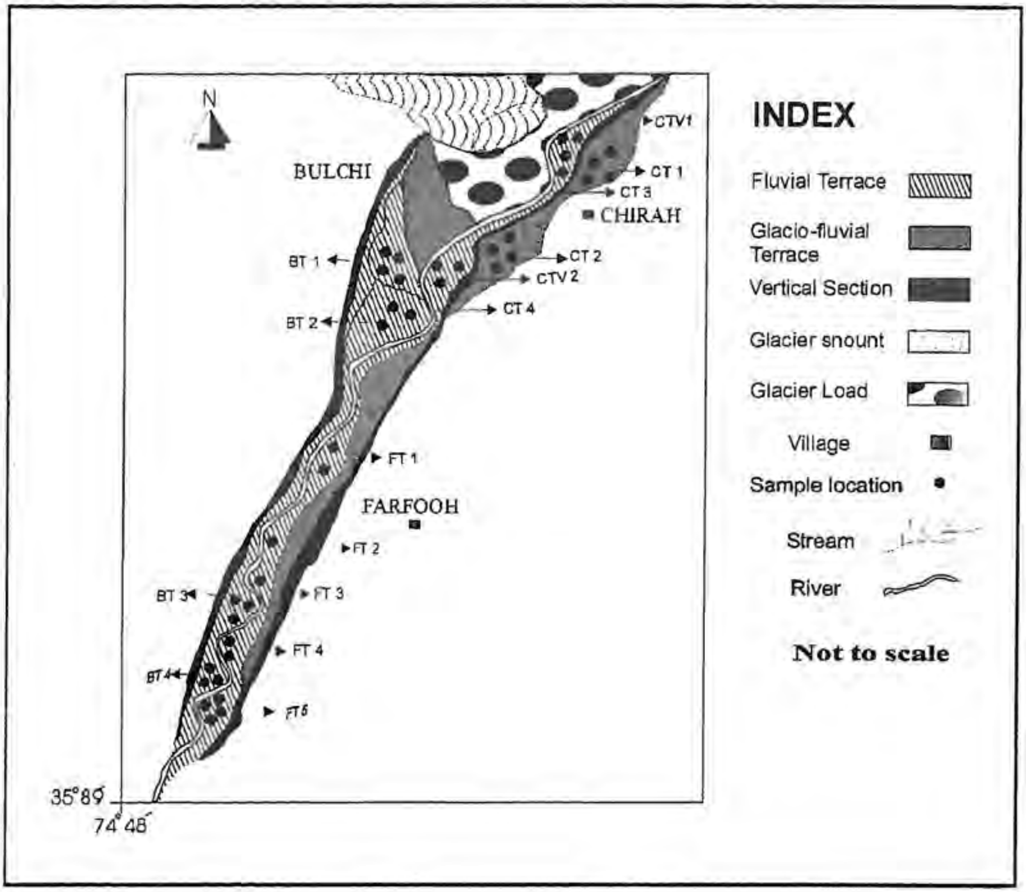

Fig. 2. Sample location map of the study area.

This study is mainly based on the exploration and extraction of gold, which include determination of characteristics of placer gold particles such as size and morphology, bulk mineralogy and chemistry of panned concentrates and the techniques involving mechanism of extraction of placer gold, in the Bagrot valley. The idea is to find out ways and means, which can reduce the wastage of gold and the recovery of maximum placer gold from the fluvial and glacio-fuvial deposits covering the vast area of northern Pakistan.

GEOLOGY OF THE AREA

The geology of Bagrot valley is mainly composed of the rocks of the Chalt Group (Searle et al., 1996). In the study area, the chalt metvolcanics of this group are mainly covering the study area along the eastern and western part of the Bagrot river. However, a small exposure of ultramafic rocks is also exposed in the south-eastern portion of the study area (Fig. 2). The terraces of glacio-fluvial and fluvial sediments generally cover the chalt volcanic in the area.

Chalt group

The Chalt group consists of a very heterogeneous sequence and is commonly exposed in the surroundings of upper Gilgit and lower Hunza area. It consists of alternating meta-sediments and volcanics. The association of meta–sediments with tuffs and basaltic to andesitic lavas is well observed in the Bagrot valley. The large number of diorites and granites, which belong to younger igneous phase, are intruded into the Chalt group. In the upper reaches of the Bulchi and Chirah villages the Chalt group consists of thin bedded slates and yellowish pyrite-bearing schists, chlorite-epidote-hornblende schist with intercalation of thin beds of grey to yellowish carbonates and marbles. Towards north there is a succession of phyllites, quartzite-phyllites, and sericite-schist, which show a continuous transition from basaltic lavas tuff to the chlorite and sericites schists.

In Bagrot valley north of Datuche village and near the Gutumi glacier a formation of metamorphic rocks strikes approximately E-W and dips towards the south. It consists of phyllites, sericite-chlorite schists with quartz stringers and lenses carrying sulfides. These rocks also attained higher metamorphic grade, such as garnet–staurolite schists and gneisses in certain places of Bagrot valley.

Ultramafic rocks

Ultramafic rocks are mainly exposed south of Datuche village in Bagrot valley. Dunite and pyroxinites are the main rocks with minor amount of peridotites. These rocks are intruded by coarse-grained norite/hornblendite dikes. The ultramafic rocks of the Bagrot valley are the part of Dobani-Dassu ultramafic lineament strip of Pecher and LeFort (1995).

METHODOLOGY

Field methodology

Two types of terraces, glacio-fluvial and fluvial, were identified in the Bagrot valley. A rough sketch of the terraces in Chirah, Bulchi and Farfooh villages of the Bagrot valley is drawn where the location of each sample is marked (Fig. 3). The terraces of Chirah village are the old terraces containing glacio-fluvial sediments while the terraces of Bulchi and Farfooh villages are young terraces containing fluvial sediments.

Detail Floats (boulders, gravel, pebbles etc.) study was conducted to understand the general geology of the Bagrot valley. Before taking sediment samples each terrace was thoroughly visited to locate potential sites for gold and silver concentrates. Length and width of each terrace were measured to know its size in term of reserve. Thickness of vertical sections in old terraces were also measured.

A systematic technique was adopted to collect sample through a random pattern from all terraces. The Sample at each spot was taken at a depth of six feet below the surface in such a way that each sample may represent the bulk concentration of sampled terraces. The over size 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, having a weight of about 20 kg, was then partially panned through panning techniques and was stored in the polythene bags. These sample bags were marked with systematic numbers such as CT, BT and FT for terraces of Chirah, Bulchi and Farfooh villages respectively. The vertical sections at Chirah village were marked as CTV.

A total of about 394 kg of sediment samples from five terraces and two vertical sections of Chirah village, 228 kg samples from four terraces of Bulchi village and 271 kg samples from five terraces of Farfooh village were collected during field and were transferred to the Mineral Testing Laboratory (MTL) Peshawar.

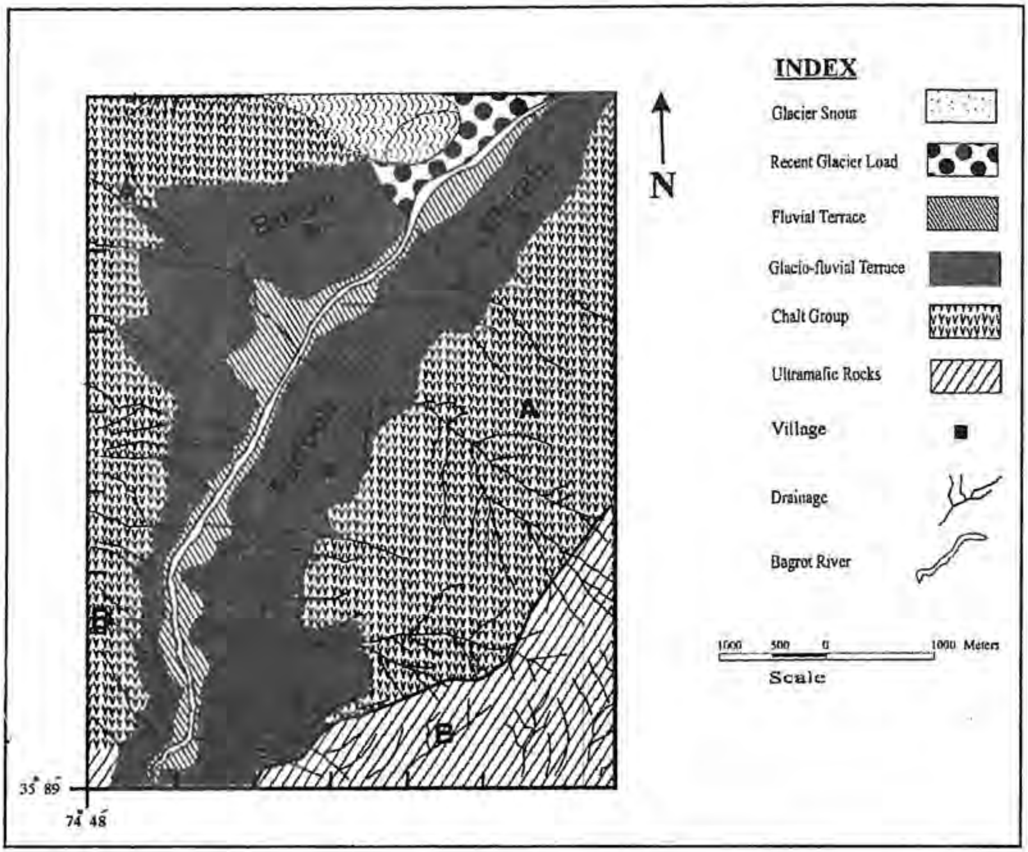

Fig. 3. Geological map of the part of the Bagrot valley, Gilgit, northern Pakistan.

Laboratory methodology

Sixteen samples of stream sediments, having total weight of about 893 kg, collected from the terraces on both sides of the Bagrot river during field work were processed through gravity seperation and mercury amalgamation techniques. Mineralogical and chemical studies were also conducted on these samples. The detail of these studies is given below:

A. Metallurgical section

Gravity separation: Each sample, collected during field, was sieved through #10 mesh size sieve. After sieving, all the samples were split through splitting machine and representative samples from the terraces of Chirah, Bulchi and Farfooh villages were selected for further studies.

The representative samples of each terrace and vertical section were separately processed through the shaking table and three products namely Concentrate, Middling and Tail were separated by gravity separation method. These three media were then dried in oven and were further sampled for mineralogical and chemical analyses and record keeping through the method of quartering and coning. After taking the representative samples for mineralogical and chemical analyses and record keeping from the Middling and Tail media, the rest of the portions of Middling and Tail were discarded.

The Concentrates of all the terraces from Chirah village were mixed together to get a bulk Concentrate and was named as Chirah Concentrate. Similarly this process was adopted for the terraces of Bulchi and Farfooh villages. In this way, the bulk sample Concentrates obtained from the terraces of Bulchi and Farfooh villages were named as Bulchi and Farfooh Concentrates.

Finally the concentrate named as Chirah, Bulchi and Farfooh were mixed and sieved through a sieve #8 mesh size and was named as Bagrot concentrate (BRC).

Mercury amalgamation: The Bagrot concentrate (BRC) was put in a glass jar for tumbling in tumbling machine. It was kept in tumbling machine for 30 minutes and then transferred into a bottle. Mercury was added to it and placed in a bottle rolling machine. The rolling process was continued up to one hour. During this time the mercury catches maximum gold. The mercury was then separated from the sample by manual panning. Residue left after separation of mercury was named as Bagrot Residue (BRR). Samples from the Bagrot Residue were taken for mineralogical test, chemical Analysis and record keeping. Gold-loaded mercury was put in a small crucible and placed in the retort furnace at temperature of 550°C for 30 minutes and 650°C for 15 minutes. Mercury was heated in the furnace, which was evaporated and condensed in a flask that was linked through a pipe to a motor engine. Mercury recovered in this way was re-used. The gold left in the crucible was saved and was named as BRRG (Bagrot residue gold).

B. Chemical section

Samples, collected during the gravity separation technique, were powdered in the grinding machine up to -200 mesh size for chemical analysis. 30g of powder sample from each sample stored for chemical Analysis was weighed and put in different beakers. 50 ml of equa-regia (ratio of 3:1, HCl and HNO_3 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 250 ml reparatory funnels and same amount of distilled water was added to it. 20 ml of Methyle Isobutyle Ketone (MIBK) was added to the separatory funnels. The funnels were shaked by the shaking machine 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 reparatory funnels and shaked again for five minutes. The lower layer was again discarded and the MIBK containing extracted gold was stored in a glass bottle for the analyses by Atomic Absorption Spectrophotometer for gold (Au).

For silver (Ag) analyses, 30 g of sample was treated with 50 ml of equa-regia by heating for about two hours on low heat and the solution was made to 50 ml of volume with distilled water. This solution was directly run through Atomic Absorption for the determination of silver.

The analyses on atomic absorption were performed in the Mineral Testing Laboratory, Peshawar and the Geochemistry laboratory of the National Centre of Excellence in Geology, University of Peshawar.

C. Mineralogical section

Each sample obtained through different metallurgical processes for the mineralogical tests was carefully examined under the binocular microscope. Gold size was identified and classified into piece (>0.5 mm), speck (0.3-0.5

mm) and color (<0.3 mm). Gold was also checked for its form, shape, roundness and color. Besides gold and silver other minerals, rock fragments and gems were also identified on the basis of their amount/percentage present in the sample such as Dominant (>50%), major (10-50%), minor (1-10%) and trace (<1%).

RESULTS AND DISCUSSION

Mineralogical and chemical constraints

Mineralogically, no distinction could be possible among the glacio-fluvial and fluvial sediments of the Bagrot valley and are, therefore, discussed together. The sediments load of Bagrot valley generally contains rock fragments, magnetite, quartz, biotite, muscovite, chlorite and epidote as major constituent with lesser amount of garnet, tourmaline, amphibole, pyroxene, olivine, pyrite and chalcopyrite. Zircon and sphene occur in trace amount. Gold in the form of colors (<0.3 mm) is present in almost all the samples while specks (0.3-0.5 mm) of gold have been identified in the sediments of few terraces. No pieces or nugget of gold has been found in the sediments of Bagrot valley. The heavy minerals and the gold particles are variably distributed among the three media (Concentrate, Middling and Tail) obtained after the gravity separation methods. Magnetite, rock fragments, pyroxene, olivine, tourmaline, garnet, amphibolite, pyrite and chalcopyrite are generally trapped in the Concentrate while rest of the phases are washed into the Middling and Tail. Almost- all the colors and specks of gold are extracted in the Concentrates and none of gold particles is noticed either in Middling or Tail. It is, however, noticed that the fluvial sediments have less number of gold particles in the Concentrates as compare to those of galcio-fluvial sediments. The floats of rocks of the Chalt group (mainly the volcanic and chlorite-carbonate schist) are dominant while diorite, granodiorite, phyllite pyroxenite and quartzite are present in lesser amount. This confirms the occurrence of the rocks of Chalt group in the major portion of the catchement areas of the Bagrot valley.

Chemically the gold and silver contents in ppm have been determined in all the four media (Head sample, Concentrate, Middling and Tail) of the glacio-fluvial and fluvial sediments of the Bagrot valley and are represented in Table 1 and 2. The gold concentration ranging from 0.70 ppm to 2.98ppm has been noticed in the Concentrates while rest of the media (i.e., Middling and Tail) have negligible amount of gold (Table 1). Silver concentration is generally below the detection limit (<0.05 ppm) while three Concentrates from Chirah terraces have silver >1.1 ppm. The bulk of the Bagrot Concentrates (BRC), which is the mixture of the concentrates of all the Terraces of Chirah, Bulchi and Farfooh villages, was treated with mercury amalgamation process (see methodology). The final extract of gold recovered from the mercury after mercury amalgamation process weighed 1.01g. In order to calculate the total recovery of gold in the bulk sample obtained during filed, the concentration of gold in ppm has been recalculated in grams in all the four media and was added to the gold obtained from the bulk of the Bagrot Concentrate after mercury amalgamation process (Table 3). It is clear from the Table 3 that 2.708 g of gold at the rate of 3.02 g per ton has been extracted from 893 kg total load of sediments.

As majority of gold is recovered in the Concentrates and a negligible amount is transferred to the light-fractions such as Middling and Tail, it is suggested that gold in the source bed rock is present in the coarse-grained native form, may be associated with sulfides in the quartz veins, and is not present as fine-grained gold (i.e., carline type). Due to the course (>0.1 mm) nature of gold in both glacio-fluvial and fluvial sediments, the method of preparation of heavy mineral concentrate by shaking table or gravity table is more appropriate. This is the reason that the Middling and Tail have negligible gold.

TABLE 1. CONCENTRATION OF GOLD (IN PPM) IN THE SEDIMENT SAMPLES OF VARIOUS TERRACES FROM THE BAGROT VALLEY

Sample. No.	Wt of sample in kg	Head	Concentrates	Middling	Tail
CT1-P1	61.10	0.16	0.92	0.09	0.05
CT2-P1	64.20	0.56	1.12	0.08	0.06
CT3-P1	63.12	0.34	0.70	0.12	0.09
CT4-P2	48.12	0.31	2.19	0.11	0.08
CT5-P1	45.20	0.28	1.14	0.15	0.10
CTV1-P1	51.30	0.27	0.89	0.09	0.05
CTV2-P1	61.12	0.12	1.08	0.09	0.03
BT1-P1	62.10	0.25	1.06	0.08	0.06
BT2-P1	58.20	0.35	1.36	0.08	0.06
BT3-P1	49.73	0.14	1.58	0.17	0.11
BT4-P1	58.12	0.16	1.08	0.08	0.05
FT1-P1	51.20	0.28	1.87	0.12	0.09
FT2-P1	60.13	0.23	2.32	0.10	0.07
FT3-P1	53.20	0.29	2.98	0.13	0.09
FT4-P1	57.12	0.13	2.08	0.09	0.06
FT5-P1	49.80	0.14	1.42	0.07	0.05

CT = Chirah Terraces; CTV= Chirah Terrace Vertical section; BT = Bulchi Terrace; FT = Farfooh Terrace

TABLE 2. CONCENTRATION OF SILVER (IN PPM) IN THE SEDIMENT SAMPLES OF VARIOUS TERRACES FROM THE BAGROT VALLEY

Sample. No.	Wt of sample in kg	Head	Concentrates	Middling	Tail
CT1-P1	61.10	<0.5	<0.5	<0.5	<0.5
CT2-P1	64.20	0.7	1.1	<0.5	<0.5
CT3-P1	63.12	<0.5	<0.5	<0.5	<0.5
CT4-P2	48.12	<0.5	1.50	<0.5	<0.5
CT5-P1	45.20	0.80	0.20	<0.5	<0.5
CTV1-P1	51.30	<0.5	<0.5	<0.5	<0.5
CTV2-P1	61.12	<0.5	1.50	<0.5	<0.5
BT1-P1	62.10	<0.5	<0.5	<0.5	<0.5
BT2-P1	58.20	<0.5	<0.5	<0.5	<0.5
BT3-P1	49.73	<0.5	<0.5	<0.5	<0.5
BT4-P1	58.12	<0.5	<0.5	<0.5	<0.5
FT1-P1	51.20	<0.5	<0.5	<0.5	<0.5
FT2-P1	60.13	<0.5	<0.5	<0.5	<0.5
FT3-P1	53.20	<0.5	<0.5	<0.5	<0.5
FT4-P1	57.12	<0.5	<0.5	<0.5	<0.5
FT5-P1	49.80	<0.5	<0.5	<0.5	<0.5

CT = Chirah Terraces; CTV= Chirah Terrace Vertical section; BT = Bulchi Terrace; FT = Farfooh Terrace

TABLE 3. THE CONCENTRATION OF GOLD, RECALCULATED IN GRAMS, IN VARIOUS SAMPLING MEDIA OF ALL THE TERRACES OF BAGROT VALLEY. THE TOTAL GOLD RECOVERED FROM THE SEDIMENTS LOAD OF ALL THE TERRACES IS ALSO GIVEN

Sample. No.	Wt. in kg	Head sample wt. in grams	Concentrate wt. in grams	Middling wt. in grams	Tail wt. in grams	Gold recovered wt. in grams
CT1-P1	61.10	0.010	0.056	0.005	0.003	0.075
CT2-P1	64.20	0.036	0.072	0.005	0.004	0.117
CT3-P1	63.12	0.021	0.044	0.008	0.006	0.079
CT3-P2	48.12	0.015	0.105	0.005	0.004	0.129
CT4-P1	45.20	0.013	0.052	0.007	0.005	0.075
CTV1-P1	51.30	0.014	0.046	0.005	0.003	0.067
CTV2-P1	61.12	0.007	0.066	0.006	0.002	0.081
BT1-P1	62.10	0.016	0.066	0.005	0.004	0.090
BT2-P1	58.20	0.020	0.079	0.005	0.003	0.108
BT3-P1	49.73	0.007	0.079	0.008	0.005	0.099
BT4-P1	58.12	0.009	0.063	0.005	0.003	0.080
FT1-P1	51.20	0.014	0.096	0.006	0.005	0.121
FT2-P1	60.13	0.014	0.140	0.006	0.004	0.164
FT3-P1	53.20	0.015	0.159	0.007	0.005	0.186
FT4-P1	57.12	0.007	0.119	0.005	0.003	0.135
FT5-P1	49.80	0.007	0.071	0.003	0.002	0.084
Total	893.76	0.226	1.311	0.091	0.060	1.688

Total sediment load = 893.76 kg

Gold recovered in four sampling media = 1.688 g

Gold recovered in the Bagrot Concentrate (BRC) = 1.01 g

Total gold recoverd = 1.688 + 1.01 = 2.70 g

In the Bagrot Valley, the gold washers usually carry out routine gold sluicing to extract gold for their livelihood by their own hand made sluice box. The residue left after sluicing, which is usually discarded, was collected and studied both mineralogical and chemically. The residue dominantly contains quartz, rock fragments, biotite, muscovite, epidote, pyroxene, hornblende, garnet and fine-grained magnetite. Traces of zircon, tourmaline, appetite and sphene are noticed. Three colors (0.15 to 0.3 mm) of gold are found, having dark-yellow color with rounded to sub-rounded in shape and flaky in form. The chemical analyses for gold and silver in this residue sample suggest that it contains 0.86 ppm of gold and 0.95 ppm of silver. This suggests that the sluicing method adopted by the gold washers of Bagrot valley does not recover the maximum gold in the Concentrates. The shaking table technique is, therefore, more appropriate for the extraction of coarse-gold of the Bagrot valley. The objective of this method is to concentrate gold from a large sample into smaller sample that can be conveniently analyzed and thereby, overcome the sample representivity problem.

Both glacio-fluvial and fluvial sediments are the useful geochemical sampling media in the Bagrot valley for gold exploration. The heavy mineral concentrates can be used for gold prospecting with greater confidence in the area. The size and shape of the gold in the heavy mineral concentrates could very effectively be used as a guide for tracing out the source bed rock in the up-stream catchments basin.

Gold characteristics to local bed rock mineralization

Information on gold particle size, shape, composition and progressive changes in the characteristics with increasing transport distance can, in many cases, be used to constrain the distance and direction to source rocks (Loen, 1995). Of course the presence of placer does not necessarily imply that mine-able hard rock deposits exist upstream because the source gold deposits could have been widespread, or could have been completely eroded away. However, placer gold can provide considerable information on source areas and placer studies should be added to the techniques used by exploration geologists to evaluate gold targets (Loen, 1995).

The characteristics of placer gold such as size and morphology (including flatness, surface texture and roundness) of the placer gold of Bagrot valley have been evaluated to understand the proximal or distal nature of gold source.

It is understood that there is a decrease in the size of placer gold particles with distance from source (Lindgren, 1933; Boyle, 1979). This reflects breakdown of particles and increasing transport of smaller particles. However, the relationship between size and distance is complicated because both the shape and size of the gold particles changes downstream. Flakes, which become more abundant downstream, are transported more easily than sphere (Kolesov, 1971). In addition, the maximum length of placer gold particles can increase downstream because of flattening, and then rapidly decrease because of folding (Loen, 1995).

Detailed measurements of the particle shape of placer gold are one of the most useful parameters for determining the transport distance to source rocks. Gold crystallize in the isometric crystal system, and in primary gold deposits tends to form aggregates of octahedrons, dodecahedrons, cubes, globules, and rarely leaf and wire forms. However, these crystal shapes rapidly become modified because of the softness and ductility of gold. Therefore, the majority of placer gold particles in a sample are commonly represented by thin flakes within a few tens of kilometers (Loen, 1995).

Changes in the shape and size of the gold from the two types of terraces, fluvial and glacio-fluvial, in Bagrot valley have been studied very carefully based on various systems of classifications (Boyle, 1979; Herail, 1984; Freyssinet et al., 1989; Dilabio, 1990; Minter et al., 1993). The gold particles show clear differences in the shape, form and size in both types of terraces. The fluvial terraces have generally gold in the form of colors with size ranging from 0.1 to 0.2 mm sub-angular to rounded in shape and flaky to solid in form. Few specks of 0.4 to 0.5 mm size with angular to sub-rounded shape and solid form are also observed. Gold in the glacio-fluvial terraces generally occurs in the form of color with relatively coarser in size (0.2-0.3 mm), angular to sub-angular in shape and solid to flaky in form. The size and morphology of the gold particals in the Bagrot valley suggest that the gold in the glacio-fluvial and fluvial terraces has been derived and transported from a distal source at least more than a few tens of kilometer, up-stream. The source of gold in both types of terraces seems to be the same, however, the difference in size and morphology of the gold particals in the glacio-fluvial and fluvial sediments is due to the high-energy abrasion of the gold particles during the transport of the later sediments. This is evident in the rounded to sub-rounded and flaky appearance of gold particles in the fluvial terraces. The gold particles in the glacio-fluvial sediments have undergone less abrasion during transportation of glacio-fluvial sediments. These particles are, therefore, angular in shape and solid in form. There are no chances of gold bearing bed-rock underneath these terraces as no pieces and suggests of gold have been observed.

To know the exact distance of bed-rock for the studied gold the calculation of Cailleux flatness index (F.1.) of Herail et al. (1990) and the determination of surface texture by scanning Electron Microscope (SEM) technique for the studied gold particles is, however, very necessary. Beside this the procurement of geochemical, geomorphic, sedimentological and fluvial paleocurrent data is necessary in order to construct the history of studied placer gold transport and concentration in the Bagrot valley. Though these kinds of studies are not a part of this research but could be conducted in future to pin point the source of gold in the region. These kinds of studies have revealed promising exploration targets elsewhere in the world (see Dilabio, 1990; Guisti, 1986; Herail et al., 1990; Loen, 1993; 1995).

Acknowledgement: We are very thankful to the Director National centre of Excellence in Geology, University of Peshawar for financial support during field and laboratory work. Some of the metallurgical facilities were performed at the Mineral Testing Laboratory, Hayatabad, Peshawar which is highly acknowledged.

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