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Comparative study of heavy mineral concentrates and fine fractions of Quaternary sediments for gold and base metal exploration in Nowshera District, Khyber Pakhtunkhwa Pakistan

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Abstract

Quaternary deposits both fluvial and lacustrine sediments are present abundantly in different parts of the Nowshera District. The geochemical study has been carried out on the samples of heavy mineral concentrates and a fine fraction of fluvial and lacustrine Quaternary deposits from Shaidu and Akora Khattak area and also from sediments of the Kabul River. All these samples were analyzed for gold (Au), silver (Ag) and base metals such as copper (Cu), lead (Pb),nickel (Ni) and chromium (Cr) using atomic absorption spectrometer.

The comparison of results of heavy mineral concentrates (HMC) and fine fractions (FF =<-80 mesh size) indicate that high concentration (>140ppm) of Au is present in HMC while low concentration (< 2 ppm) of Au is found in the FF of Shaidu and Akora Khattak. In both these sampling media HMC show a high concentration of Au as compared to FF. Further, the anomalous concentration of Au in both HMC and also in FF confirmed that the Quaternary fluvial deposits of Shaidu and Akora Khattak have greater potential for economic placer gold. This study has also confirmed that the HMC is the best sampling media for the gold exploration in the study area.

Keywords: Nowshera; Quaternary deposits; placer gold; Exploration

1. Introduction

Stream sediment survey is considered to be very successful in areas where there is distinct drainage system. Geological terrains can be explored by stream sediment survey (Ranasinghe et al., 2009), and hence by this process undiscovered deposits of the world can be explored. The sediments found in the streams are due to the transportation and deposition of weathered rocks/minerals by the rivers and streams.Usually, these sediments adsorb different metallic minerals and elements; therefore the geochemical survey can be very fruitful in discovering various minerals (Cohen et al., 2005; Sheppard et al., 2009).Moreover, the stream sediment geochemical survey has been used widely for delineating significant mineralization in the areas of high, moderate and low relief and complex geological settings (Chandrajith et al., 2001). Excellent examples are found in the North Sulawesi, Indonesia, Papua New Guinea, Malaysia, Australia, Thailand, Canada, Brazil and SE Asia.

The HMC are important sources of placer deposits. The placer deposits are formed due to the accumulation of minerals with aspecific gravity more than 2.6 (Mudaliar et al., 2007) and comprise of 69 percent of world gold (Sutherland, 1985). Several important such as garnet, rutile, ilmenite, diamond, gold and platinum can be found in placer deposits. For example placer depositsin Ghana (Komla and Sammy, 1995), New Mexico (McLemore, 1994; North and Mclemore, 1988), South Africa (Lalomov and Tabolitch, 1997), Canada (McCracken et al., 2007) and United States (Wilson, 1961).

Shah et al. (2007) investigated Shaidu area for the extraction of placer gold based on HMC. They collected a limited number of HMC samples and studied their mineralogy and geochemistry. Although reconnaissance geochemical investigations of the only HMC was executed on the fluvial Quaternary

deposits in some parts of Shaidu town showing high potential for gold (Shah et al., 2007). Nevertheless, no any study has been conducted to compare the results of heavy mineral concentrates and the fine fraction (FF = <-80 mesh size) of fluvial and lacustrine Quaternary deposits of the Nowshera District. In the current study, the geochemical studies of the sediments of Akora Khattak, Shaidu, and Kabul River have been conducted in order to, 1) to determine gold in HMC and FF of Quaternary deposits of Shaidu and Akora Khattak and Kabul River sediments (KRS), 2) to compare the results of different sampling media, and 3) to investigate the Quaternary deposits from economic point of view.

2. Geological background of the study area

The study area is located at the latitude 33° 58′ 22.00″N and longitude 72°11′ 12.1″E (Fig. 1) which covers an area of about 20 km^2. The research area including the Quaternary deposits of both lacustrine and fluvial sediments composed of boulders, cobbles, pebbles, sand and silts.

The source of these Quaternary deposits is same as found in Peshawar basin including fluvial and lacustrine sediments ranging in age between 2.8-0.6 Ma (Burbank, 1982; Burbank and Tahirkheli, 1985). These deposits also include catastrophic flood deposits, alluvial fan and loess deposits (Khan and Ahmed, 1987). Burbank (1982) observed about 40 catastrophic inundates which flooded the basin at the prehistoric time, including unlithified sediments such as gravel, fluvial sand and silts (Hussain et al., 1991). Kabul river is flowing from east to west and draining the basin (Tariq, 2001) which merges with river Indus near Attock. Kabul river starts from Chitral (Pakistan) passes through Afghanistan and entering back into Pakistan, flowing through Warsak and Nowshera (Pakistan) and join the Indus River at Khairabad. Nowshera District is part of Peshawar intermountain basin having primarily the rocks of Quaternary age ranging from Pleistocene to recent, located in the southern Himalayas. In the north-east, it is bordered by Swat, in the west and northwest by Khyber mountain ranges. In the south, it is bounded by the Attock-Cherat Ranges and Indus River in the southeast (Moores and Fairbridge, 1997; Shah et al., 2007). Gandghar Range is in the east while the Khyber Range is to the west of Peshawar basin (Hussain et al., 1991). Kabul, Swat, and Indus rivers are the major agents of transporting sediments. The sediments include cobbles, gravels, sands, and silts that have been shifted to a greater distance. The research area including Shaidu and its surrounding areas are part of district Nowshera, which is located in Peshawar basin (Shah et al., 2007).

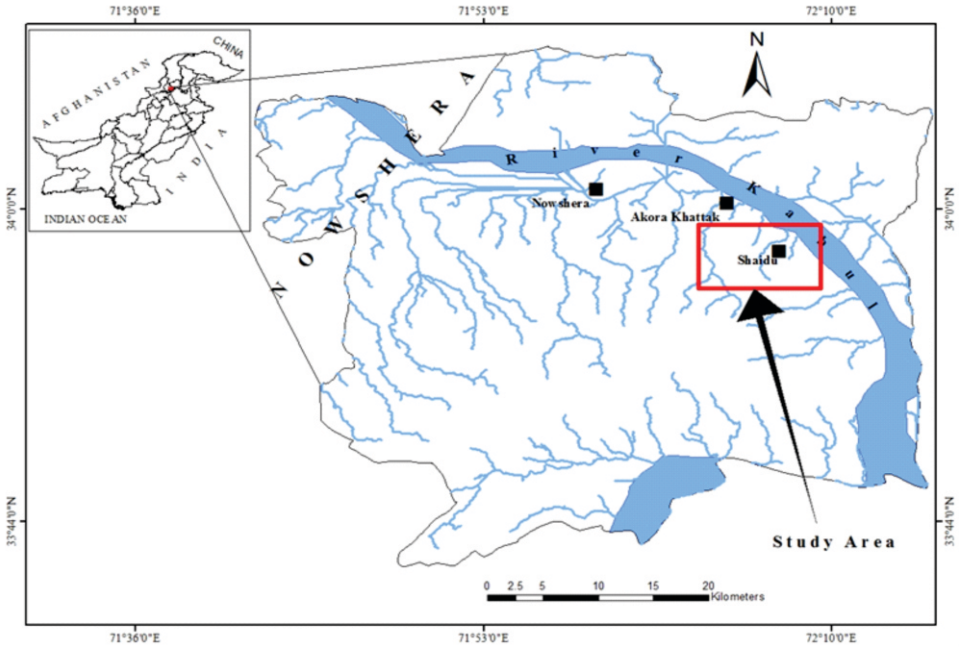

Fig. 1. Map showing location of the study area.

3. Methodology

3.1. Sample collection and processing

The samples of HMC and FF have collected from various sampling media Quaternary deposits of Shaidu and Akora Khattak and stream sediments of Kabul River. To represent the bulk concentration, both types of samples i.e., HMC and FFs were taken randomly from all the potential sites. The location of each sample was noted by using GPS. Forty samples of fluvial (20 HMC and 20 FF) and four samples of HMC of lacustrine sediments from Shaidu, twenty samples of fluvial (10 HMC and 10 FF) and three samples of HMC of lacustrine sediments from Akora Khattak and four samples (2 HMC and 2 FF) from Kabul Rivers have been collected.

Each sample of HMC was collected from a depth of up to 1 meter, while that of FF was collected from a depth of about 30 cm. About 20 kg bulk sample was collected from each site and was panned until about 200 grams of HMC was obtained. The HMC was stored in the polythene bag.

The samples of FF of fluvial and lacustrine sediments were sieved through 2 mm sieve and then through -80 mesh size sieve and about 1 kg sample of FF was collected from each site. All the samples of HMC and FF were processed in the Geochemistry Laboratory of the National Centre of Excellence in Geology, University of Peshawar. The samples of FF were passed through asplitter and representative samples of about 200 g were collected. The finally collected samples of both HMC and FF were dried in the oven at 110°C overnight and were then stored in the bottles for chemical analyses.

3.2. Chemical analysis

a) Preparation of gold solutions

A method of Hubfrt and Chao (1985) was followed by digestion of samples. About 20 g of each representative sample of HMC and FF was added in the glass beaker. The samples were digested in glass beaker using aqua regia (3HCl: 1HNO_3). After completing the digestion process, the constituents in beaker was filtered, cleaned and washed with 6 N HCl.The solution was then taken into separatory funnel and Methyl Isobutyl Ketone (MIBK). The solution was thoroughly shaked resulting in two layers, the lower layer was removed and upper MIKB layer remained in separating funnel.The lower layer is removed and upper MIKB layer, containing extracted Au, was taken in a glass bottle to be stored and analyzed Au using graphite furnace atomic absorption.

b) Preparation of solutions for trace elements

Trace elements like Ag, Cu, Pb, Cr and Ni in all the samples of HMC and FF the methodology of Jeffery and Hutchison (1986) was adopted. One gram from each sampling medium was taken in Teflon beaker. Approximately, 10 ml of HF was taken in the beaker and it was heated for an hour. After one hour, 20 ml aqua regia was added into beaker and heating under low temperature for an hour till the content in the beaker become dried. The contents of the beaker were then washed and filtered into 50 ml flask and the volume was made to the mark with deionized water. The solution was then analyzed for selected trace elements using graphite furnace atomic absorption spectrometer.

4. Results

4.1. Quaternary fluvial sediments

Heavy Mineral Concentrates

The concentrations of trace elements of HMC from the Quaternary fluvial sediments (QFS) of Shaidu and Akora Khattak and stream sediments of the Kabul River are given in Table 1. In Shaidu, the concentration of Ag, Cu, Ni, Cr and Pb is ranging from 0,00 ppm to 0.17 ppm, 0.29 ppm to 0.72 ppm, 0.02 ppm to 0.88 ppm, 0.97 ppm to 7.36 ppm, 0.00 ppm to 1.73 ppm. Minimum and maximum values of Au are found as 0.08 ppm and 147.60 ppm respectively with an average value of 46.50 ppm. Among all the elements only significant concentration of Au is found in the majority of the HMC of QFS from Shaidu town.

Majority of the elements in the HMC of QFS from Akora Khattak are having relatively low concentration of Ag (0 ppm to 0.24 ppm), Cu (0.39 ppm to 3.93 ppm), Ni (0 ppm to 1.05 ppm), Cr (1.20 ppm to 6.72 ppm), Pb (0.10 ppm to 5.47 ppm). However, Au, like Shaidu, is also present in a significant amount (0.10 ppm to 159.30 ppm; average = 33.3 ppm) in Akora Khattak.

Low concentration of Ag (0.032 ppm to 0.063 ppm), Cu (0.40 ppm to 0.67 ppm), Ni (0.71 ppm to 0.86 ppm), Cr (5.89 ppm to 8.73 ppm), Pb (0.06 ppm to 0.46 ppm) has also been found in the HMC of Kabul River. The concentration of Au ranging from 10 ppm to 15 ppm with an average amount of 12.50 ppm was found in the samples of River Kabul. The anomaly map of Au in the HMC of the QFS from Shaidu and Akora Khattak and of stream sediments of Kabul River, indicating the anomalous gold values, is shown in figure 2.

Fine fractions

The trace element concentrations in the samples of FF of QFS collected from Shaidu area are given in Table 2. Data show Ag is ranging from 0.00 ppm to 0.08 ppm, Cu from 0.33 ppm to 0.63 ppm, Ni from 0.15 ppm to 0.70 ppm, Cr from 0.69 ppm to 1.69 ppm and Pb from 0.14 ppm to 0.80 ppm.However, relatively high concentration of Au (0.00 ppm to 1.24 ppm; average = 0.15 ppm) has been observed in the samples of FF of the Quaternary Sediments of Shaidu area.

Table 2 shows the concentration of various trace elements in the samples of FF collected from QFS from Akora Khattak. The concentration of Ag is ranging from 0.00 ppm to 0.11 ppm, Cu from 0.40 ppm to 0.79 ppm), Ni from 0.17 ppm to 0.85 ppm, Cr from 0.84 ppm to 1.82 ppm and Pb from 0.25 ppm to 0.67 ppm). Gold is ranging from 0.04 ppm to 0.08 ppm with an average amount of 0.01ppm (Table 2).

The FF of stream sediment samples collected from Kabul River have the concentration of Au in the range from below detection limit to 0.14 ppm, Cu from 0.41 ppm to 0.44 ppm, Ni from 0.14 ppm to 0.34 ppm, Cr from 0.89 ppm to 1.30 ppm and Pb from 0.19 ppm to 0.36 ppm (Table 2). However, the concentration of Ag is below the detection limit. The anomaly map of Au in the FF samples of QFS from Shaidu and Akora Khattak and of stream sediments from Kabul River, indicating the anomalous Au values, is shown in figure2.

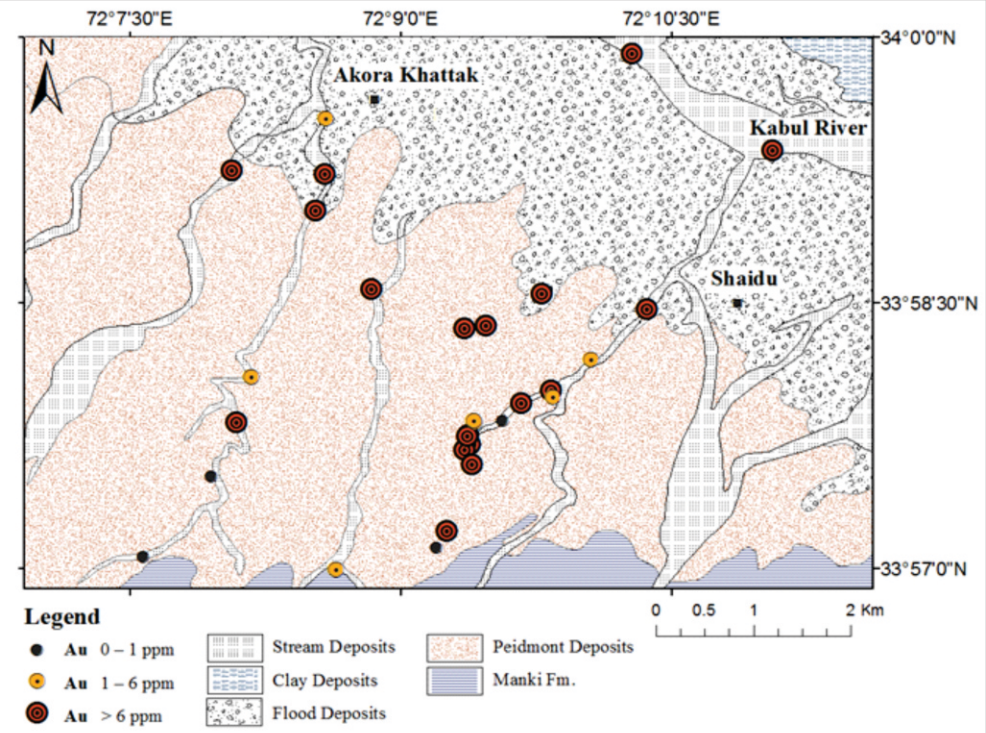

Fig. 2. Anomaly map of Au in the HMC from Shaidu, Akora Khattak and Kabul River (modified from GSP, 1984).

Table 1. Trace element concentration in the HMC of QFS of Shaidu and Akora Khattak and Kabul River sediments.

		Au ppm	Ag ppm	Cu ppm	Ni ppm	Cr ppm	Pb ppm
Shaidu	Min	0.08	0.00	0.29	0.02	0.97	0.00
	Max	147.60	0.17	0.72	0.88	7.36	1.73
	Average	46.50	0.028	0.44	0.45	5.13	0.41
Akora Khattak	Min	0.10	0.00	0.39	0.00	1.20	0.10
	Max	159.30	0.24	3.93	1.05	6.72	5.47
	Average	33.31	0.053	1.06	0.41	3.94	1.04
Kabul River	Min	10.00	0.032	0.40	0.71	5.89	0.06
	Max	15.00	0.063	0.67	0.86	8.73	0.46
	Average	12.50	0.048	0.54	0.79	7.31	0.26

Table 2. Trace element concentrations in the FF samples of the QFS from Shaidu and Akora Khattak and from Kabul River sediments.

		Au ppm	Ag ppm	Cu ppm	Ni ppm	Cr ppm	Pb ppm
Shaidu	Min	0.00	0.00	0.33	0.15	0.69	0.14
	Max	1.24	0.08	0.63	0.70	1.69	0.80
	Average	0.15	0.015	0.46	0.44	1.08	0.39
Akora Khattak	Min	0.04	0.00	0.40	0.17	0.84	0.25
	Max	0.08	0.11	0.79	0.85	1.82	0.67
	Average	0.01	0.02	0.58	0.45	1.18	0.41
River Kabul	Min	0.00	0.00	0.41	0.14	0.89	0.19
	Max	0.14	0.00	0.44	0.34	1.30	0.36
	Average	0.07	0,00	0.43	0.24	1.10	0.27

4.2. Quaternary lacustrine sediments

The trace element concentrations of the HMC of Quaternary lacustrine sediments (QLS) collected from Shaidu and Akora Khattak are given in Table 3. Data in this table show that Ag varies from 0.01 ppm to 0.06 ppm, Cu from 0.78-0.98 ppm, Ni from 0.91 to 2.02 ppm, Cr from 2.27 to 5.76 ppm and Pb from 0.03 to 1.53 ppm in the HMC samples from the QLS collected from Shiadu area. Gold is up to 3.44 ppm that is relatively higher concentration as compared to the other trace elements of the Sahidu area (Table 3).

Table 3 shows that the HMC samples of QLS collected from Akora Khattak have Ag in the range of 0.00 ppm to 0.09 ppm, Cu from 0.89 ppm to 1.46 ppm, Ni from 0.89 ppm to 1.02 ppm, Cr from 2.50 ppm to 6.81 ppm and Pb from 1.00 ppm to 4.76 ppm. However, Au has been found below the detection limit in these samples. Figure 4 shows the anomaly map of Au for HMC samples from Shaidu and Akora Khattak.

5. Discussion

Both HMC and FF of stream sediments have successfully delineated gold anomalies related to geology and structure in different parts of the world(Watters et al., 1991). However, HMC recovered in the field are easier to prepare, but give intermittent results and are not suitable if the exploration targets are fine-grained gold deposits (Fletcher et al., 1995). On the other hand, sieving technique gives a high concentration of fine sediments rather than

panning due to the fact that fine sediments are washed during the panning (Callahan., 1976 and Beeson., 1995). Therefore, the comparative studies of these two types of sampling media have been used in the current study in order to devise best sampling media for low-lying areas of district Nowshera.

The comparison of different sampling media such as HMC and FF of both fluvial and lacustrine Quaternary sediments from Shaidu and Akora Khattak and Kabul River sediments are shown in figure 5. Valuable information can be obtained from these graphs regarding the relative concentration of trace elements in all these sampling media. It is clearly evident that the average values of Au in HMC samples of QFS of Shaidu, Akora Khattak, and Kabul River sediments are high when contrasted with the QLS (Fig. 5). The majority of the trace elements in all inspecting areas has a low concentration in all sampling media and gives low information about the geochemical relationship in Shaidu and Akora Khattak. Though, Cr is showing similar concentration in HMC as compared to FF (Fig. 5b). However, there is no greater variation of other elements in both samples of HMC and FF but is still not demonstrating any substantial anomaly in the area. Different factors affect the vacillation and deviations in geochemical compositions such as geology of the parent rocks, weathering and transportation processes, high, moderate and low relief and complex geological settings (Chandrajith et al., 2001) and the process of dilution during the transport and dispersion in the streams and rivers (Mokhtari and Nezhad, 2015).In the current study, the low concentration of the majority of the elements (Ag, Cu, Ni, Cr and Pb) in both the samples of HMC and FF from Shaidu, Akora Khattak and Kabul River, bolsters that these sediments can't be correlated with their source/ sources.

The heavy mineral concentrations, which can be deliberated as mini-placer deposits are valuable because of the difference of anomaly with the background values (Fletcher and Day., 1989; Paopongsawan and Fletcher., 1993). Heavy minerals deposited on stream beds because heavy minerals are transported more gradually than the sediment as a whole (Fletcher and Loh., 1996). Overall HMC provides decent results for Au, Ag and trace elements for Shaidu and also Akora Khattak and Kabul River with comparatively high average concentration as compared to FF for both fluvial and lacustrine Quaternary sediments (Fig. 6). However, gold concentration in the majority of the samples is varied due to its high specific gravity, particularly in stream sediments. In addition to finding the anomalies of Au, Ag and associated elements, the HMC provided a better sampling media for geochemical exploration of the study area.

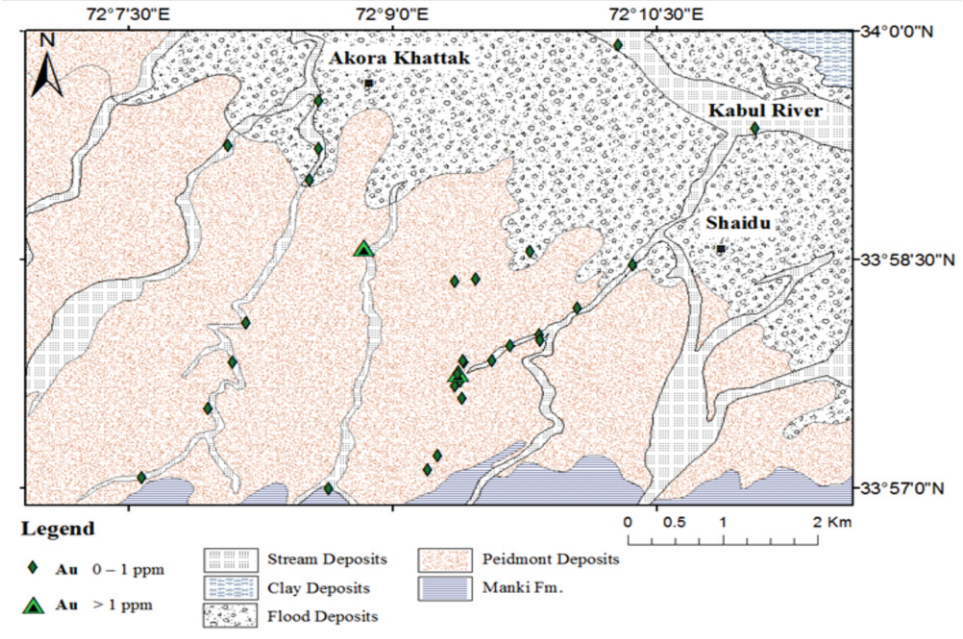

Fig. 3. Anomaly map of Au in samples of FF from Shaidu, Akora Khattak and Kabul River (modified from GSP, 1984).

Table 3. Trace element concentrations in the HMC samples of QLS collected from Shaidu and Akora Khattak.

		Au ppm	Ag ppm	Cu ppm	Ni ppm	Cr ppm	Pb ppm
Shaidu	Min	0.00	0.00	0.78	0.91	2.27	0.03
	Max	3.44	0.06	0.98	2.02	5.76	1.53
	Average	1.65	0.04	0.88	1.24	4.41	0.50
Akora Khattak	Min	0.00	0.00	0.89	0.89	2.50	1.00
	Max	0.00	0.09	1.46	1.02	6.81	4.76
	Average	0.00	0.05	1.23	0.97	4.67	2.53

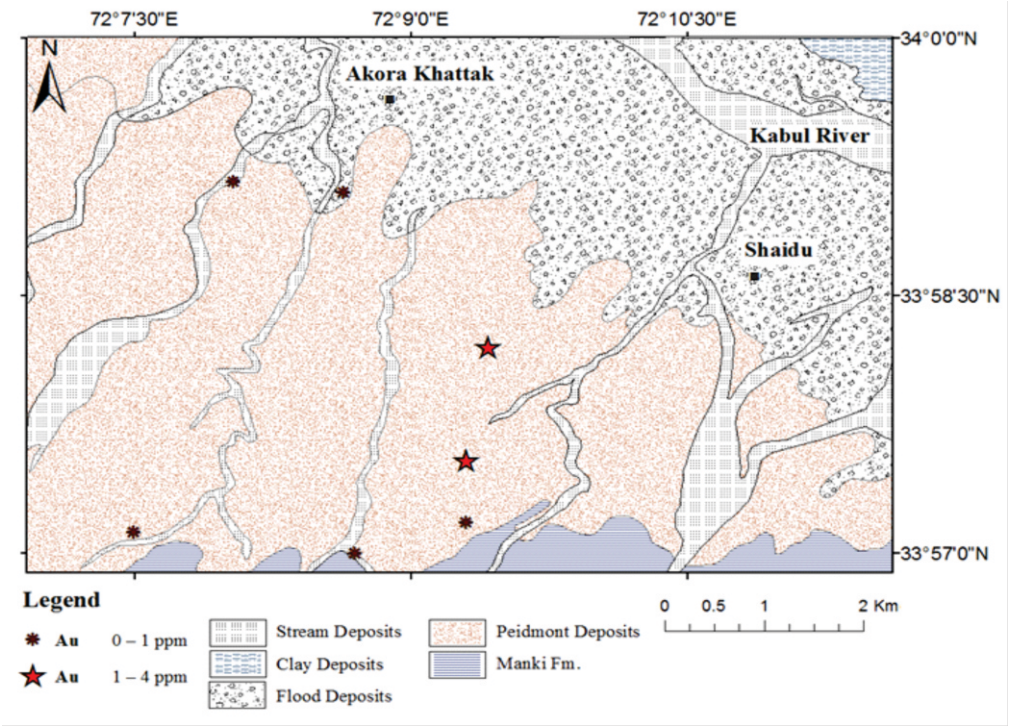

Fig. 4. Anomaly map of Au in HMC samples collected from the QLS of Shaidu and Akora Khattak (modified from GSP, 1984).

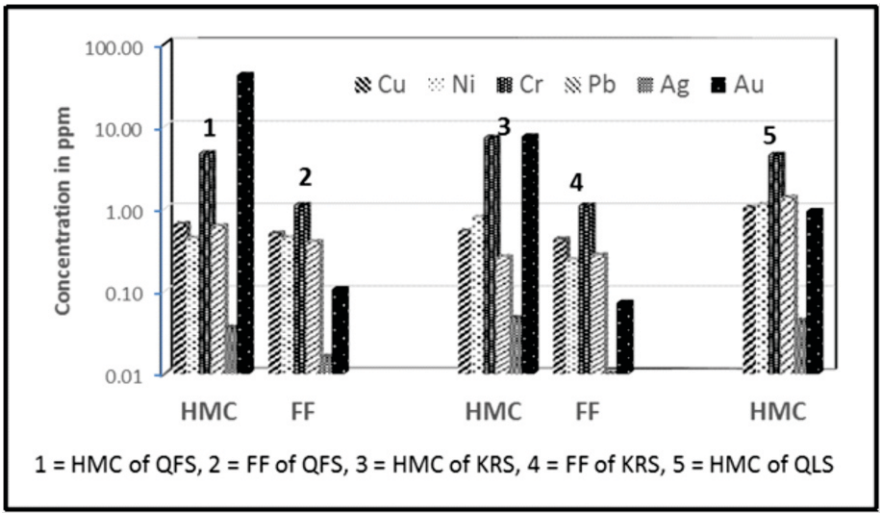

Fig. 5. Comparison of average values of various elements in the samples of HMC and FF of Quaternary fluvial and lacustrine sediments of Shaidu and Akora Khattak and of Kabul River sediments.

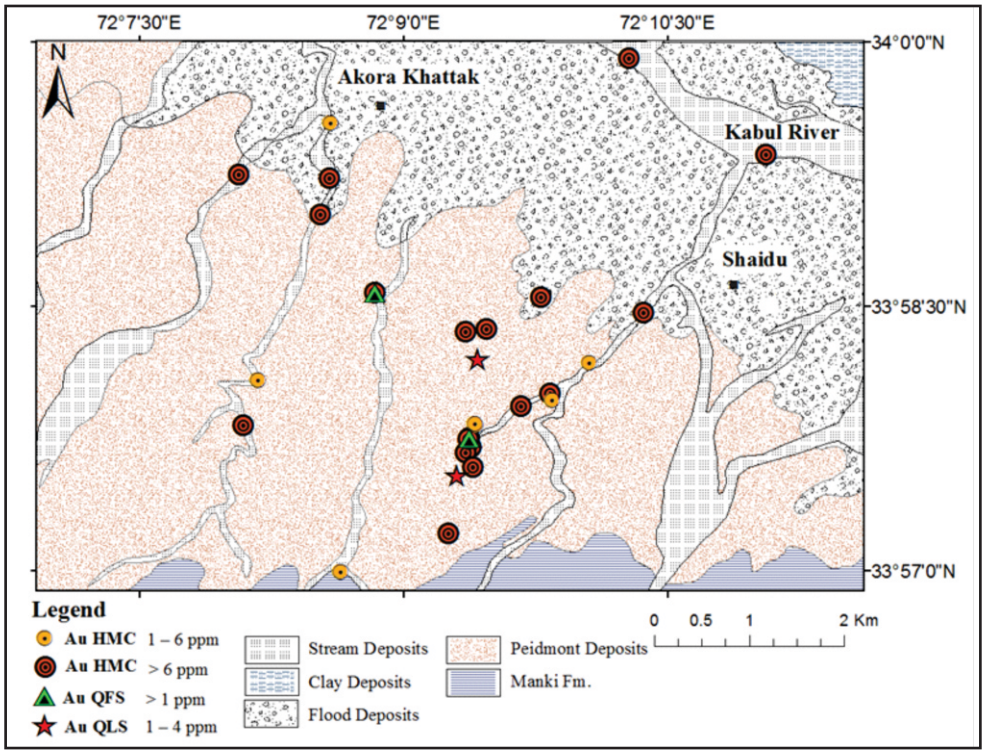

Fig. 6. Anomaly Map showing potential areas for Au on the basis of HMC, QFS and QLS from the study area (modified from GSP, 1984).

6. Conclusion

- The majority of the elements (Ag, Cu, Ni, Cr and Pb) analyzed in this study show low concentration in all the sampling media which does not allow finding the source of these elements.
- In both HMC and FF, there is anextremely feeble geochemical association of gold and related elements which indicates that gold in these areas is of placer origin.
- There are generally high geochemical anomalies of gold found in HMC as compared to the FF. Gold anomalies in the HMC in Shaidu and Akora Khattak show high grade suggesting that Quaternary fluvial deposits of the study area have the remarkable potential for the occurrence of placer gold and can be further investigated.

Authors' contribution

Mr. Muhammad Farhan is the main author and this manuscript is part of his MS thesis. Dr. Liaqat Ali is the thesis supervisor, Prof. Dr. M. Tahir Shah is the thesis Co-supervisor. Prof. Dr. Nimat Ullah Khattak hepled in analysis. Dr. Seema Anjum Khattak helped in lab techniques/analysis. Dr. Asghar Ali helped in samples collection. Izhar Sadiq arranged all the research data.

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