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Geochemical investigation for gold, silver and base metals in stream sediments, panned concentrates and talus deposits of District Tank, KP, Pakistan

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Abstract

The Tank district lies to the north-west of river Indus. Tectonically, Tank area is a part of Sulaiman basin in which the dominant sediments are of Quaternary alluvium type. The Nagri and Dhok Pathan formations of the Siwalik Group are also present in the study area. In this research work, geochemical studies of stream sediments, panned concentrates and talus deposits were carried out for gold, silver and base metals.A total of 96 samples comprised of fifty four stream sediments (SS), twenty threepanned concentrates (PC) and nineteen talus samples (TS) were collected and analyzed for gold, silver and base metals using atomic absorption spectrometer.Geo-statistical analyses such as Pearson correlation and Factor analyses were carried out in order to determine correlation among the elements.Histograms were plotted in IBM SPSS Statistics 21 software in order to find out the threshold value for each element. The geochemical data were overlaidin Arc GIS 10.1 to get information about the anomalous concentration of gold, silver and base metals in different sampling media.Results indicate that the Au (up to 6 ppm) and base metals arein higher concentration in panned concentrates as compared to stream sediments and talus deposits. Whereas Ag and Cd are relatively higher in stream sediments and talus deposits. Interpretation of geochemical, geo-statistical and geo-spatial data of panned concentrates, stream sediments and talus deposits reveal that the area is having low economic potential for placer gold, while no economic potential for base metals.

Keywords: Tank; Geostatistical; GIS; Economic potential; Placer gold.

1. Introduction

Many of the world's most important mineral commodities are extracted from placers, for instance, placer gold mined in South Africa from Witwatersrand sedimentary rocks which is almost half of all the gold ever mined in the world (Els and Eriksson, 2006; Slingerland and Smith, 1986; Pretorius, 2012). Other deposits include placer gold from South Africa (Lalomov and Tabolitch, 1997) and Ghana (Komla and Sammy, 1995).Hunt for economic mineral deposits is the utmost desire of every geochemical explorer. Geochemical mineral exploration incorporates any technique of mineral prospecting based on the systematic analysis of chemical properties of a particular mineral (Hawkes, 1957; Reimann and Melezhik, 2001).

Stream sediments provide useful information about the source of mineralization of mineral deposits. It is a fact that stream sediments not originally indicate concentration and grade of the gold in the area but can provide valuable information about the presence of gold in the stream (Nimick and Moore, 1991). The geochemical composition of stream sediments represent the average composition of the whole drainage basin (Reimann and Melezhik, 2001; Halamić et al., 2001). Although stream sediments are affected by different chemical, biological and physical weathering processes, yet they retain the original geochemical composition of the source (Naseem et al., 2002; Formoso, 2006; Dill, 2008).

Both stream sediments and panned concentrates provide a useful media for sampling and each one has its own importance. All the tributaries of Tank Zam River and Gomal River were targeted to collect such kind of samples as these tributaries are passing through the rocks of South Waziristan and Siwaliks in Tank area before joining the River Indus. The study area lies to the north-west of river Indus. The River Indus in northern part of the province has already been known to have economic mineral deposits especially placer gold (Shah and Khan, 2004). According to Tahirkheli (1974) and Austromineral (1976), the river Indus is the primary source for transporting and depositing the placer gold along the banks and terraces. Zaheenullah et al., (2012) carried out geochemical studies in the district Karak and concluded that the Nagri and Dhok Pathan formations of Siwalik Group have economic potential for heavy minerals, particularly gold, silver and zircon. Farhan (2015)carried out detailed geochemical investigations of stream sediments and Quaternary sediments from Shaidu and Akora Khattak areas of District Nowshera. He indicated that the quaternary sediments in these areas have greater potenrtial for the occurance of placer gold. The current study in perspective of gold, silver and base metals is carried out in Tank area due to the fact that this area has not been geochemically explored using stream sediments and panned concentrates.

2. Geological background

The Tank area predominantly consists of Quaternary deposits which occur in the form of extensive blanket throughout the region (Fig. 1). According to Hemphill and Kidwai (1973), the Tank area lies in the south-western extremity of the Bannu quadrangle. Geology of the Bannu quadrangle is comprised of, i) Waziristan-Sulaiman Ranges, ii) Khisor-Bhittanni-Marwat Ranges, and iii) Quaternary deposits (Hemphill and Kidwai, 1973). The Sulaiman Limestone Group of Jurassic age is the oldest rock unit recognized in the Sulaiman Range and eastern Waziristan (Hemphill and Kidwai, 1973). The Sulaiman Limestone Group is disconformably overlain by Cretaceous rocks, which from oldest to youngest are: Sembar Formation, Parh Limestone, Mughal Kot Formation, and the Pab Sandstone. Cretaceous rocks in the eastern part of the Bannu quadrangle are limited to the Chichali Formation and the Lumshiwal Sandstone. In the Sulaiman Range, the Dungan Formation of Paleocene age overlies the Pab Sandstone. The Dungan Formation as well as other rocks of early and middle Tertiary age are not present at Sheikh Badin and in the Khisor Range. The Dungan Formation is followed by the Ghazij Shale, Baska Shale, and Kirthar Formation. The Chitarwatta Formation of late Oligocene to Late Miocene age disconformably overlies the Kirthar Formation in the eastern foothills of the Sulaiman Range, but the unit is not recognized in Waziristan (Hemphill and Kidwai, 1973).

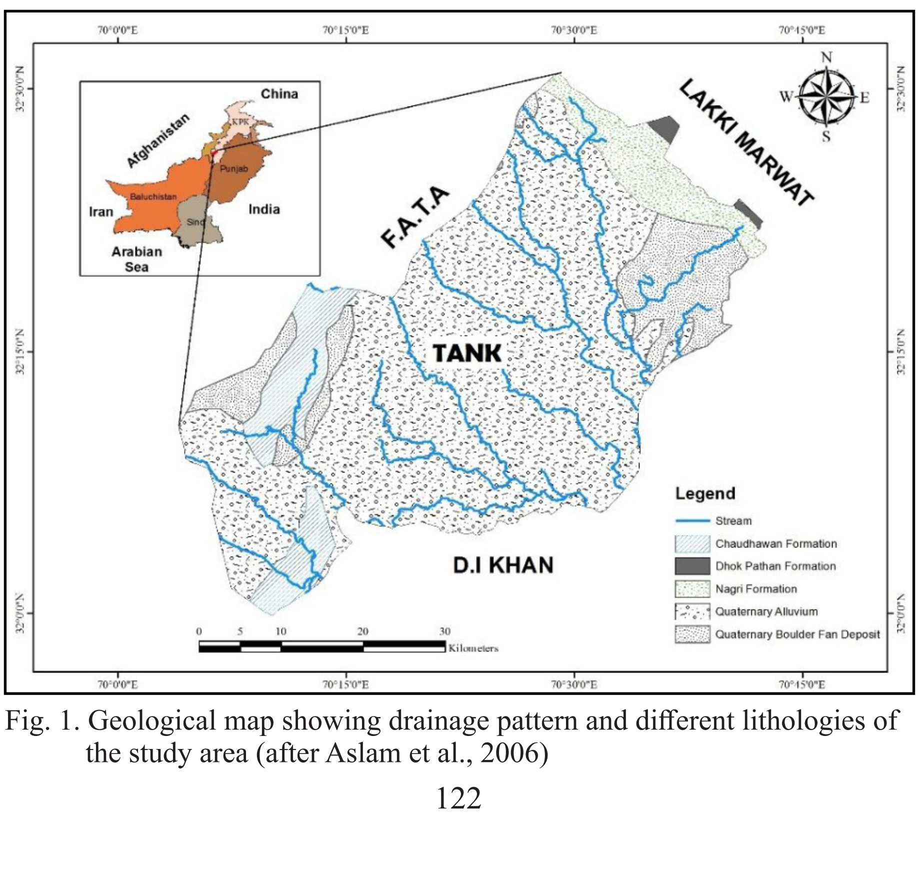


Fig. 1. Geological map showing drainage pattern and different lithologies of the study area (after Aslam et al., 2006)

In Waziristan and the Sulaiman Range, rocks of the Siwalik Group are of probable Pliocene age and overlie the Chitarwatta and Kirthar formations (Hemphill and Kidwai; (1973). In this area the Siwalik group is divided into three formations; the Vihowa, Litra, and Chaudhwan Formations. The Chaudhwan Formation may be as young as Pleistocene. At Sheikh Badin and in the Khisor Range, rocks of the Siwalik Group overlie Cretaceous and older rocks. In this area the Siwalik Group is believed to be as young as Pleistocene and is divided into four formations: the Chinji, Nagri, Dhok Pathan, and Malagan formations (Fig. 2).

According to Hemphill and Kidwai (1973), the Quaternary deposits in Bannu quadrangle are mostly of Pleistocene and Holocene age. They include alluvium and Eolian deposits of the Indus and Bannu Plains, alluvial fans, and unconsolidated debris along the slopes and in the valleys of the mountain ranges and foothills. Older terrace deposits are covering huge areas underlain by Early Tertiary rocks in the foothills of the Sulaiman Range and early-late Tertiary rocks towards east of Waziristan. The alluvium deposits are unconsolidated surficial deposits which include gravel, sand and silt in streambeds of rivers flowing towards the Indus and Kurram Rivers. Eolian deposits include wind blown sand and silt, unevenly distributed as dunes, and are mostly stabilized towards east of Kurram River and west and south of Sheikh Badin.

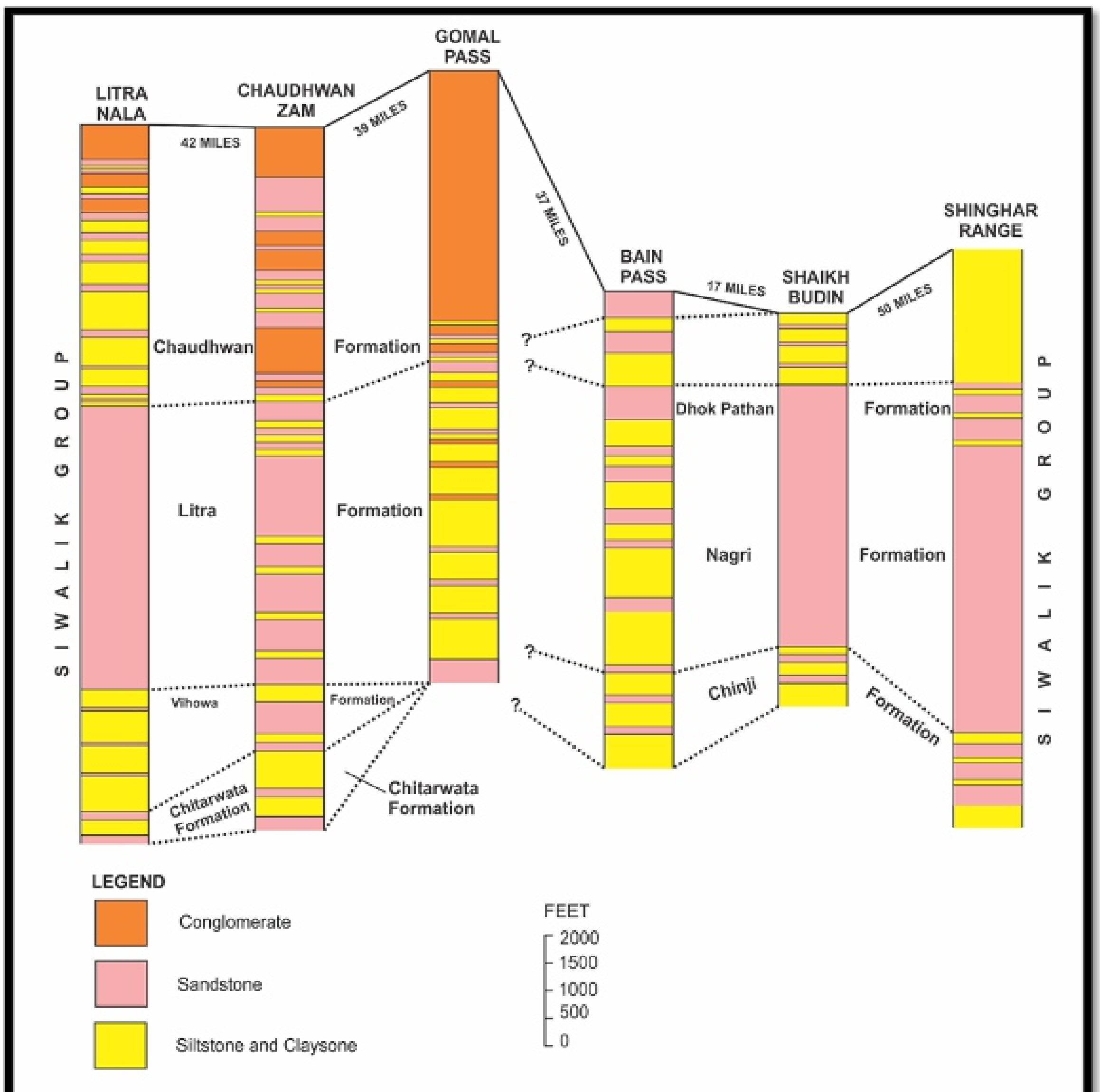


Fig.2. Probable correlation of rocks of the Siwalik Group and the Chitarwatta Formation in the Bannu and Dera Ismail Khan areas. Column for Sheikh Badin interpreted from Morris (1938); column for Shinghar Range modified from Danilchik and Shah (1967).

3. Methodology

Field work was conducted in district Tank and sample sites were identified on the basis of Arc-GIS based drainage map. A systematic technique was adopted to collect the samples at each spot. A total of 44 samples from stream sediments, 23 samples from panned concentrates and 19 from talus were collected. The stream sediment samples were dried in the sun light and then passed through -80 mesh sized sieve. The panned concentrate samples were mineralogically studied under the microscope. Gold grains were identified and classified as color (<0.3 mm), speck (0.3 – 0.5) mm and piece (> 0.5 mm). All the samples were then digested using aqua regia. The method of Hubert and Chao (1985) was followed for digestion. The final stock solutions were then analyzed for gold, silver and base metals using Atomic Absorption Spectrometer. The geochemical data obtained were then subjected to different softwares to get geo-statistical and geo-spatial results.

4. Result

4.1. Geochemical Analysis

The stream sediments, panned concentrates and talus samples were analyzed for gold, silver and base metals using Atomic Absorption Spectrometer (AAS). Table 4.1, table 4.2 and table 4.3 show the concentrations of copper, lead, zinc, nickel, chromium, cadmium, manganese, silver and gold in stream sediments, panned concentrates and talus samples respectively. These results indicate that the majority of the base metals such as Cu, Pb, Zn, Ni, Cr, Co and Mn are below the background values in all the sampled media. However, higher concentrations of Au, Ag and Cd were obtained in panned concentrates as compare to stream sediments and talus deposits.

4.2. Statistical Analyses

i. Univariate Statistical Analysis

Different statistical parameters like arithmetic mean, median, standard deviation, minimum, maximum and percentiles (50th, 75th, 90th and 95th) of stream sediments, panned concentrates and talus are determined in order to get information about the elements of interest in the study area (Table 4). Histograms for different elements (Au, Ag, Cu, Pb, Zn, Ni, Cr, Co, Mn and Cd) are plotted in order to account for background and anomalous concentrations (Fig. 3).

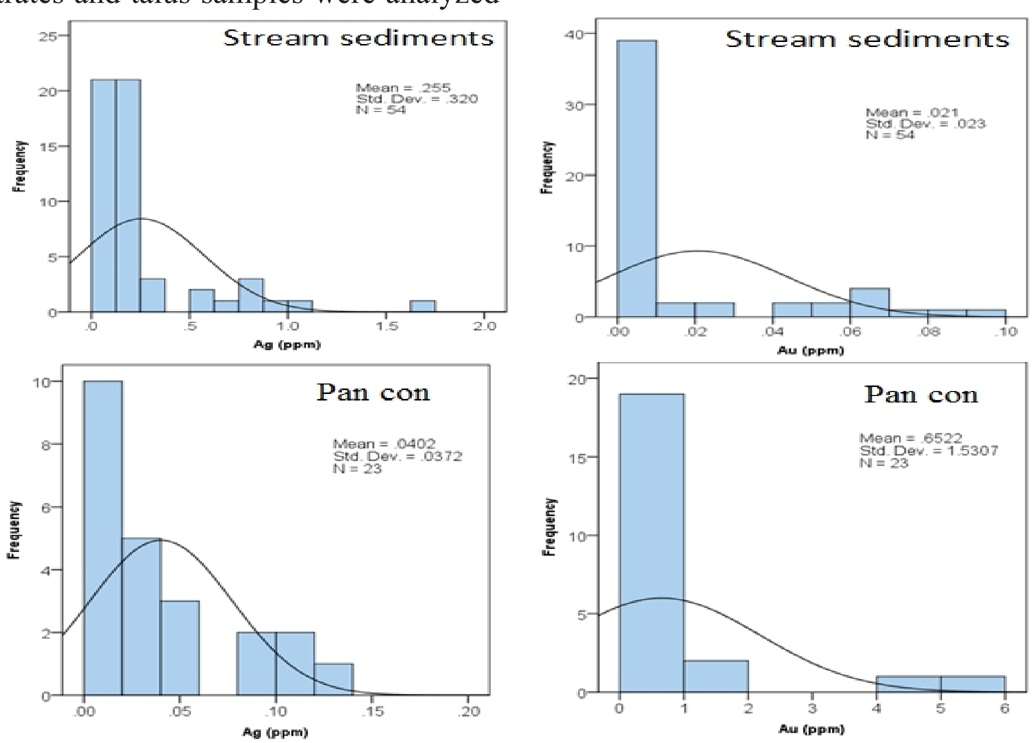


Fig. 3. Histograms of Au and Ag for stream sediments and Panned concentrates.

Table 1. Concentrations (ppm) of gold, silver and base metals in stream sediments from study area.

Sample No	Cu (ppm)	Pb (ppm)	Zn (ppm)	Ni (ppm)	Cr (ppm)	Co (ppm)	Cd (ppm)	Mn (ppm)	Ag (ppm)	Au (ppm)
2501B	0.418	0.227	1.169	0.078	0.678	0.479	0.076	11.68	0.813	0.091
2502B	0.385	1.042	0.903	1.154	0.487	0.301	0.137	10.21	0.147	0.009
2503B	0.386	1.006	0.789	0.023	0.435	0.33	0.083	11.54	0.119	0.009
2504B	0.428	0.785	0.845	0.054	0.972	0.263	0.082	7.987	0.034	0.009
2505B	0.574	0.795	1.205	0.245	0.314	0.398	0.06	10.38	1.625	0.06
2506B	0.527	0.316	0.996	0.084	0.709	0.431	0.085	10.14	0.364	0.009
2509B	0.294	0.885	0.77	0.193	0.811	0.421	0.108	7.741	0.036	0.009
2510B	0.341	1.146	0.811	0.025	0.528	0.231	0.141	10.51	0.164	0.009
2511B	0.35	0.77	0.761	0.081	0.639	0.294	0.037	9.22	0.039	0.009
2514B	0.459	0.324	0.877	0.89	0.049	0.356	0.131	0.548	0.13	0.009
2515B	0.604	0.659	0.816	0.059	0.772	0.255	0.107	0.676	0.041	0.001
2516B	0.665	0.706	1.132	0.559	0.818	0.317	0.119	0.584	0.022	0.009
2517B	0.616	0.153	1.102	0.022	0.25	0.334	0.172	0.593	0.173	0.009
2519B	0.537	0.936	0.839	0.634	0.442	0.117	0.085	0.664	0.041	0.009
2521B	0.518	0.621	0.88	0.083	0.308	0.26	0.06	11.44	0.662	0.064
2522B	0.217	0.53	1.425	0.065	0.796	0.251	0.085	5.141	0.022	0.029
2523B	0.188	0.482	0.672	0.797	0.236	0.215	0.1	5.014	0.113	0.009
2524B	0.212	0.776	0.124	0.891	0.765	0.224	0.04	8.76	0.321	0.022
2526B	0.143	0.891	0.586	0.012	0.255	0.159	0.096	4.527	0.155	0.009
2527B	0.321	0.888	0.855	0.013	0.362	0.196	0.149	8.337	0.159	0.017
2528B	0.131	0.675	0.554	0.999	0.368	0.228	0.072	4.846	0.106	0.083
2529B	0.181	0.226	0.576	0.791	0.77	0.34	0.05	6.2	0.029	0.009
2531B	0.382	0.977	0.685	0.083	0.496	0.177	0.034	10.37	0.196	0.009
2532B	0.164	0.837	0.47	0.06	0.51	0.163	0.159	5.325	0.204	0.009
2533B	0.236	0.991	0.703	1.207	0.468	0.171	0.172	5.994	0.186	0.052
2534B	0.213	0.323	0.493	0.092	0.817	0.252	0.089	6.433	0.042	0.009
2535B	0.209	0.631	0.506	0.002	0.903	0.298	0.068	5.826	0.027	0.053
2536B	0.18	0.708	0.489	0.722	0.676	0.302	0.119	5.677	0.149	0.049
2538B	0.361	0.929	0.605	0.847	0.728	0.2	0.056	10.37	0.091	0.009
2539B	0.472	0.808	0.702	0.142	0.219	0.343	0.07	10.49	0.939	0.009
2541B	0.58	1.085	0.873	0.202	0.464	0.293	0.104	0.544	0.597	0.009
2542B	1.068	0.984	1.054	0.01	0.798	0.233	0.094	10.64	0.149	0.074
2543B	0.569	1.068	0.945	0.205	0.673	0.454	0.11	0.779	0.169	0.009
2544B	0.514	1.074	1.029	0.941	0.315	0.331	0.057	0.552	0.125	0.009
2545B	0.634	0.945	0.378	0.655	0.157	0.355	0.095	11.34	0.096	0.009
2546B	0.638	0.799	0.864	1.044	0.115	0.367	0.112	0.689	0.117	0.009
2547B	0.212	0.612	0.731	1.089	0.118	0.412	0.223	0.631	0.09	0.061
2548B	0.546	1.062	0.841	0.309	0.539	0.354	0.105	0.665	0.244	0.009
2549B	0.461	0.953	0.264	1.719	0.456	0.352	0.091	0.654	0.836	0.069
2550B	0.532	1.19	0.929	0.811	0.394	0.249	0.035	0.766	0.282	0.011

Table 1 continued.

2555B	0.488	1.033	0.726	0.829	0.681	0.354	0.055	0.502	0.032	0.009
2556B	0.312	1.089	0.032	0.987	0.512	0.151	0.088	5.96	0.223	0.003
2558B	0.478	0.405	0.828	0.676	0.212	0.283	0.118	7.788	0.117	0.045
2560B	0.497	0.717	0.842	0.05	0.324	0.222	0.043	9.752	0.614	0.009
2561B	0.429	0.529	0.844	0.106	0.157	0.283	0.108	10.27	0.156	0.009
2562B	0.315	0.784	0.725	0.961	0.787	0.44	0.098	0.488	0.166	0.009
2564B	0.47	1.005	0.666	0.01	0.447	0.196	0.108	3.216	0.145	0.009
2565B	0.557	1.104	1.015	1.291	0.475	0.388	0.056	0.621	1.096	0.009
2567B	0.447	0.802	1.126	0.02	0.254	0.401	0.178	0.542	0.14	0.009
2568B	0.868	0.771	1.18	0.786	0.323	0.383	0.105	0.714	0.144	0.009
2569B	0.615	0.446	1.049	0.714	0.481	0.466	0.073	10.43	0.804	0.009
2570B	0.435	0.417	1.178	1.146	1.231	0.404	0.12	0.454	0.177	0.009
2572B	0.345	0.802	0.821	0.086	0.743	0.384	0.122	0.62	0.041	0.009

Table 2. Concentrations (ppm) of gold, silver and base metals in panned concentrates from study area.

Sample No	**Cu (ppm)**	**Pb (ppm)**	**Zn (ppm)**	**Ni (ppm)**	**Cr (ppm)**	**Co (ppm)**	**Cd (ppm)**	**Mn (ppm)**	**Ag (ppm)**	**Au (ppm)**
2501A	0.039	0.758	0.577	0.126	1.838	0.359	0.075	4.568	0.002	1.717
2502A	0.264	0.806	0.777	0.547	1.699	0.381	0.064	6.001	0.017	0.009
2503A	0.363	0.038	1.034	0.49	2.192	0.554	0.037	8.826	0.018	5.863
2505A	0.41	1.142	0.428	0.009	0.638	0.114	0.011	2.489	0.013	4.608
2515A	1.335	1.727	1.216	0.739	0.474	0.033	0.095	0.801	0.04	0.009
2516A	0.037	0.279	0.207	0.002	0.003	0.028	0.021	2.145	0.04	0.009
2517A	0.841	0.799	1.045	0.058	0.003	0.348	0.033	0.56	0.018	0.009
2519A	1.236	1.537	1.235	0.292	1.471	0.484	0.015	0.577	0.037	1.519
2538A	0.867	0.744	1.078	0.586	0.896	0.433	0.014	10.26	0.102	0.313
2539A	0.875	1.745	1.537	0.968	1.589	0.718	0.044	0.613	0.034	0.59
2546A	2.052	2.068	1.801	2.03	1.664	0.833	0.016	3.712	0.128	0.118
2547A	8.942	1.123	1.149	1.265	0.923	0.502	0.011	2.309	0.015	0.009
2548A	1.698	0.174	1.461	1.01	0.975	0.542	0.057	2.784	0.086	0.008
2549A	1.537	0.6	1.455	1.479	1.707	0.645	0.078	3.164	0.096	0.009
2550A	1.077	1.527	1.091	0.754	0.989	0.491	0.052	2.071	0.03	0.06
2558A	0.748	1.445	0.995	0.943	0.419	0.473	0.025	0.66	0.014	0.009
2560A	1.578	2.327	1.669	1.456	0.951	0.91	0.05	0.961	0.003	0.002
2561A	0.913	1.545	1.251	0.731	1.269	0.612	0.003	0.786	0.024	0.016
2564A	0.853	1.442	1.173	1.27	1.90	0.522	0.063	10.69	0.012	0.009
2565A	1.239	0.658	1.29	0.747	1.00	0.532	0.047	0.525	0.111	0.042
2567A	1.249	1.823	1.163	0.939	0.003	0.725	0.072	0.567	0.011	0.055
2570A	1.355	1.304	1.747	0.613	0.659	0.458	0.094	0.645	0.045	0.009
2572A	2.056	2.257	2.356	1.336	0.612	0.764	0.067	0.979	0.029	0.009

Table 3. Concentrations (ppm) of gold, silver and base metals in talus deposits from study area.

Sample No	Cu (ppm)	Pb (ppm)	Zn (ppm)	Ni (ppm)	Cr (ppm)	Co (ppm)	Cd (ppm)	Mn (ppm)	Ag (ppm)	Au (ppm)
2507T	4.004	1.085	0.867	0.673	0.22	0.313	0.086	10.68	0.03	0.082
2508T	0.417	1.13	0.962	0.57	0.031	0.236	0.067	0.541	0.017	0.009
2512T	0.41	0.794	0.843	0.35	0.763	0.264	0.058	8.665	0.652	0.009
2513T	0.532	1.2	0.62	0.212	0.09	0.162	0.232	4.32	0.015	0.009
2518T	0.415	0.57	0.682	0.146	0.39	0.346	0.135	11.44	0.006	0.009
2520T	0.441	0.736	0.754	0.254	0.454	0.223	0.117	0.552	0.028	0.038
2525T	0.129	0.435	0.454	0.065	0.448	0.141	0.165	3.908	0.014	0.009
2530T	0.291	0.64	0.826	0.801	0.99	0.198	0.125	6.848	0.013	0.009
2537T	0.339	0.602	0.662	0.677	0.354	0.183	0.13	7.6	0.045	0.009
2540T	0.472	0.778	0.688	0.539	0.135	0.252	0.039	9.045	0.023	0.009
2551T	0.662	0.912	0.561	0.326	0.241	0.421	0.056	6.05	0.057	0.04
2553T	0.532	1.035	0.769	0.577	0.899	0.242	0.047	9.596	0.137	0.045
2554T	0.784	0.164	1.114	0.666	0.223	0.316	0.114	0.593	0.058	0.003
2557T	0.488	0.785	0.855	0.338	0.59	0.252	0.162	11.02	0.022	0.021
2559T	0.504	1.052	0.694	0.308	0.838	0.268	0.169	0.56	0.029	0.021
2563T	0.429	0.86	0.883	0.287	0.824	0.172	0.108	7.915	0.018	0.069
2566T	0.47	0.694	0.727	0.528	0.104	0.271	0.128	11.19	0.044	0.039
2571T	0.374	0.294	0.561	0.952	0.12	0.423	0.051	10.98	0.401	0.009
2573T	0.435	0.314	0.662	0.701	0.576	0.247	0.127	6.081	0.045	0.009

ii. Bivariate and Multivariate Statistical Analysis

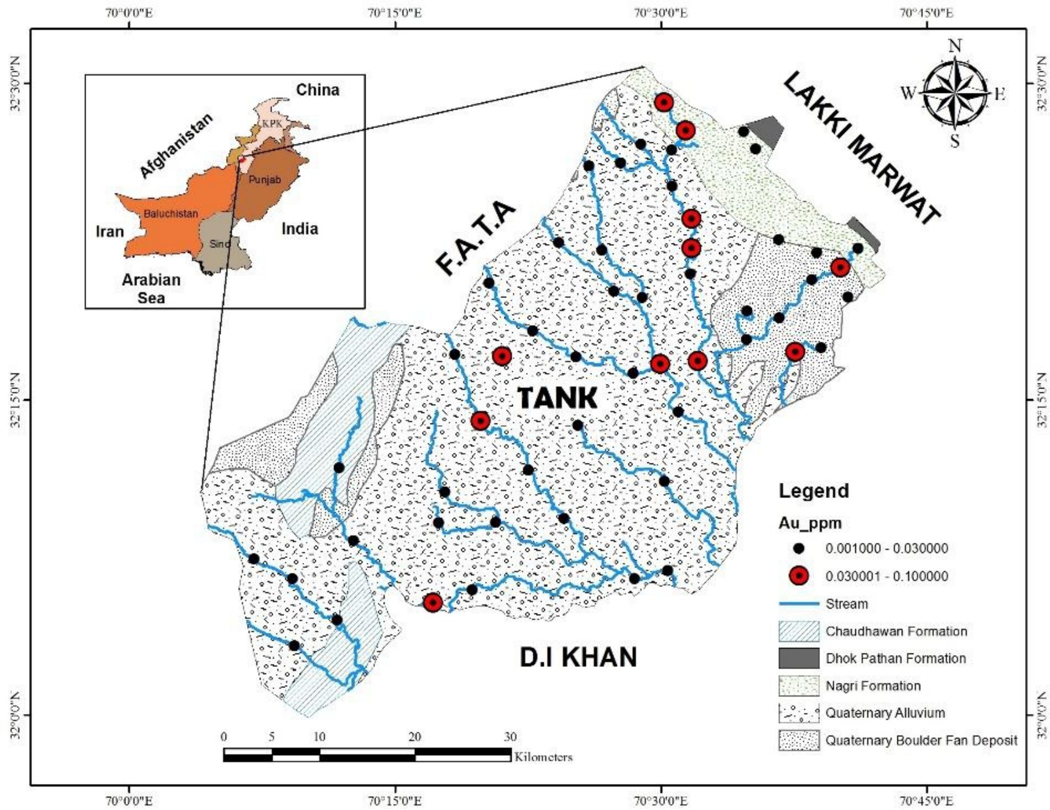
Results of bivariate (Pearson correlation) and multivariate (Factor Analysis) statistical analyses are shown in Table 5. As evident from this table, for base metals the stream sediments and talus show weak signature (< 0.5) of Cu vs Zn, Cu vs Co, Zn vs Co, Cu vs Ni, Zn vs Ni and Ni vs Co. While the panned concentrates show relatively good Pearson correlation (> 0.5) for Cu vs Zn, Cu vs Ni, Zn vs Ni, Zn vs Co, Ni vs Co and Ni vs Cr. Poor Pearson correlation was observed in stream sediments and panned concentrates for Au and Ag as evident from Cu vs Ag for panned concentrates. Similarly low values of Pearson correlation were also obtained for Cu vs Au, Ni vs Ag and Co vs Ag. Good Pearson correlation is obtained for Pb vs Au (0.59) in talus as compared to stream sediments and panned concentrates. Results of important factor scores are also mentioned in Table 5. Factor 1 and 2 show association of Au-Ag-Cu-Zn-Ni-Co and Au-Mn-Cr in stream sediments. For panned concentrates, Factor 1 show association of Cu-Zn-Ni-Co, while Factor 2 is also showing similar association of Au-Mn-Cr as that of stream sediments. Similarly Factor 1 for Talus is also showing association of Cu-Zn-Ni-Co-Ag and Factor 2 with association of Cu-Pb-Au.

4.3. Spatial Analysis

For stream sediments, panned concentrates and talus geochemical maps for stream sediments were prepared by plotting the data on topographic maps (1:50,000) and regional geological maps. The threshold value of each element was estimated after considering the histograms and statistical parameters. The data was then plotted in the order of increasing concentration for Au, Ag, Cu, Pb, Zn, Ni, Cr, Co, Cd and Mn based on threshold value of each element. As majority of the base metals are below background values, so their geochemical maps did not provide any useful information. The spatial geochemical anomaly map of Au and Ag for stream sediments and panned concentrates are shown in Figures 4 and 5,while no significant concentrations of Au and Ag were obtained in the talus (Fig. 6).

Table 4. Statistical parameters of the studied Stream sediments (SS), Panned concentrates (PC) and Talus samples (TS).

Element	Sample Type	Mean	Median	Std. Deviation	Minimum	Maximum	Percentiles			
							50th	75th	90th	95th
Cu	**SS**	0.43	0.441	0.184	0.131	1.068	0.441	0.539	0.625	0.716
	PC	1.372	1.077	1.744	0.037	8.942	1.08	1.54	2.05	7.57
	TS	0.638	0.441	0.826	0.129	4.004	0.441	0.532	0.784	-
Pb	**SS**	0.77	0.801	0.264	0.153	1.19	0.801	0.986	1.08	1.115
	PC	1.212	1.304	0.647	0.038	2.327	1.304	1.727	2.181	2.313
	TS	0.741	0.778	0.297	0.164	1.2	0.778	1.035	1.13	0.741
Zn	**SS**	0.798	0.827	0.268	0.032	1.425	0.827	0.958	1.151	1.186
	PC	1.206	1.173	0.465	0.207	2.356	1.173	1.461	1.779	2.245
	TS	0.747	0.727	0.156	0.454	1.114	0.727	0.855	0.962	0.747
Ni	**SS**	0.483	0.277	0.455	0.002	1.719	0.277	0.858	1.118	1.228
	PC	0.8	0.747	0.523	0.002	2.03	0.747	1.265	1.47	1.92
	TS	0.472	0.528	0.241	0.065	0.952	0.528	0.673	0.801	0.472
Cr	**SS**	0.515	0.484	0.252	0.049	1.231	0.484	0.732	0.814	0.92
	PC	1.038	0.975	0.639	0.003	2.192	0.975	1.664	1.875	2.134
	TS	0.436	0.39	0.308	0.031	0.99	0.39	0.763	0.899	0.436
Co	**SS**	0.302	0.3	0.091	0.117	0.479	0.3	0.371	0.426	0.457
	PC	0.498	0.502	0.228	0.028	0.91	0.502	0.645	0.805	0.895
	TS	0.259	0.252	0.078	0.141	0.423	0.252	0.313	0.421	0.259
Cd	**SS**	0.097	0.096	0.039	0.034	0.223	0.096	0.118	0.154	0.174
	PC	0.045	0.047	0.028	0.003	0.095	0.047	0.067	0.088	0.095
	TS	0.111	0.117	0.051	0.039	0.232	0.117	0.135	0.169	0.111
Mn	**SS**	5.494	5.752	4.266	0.454	11.68	5.772	10.225	10.73	11.465
	PC	2.9	2.071	3.151	0.525	10.69	2.071	3.712	9.686	10.6
	TS	6.715	7.6	3.948	0.541	11.44	7.6	10.68	11.19	6.715
Ag	**SS**	0.255	0.148	0.32	0.022	1.625	0.148	0.228	0.809	0.978
	PC	0.04	0.029	0.037	0.002	0.128	0.029	0.045	0.107	0.125
	TS	0.087	0.029	0.163	0.006	0.652	0.029	0.057	0.401	0.087
Au	**SS**	0.021	0.009	0.023	0.001	0.091	0.009	0.018	0.063	0.076
	PC	0.652	0.009	1.531	0.002	5.863	0.009	0.313	3.452	5.612
	TS	0.024	0.009	0.023	0.003	0.082	0.009	0.039	0.069	0.024



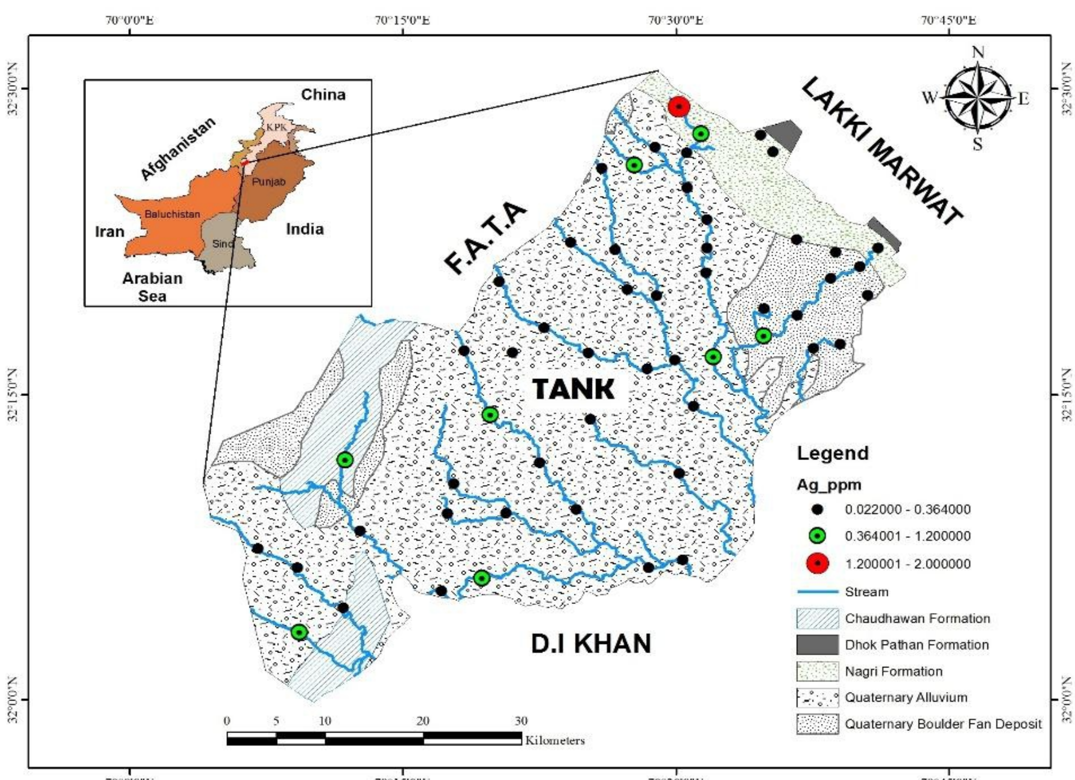
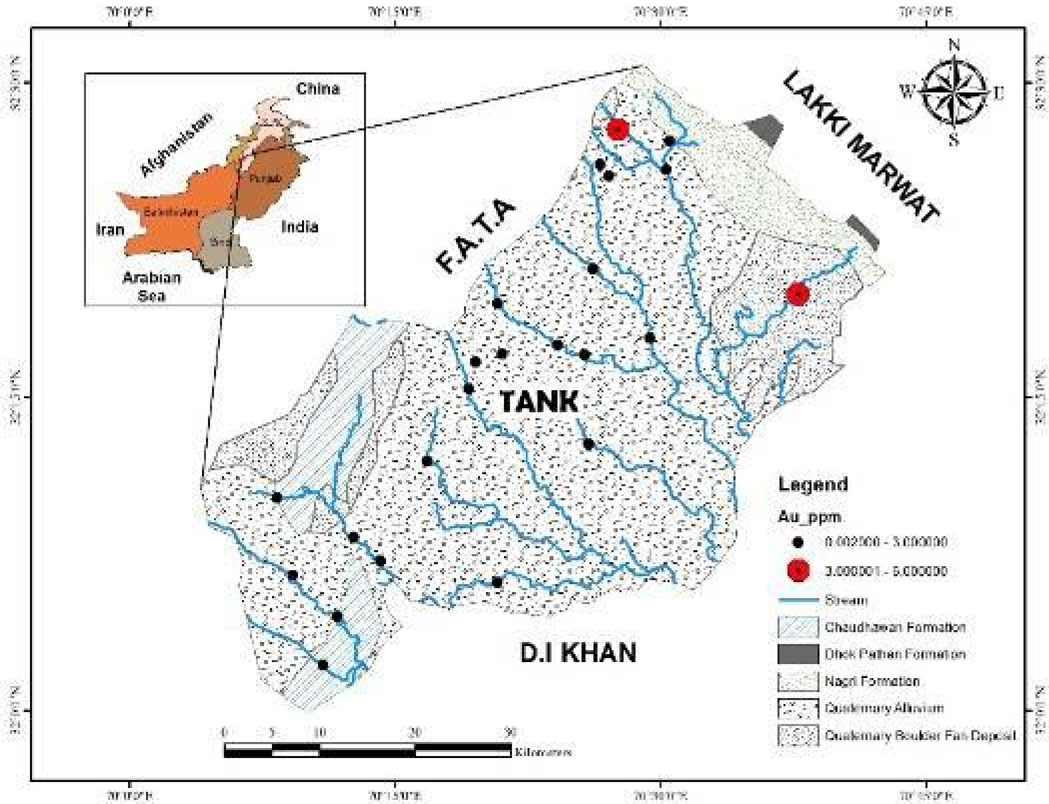
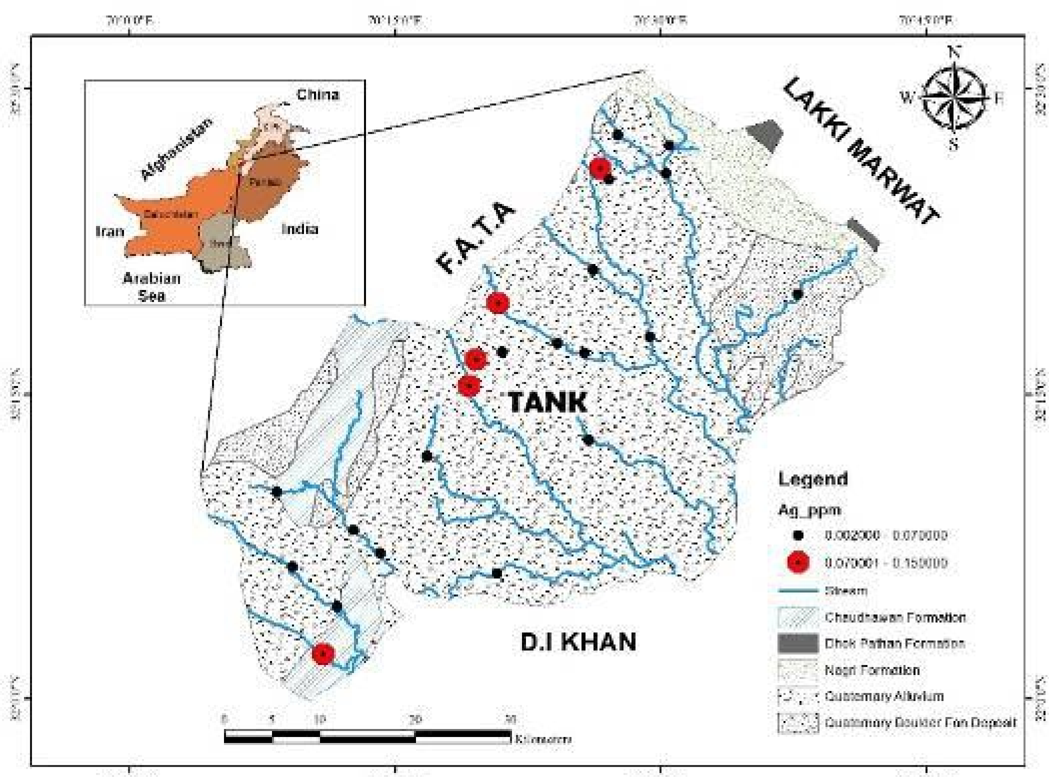
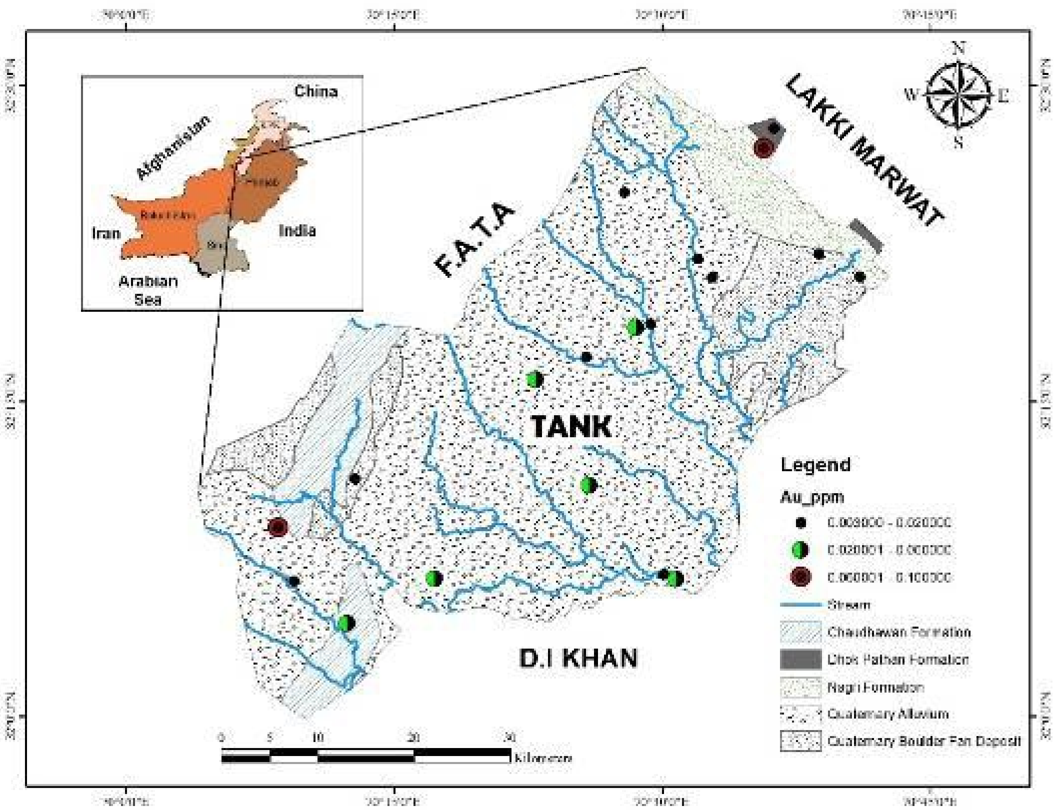


Fig. 4. Geochemical maps of Au and Ag in stream sediments of study area.





.Fig.5. Geochemical map of Au and Ag in panned concentrates of study area.



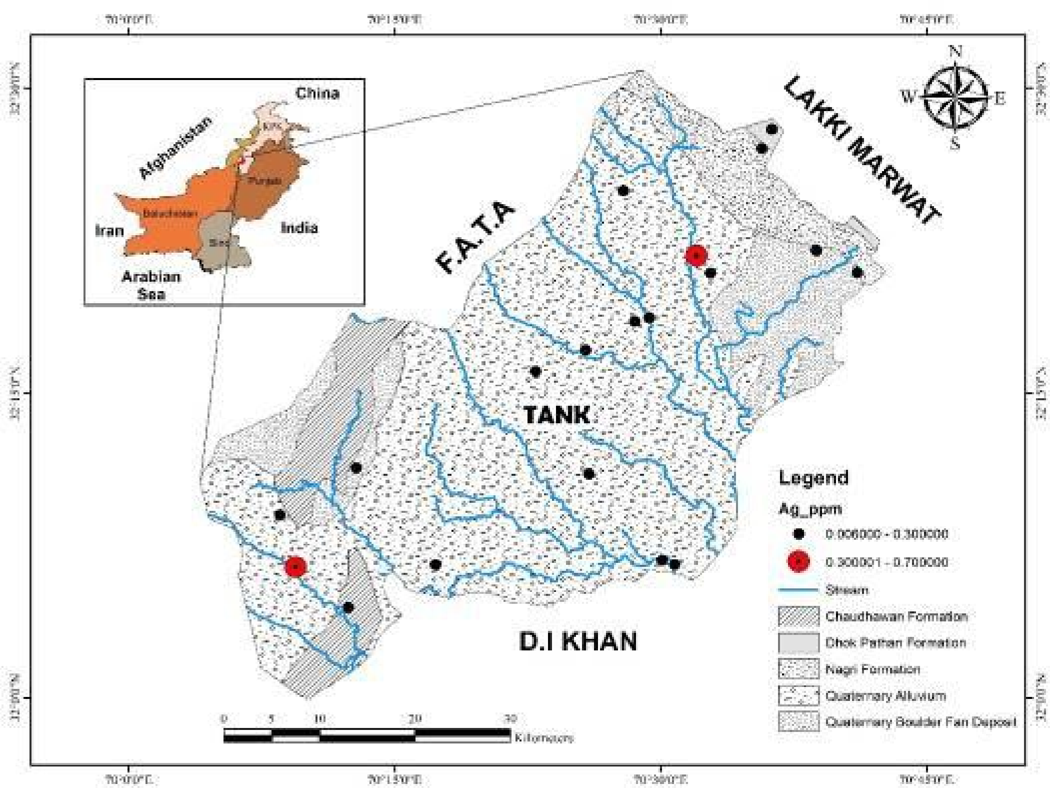


Fig.6. Geochemical map of Au and Ag in talus samples of study area.

Table 5. Summary of important Pearson correlations and Geochemical Association from Factor Analysis

	Important Factor Scores	Pearson Correlation
Stream Sediments	Factor 1 Au-Ag-Cu-Zn-Ni-Co Factor 2Au-Mn-Cr	Cu vs Zn (0.37), Cu vs Co (0.33), Zn vs Co (0.38),
Panned Concentrates	Factor 1 Cu-Zn-Ni-Co Factor 2 Au-Mn-Cr	*Cu vs Pb (.37), Cu vs Zn (0.79),* *Cu vs Ni (0.7),* *Cu vs Co (0.48), Cu vs Ag (0.33),* *Pb vs Zn (0.33), Zn vs Ni (0.88),* *Zn vs Cr (0.40), Zn vs Co (0.71),* Ni vs Cr (0.53), Ni vs Co (0.71)
Talus	Factor 1: Cu-Zn-Ni-Co-Ag Factor 2: Cu-Pb-Au	Cu vs Zn (0.45), Cu vs Ni (0.40), Cu vs Co (0.46), **Cu vs Au (0.44),** **Pb vs Au (0.59),** Zn vs Ni (0.45), Ni vs Co (0.39), Ni vs Ag (0.43), Co vs Ag (0.40)

5. Discussion

5.1.Stream sediment survey as exploration tool

The stream sediment geochemical investigation for identifying significant anomalies of economic mineral deposits is being in practice for many decades with the premise that the stream sediments act as representative of the weathering and erosion products upstream of the sampling locations (Fletcher, 1997; Hawkes, 1957). In the current geochemical survey for gold, silver and base metals, the stream sediments are showing comparatively higher concentrations of gold and silver than that of talus deposits. Although different sampling media like stream sediments, panned concentrates and talus were used for investigating the above mentioned elements but now it is event that the stream sediments act as reliable medium of sample collection. The concentrations of gold, silver and other base metals in stream sediments are solely dependent upon the upstream source lithology (Rose et al., 1979). The accumulation of these elements is due to the weathering, erosion, transportation, sediment sorting and geochemical nature of individual element (Rollinson, 2014).During the sediment transport within the stream channel, the light mineral fractions are swept away in the form of suspension, resulting change in texture and geochemical composition (Fletcher and Loh, 1996).In the current studies provided preliminary exploration information with the existence of placer gold in the District Tank. The investigated area has a well-developed drainage system comprising of the tributaries coming from Tank Zam River and Gomal River. It is evident that there is no primary source of Au, Ag and base metals in the study area and it is considered that the decrease in elemental concentrations of base metals such as Cu, Pb, Zn, Ni, Cr and Co may possibly be due to dissolution factor explained by a model formalized by Hawkes (1976) which explains the relation of the anomaly source to the metal content of the anomalous sample and size of the catchment basin.

5.2. Spatial and Statistical Analyses

The Spatial analysis indicate that anomalous concentration of Au is found in the panned concentrate as compare to stream sediments and talus deposits in district Tank. While low concentration of Ag, Cd and other base metals is evident in all sampling media. Although there is no significant association of Au, Ag, Cu, Pb, Zn, Ni, Co and Cr. However some significant factor scores obtained from factor analysis can give indication for the existence of potential mineral deposits in the vicinity of the study area. The poor correlation of Au and base metals also indicate that gold in the district Tank is of placer origin. The Pearson correlation of panned concentrate samples indicate that there is a positive correlation of Cu with Pb, Zn, Ni and Co, however poor correlation of Au with Cu, Pb and Zn as evident from scatter plot (Fig. 7). Likewise, in stream sediment samples, Cu shows a positive significant correlation with Zn, Cr and Mn and negative correlation with Au and Ag. However, the concentration of all base metals (Cu, Pb, Zn, Ni, Cr and Co etc.) is below background values which indicate no source of mineralization in the study area.

5.3. Relative Concentration of Au, Ag and base metals

The geochemical analyses of stream sediments, panned concentrates and talus deposits show that the concentrations of Cu, Pb, Zn, Ni, Cr, Co and Au are relatively higher in panned concentrate samples as compared to the other two sampled media (Fig. 8). While relatively high concentration of Mn, Ag and Cd is found in the stream sediments and talus as compare to panned concentrates. Therefore panned concentrate provide better sampling media for majority as compare to stream sediments in the study area.

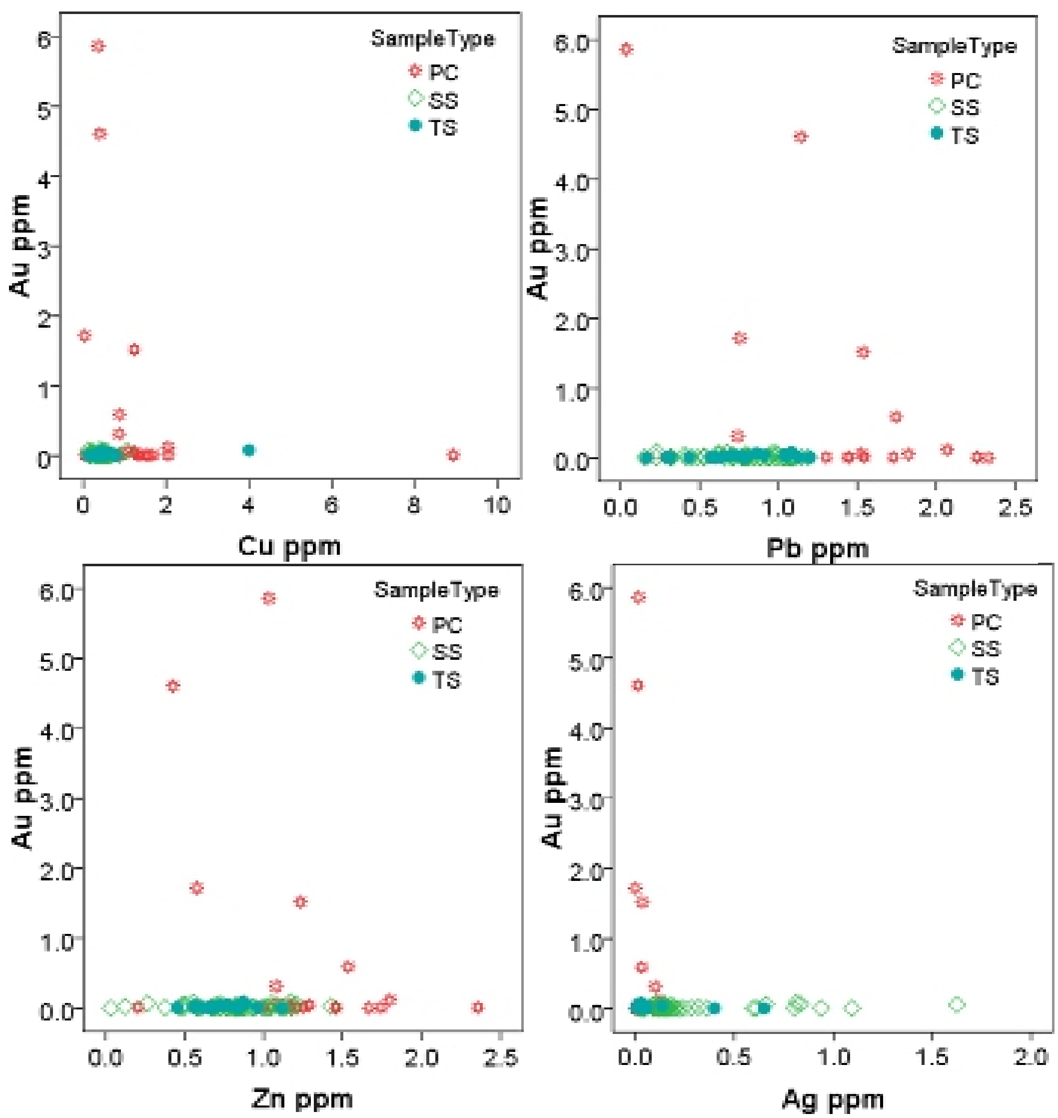


Fig. 7. Scatter plotshowing correlation of various elements in stream sediments (SS), panned concentrates (PC)and Talus samples (TS) from the study area.

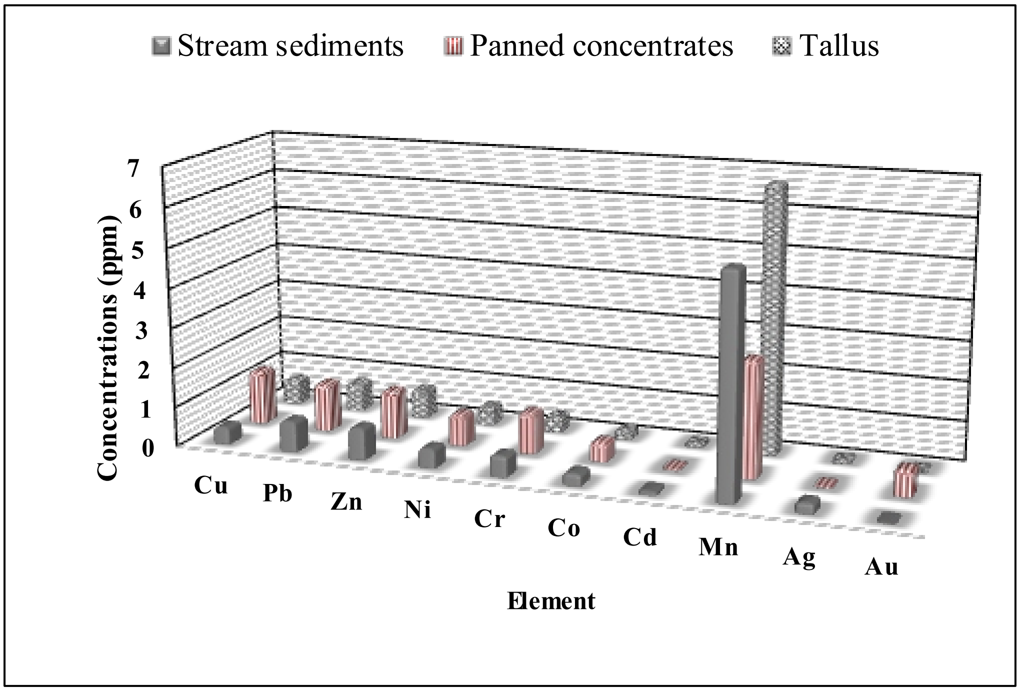


Fig. 8. Histogram showing a comparison between the elemental concentrations determined in stream sediments, panned concentrates and talus samples.

It is generally considered the presence of organic matter in surficial sediments (Wehrmann et al., 2014), the relatively high concentration of Mn, Ag and Cd is due to the high content of organic matter in the stream sediments and talus as compare to panned concentrates. The usefulness of panning or sluicing exploration has already been indicated as the best technique for geochemical exploration of gold and base metals (Shah et al., 2007; Ali, 2011; Ali et al., 2015).

6. Conclusions

The following conclusions are made after the completion of this study;

The stream sediment geochemical survey for exploring economic minerals is the most reliable, less-expensive and worldwide established technique and has successfully used for anomly identification in the current study

- Both the geo-statistical and GIS techniques indicates low association of gold and base metals, while anomalous concentration of gold is found in panned concentrates.
- In addition to the geochemical analysis on Atomic Absorption Spectrometer, panning or sluicing is the best technique for determining the gold concentration in terms of colors, specks or piece.
- The float study of the investigated area suggests that the sediments are mostly of igneous, metamorphic and reworked sedimentary origin.
- In all sampling media panned concentrate provide the best sampling media in the study area as compare to stream sediments and talus.
- It is concluded from the detailed geochemical, geo-statistical and geo-spatial analyses that the Tank area is having low economic potential for gold and silver while no economic potential for base metals.

Authors' contribution

Mr. Raham Jalil – the corresponding author of the research paper has carried out a detailed field work in the study area and collected samples which were then analyzed in the Geochemistry Laboratory of National Centre of Excellence in Geology, University of Peshawar under the kind guidance of Dr. Liaqat Ali. His kind advises and supervision made the compilation of this paper possible. Prof. Dr. M. Tahir Shah contributed a lot in

drafting the manuscript. His constructive criticism and fruitful discussion for completing this laborious work has been invaluable. Prof. Dr. Nimatullah Khattak critically read the manuscript and provided useful suggestions for its improvement. Mr. Asad Khan greatly helped in the software related issues as well laboratory analyses of the samples.

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