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The preliminary investigation and mineral characterization of the Gold and Copper at Gindai Yasin, Ghizer, Pakistan

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Abstract

Gilgit-Baltistan is known for the extraction of placer gold as well as base metals however, no significant work has been done to investigate the host rock. This study is mainly focused on identification of the host rock for metallic minerals of Gindai Yasin, Ghizer district of Gilgit Baltistan, located towards south-west of the Main Karakorum Thrust (MKT), a mega thrust separating Kohistan Island Arc from the Karakoram plate. The Shamaran volcanics consist of heterogeneous basaltic-andesite to andesite and calc-alkaline rock units. Petrographic results indicate that, the rocks of mineralised zone are felsic to mafic in composition, optical analysis showed that these rocks had gone through extrusive hydrothermal alteration. The rocks mostly comprised of metallic minerals include chalcopyrite, malachite, pyrite and azurite. From the geochemical analysis, a significant portion of the sample is basaltic-andesite to andesite in composition, and mineralised zones are mafic to ultramafic. Gold and copper concentrations varies from 2.43–4.76 ppm, and 26800–98600ppm respectively.

Keywords: Gilgit-Baltistan, Gold, Copper, Shamaran volcanics, MKT.

1. Introduction

The precious and base metal deposit in the Tethys collisional zone drew full and successive attention in the economic geology (Yigit, 2009). Gilgit-Baltistan is known for the extraction of different verities of gems stones along with placer gold and base metals along the Hunza and Gilgit rivers and Indus river from many years, but no any considerable work has been done on exploration of the host rock. This study mainly focuses on identifying the host rock for gold and base metals of Gindai Yasin, Ghizer district of Gilgit Baltistan, Pakistan. Gindai copper and gold deposit are located at 36°17′26″ N, 73°28′2″E, above 14 thousand feet from sea level in Gindai Yasin District Ghizer, and west part of Gilgit Baltistan. It is approximately 100 km away from Gilgit city. Gindai copper and gold deposit as typical anatomy in Pakistan, propose through the research of the ore deposit to find out the basic characteristics and its genesis of the porphyry copper deposits. There is no doubt that, the topic of this paper has important scientific significance in mineral prospecting.

2. Regional geology

Gilgit-Baltistan (GB) consists of different type of geological features and settings such as Island arc, Ophiolite belts, and pegmatite which define the geological events and background of the area and its importance. Gilgit-Baltistan constituted of three main tectonic terranes. From south to north, Indo Pakistan plate and Karakoram plate. Kohistan Island Arc is sandwiched between the Indo Pakistan and Karakoram plates and having two main thrust faults. The Main Mantle Thrust separates it from the Indian Plate to the south and Main Karakorum Thrust makes its boundary with the Karakorum plate to the north (Fig. 1; Burg et al., 1998). Mafic-ultramafic and acidic plutons (Pudsey et al., 1985). The Kohistan island arc is composed of volcano sedimentary units include the Chalt volcanics, Shamran volcanics and Yasin sediments. Chalt volcanic composed of boninites, basaltic andesites and tholeiitic meta-basalt (khan et al., 1998; Petterson and Treloar, 2004). The Shamaran volcanic composed of undeformed or less deformed metamorphosed volcanic rocks with thickness of 3 km (Searle et al., 1999), whereas Kohistan batholith is composed of plutons, dykes and sheets of diorites, granodiorite, quartz diorites, gabbros and pegmatites (Kazmi and Jan, 1997). The Karakoram plate composed of Karakoram metamorphic belt, central Karakoram batholith and north Karakoram sedimentary domain (Kazmi and Jan, 1997). The northern sedimentary belt was also called as northern Tethyan metasedimentary zone by different geologists, like Tahirkheli (1982), they categorised this unit into six sub-categories like Kilik Formation, Khyber Series, Misgar Slates, Gojal Dolomite, Passu Slates, Shanoz Conglomerate (Tahirkheli, 1979). The southern Metamorphic belt is lithologically composed of interlayered meta sediments of Darkot Group and dolomitic marble comprising quartz, phlogopite, diopside. MKT and MMT are considered as a mega level faults in Gilgit-Baltistan. It indicates the vast level of collision between the Kohistan island arc and Karakoram plate. This happened in 102-75 million years ago, Matum-Dass dykes age is 75Ma, and they cut MKT. The Matum-Dass granites are oldest rocks, and its age is 102Ma, so the age of MKT must be earlier than 75Ma (Searle and Cox, 1999). According to Khan and Jan (1991) , it is about 1km to 1.5 km wide near the Chalt valley. The MKT dip northwards at 50° according to the gravity data modelling (Kazmi and Jan 1997) . When the Indian plate started drifting northward in the last Jurassic to early Cretaceous time from Gondwana land mass, at that time the Kohistan arc started to form. Now it covers an area of 3600 square kilometres (Tahirkheli, 1979). From south of MKT and north of MMT there are seven major geologic bodies which are as follow: Yasin group, Chalt volcanic, Jaglot Group, Kohistan Batholith, Chilas complex, Kamila amphibolites and Jijal complex. Show them on a geological map of figure 2.

3. Local geology

Gindai Copper mine is located at latitude 36°17′26″ N and longitude, 73°28′2″E, over 4193 meter above the sea level in Yasin, Ghizer district of Gilgit-Baltistan, Pakistan. It is approximately 100 km away from Gilgit city. Four geological formations are crop out in Ghizer district, the Ghizer Formation, Kohistan Batholith, Yasin group and Darkot group (Searle, Khan et al., 1999). The focus of the current research has been mentioned as the Ghizer Formation by Petterson and Treloar (2004). The Ghizer Formation consists of heterogeneous andesite dominant volcanic rocks. Basalts and andesite of the Ghizer Formation of Chalt volcanic group (CVG) are tholeiitic to calc-alkaline but mostly calc-alkaline. As concern to the polarity of subduction, Khan and Jan (1991) and Kazmi and Jan (1997) have concluded that Chalt volcanic have formed over south dipping subduction zone. Chalt volcanic overlies the Jaglot Group in the south and Yasin group in the north (Petterson and Treloar, 2004).

The meta-sedimentary rocks of the Yasin group are a variable proportion of limestone, slates and quartzites. These rocks are intensely sheared and exhibit boudinage structures and schistosity. There is a thick sedimentary sequence exposed along the Yasin River. This sequence belongs to Yasin Group Sediments, sandstone, limestone and shale are present in this sequence in the Yasin valley, and pieces of volcanic material are also present with limestone. Yasin group is approximately 1.5 Km thick in Yasin. The age given to this group is Cretaceous and exposed between Darkot village and Darkot pass. Limestone, quartzite, garnet mica schists are exposed in Darkot group; the group is widespread extending up to Hunza valley and parts of Chitral. These metasediments divided into different groups and given various names such as, Baltit Group, Chalt schist and Hunza schist group (Stauffer and Peng, 1986).

4. Material and method

Twenty random rock samples were collected to investigate the copper and gold mineralization in the Gandai, Yasin deposit with Global Positioning System; GPS points. The samples were crushed and pulverised in the lab using jaw crusher to the size of less than 1 cm, further samples converted into powder form by quartering and conning method. Similarly, ten samples were selected for geochemical analysis in the laboratory. The technique of X-Ray Fluorescence (ED-XRF) was used to identify the major elements concentrations of the Rock samples at the Geosciences Advance Research Laboratories (GARL-GSP), Islamabad, Pakistan.

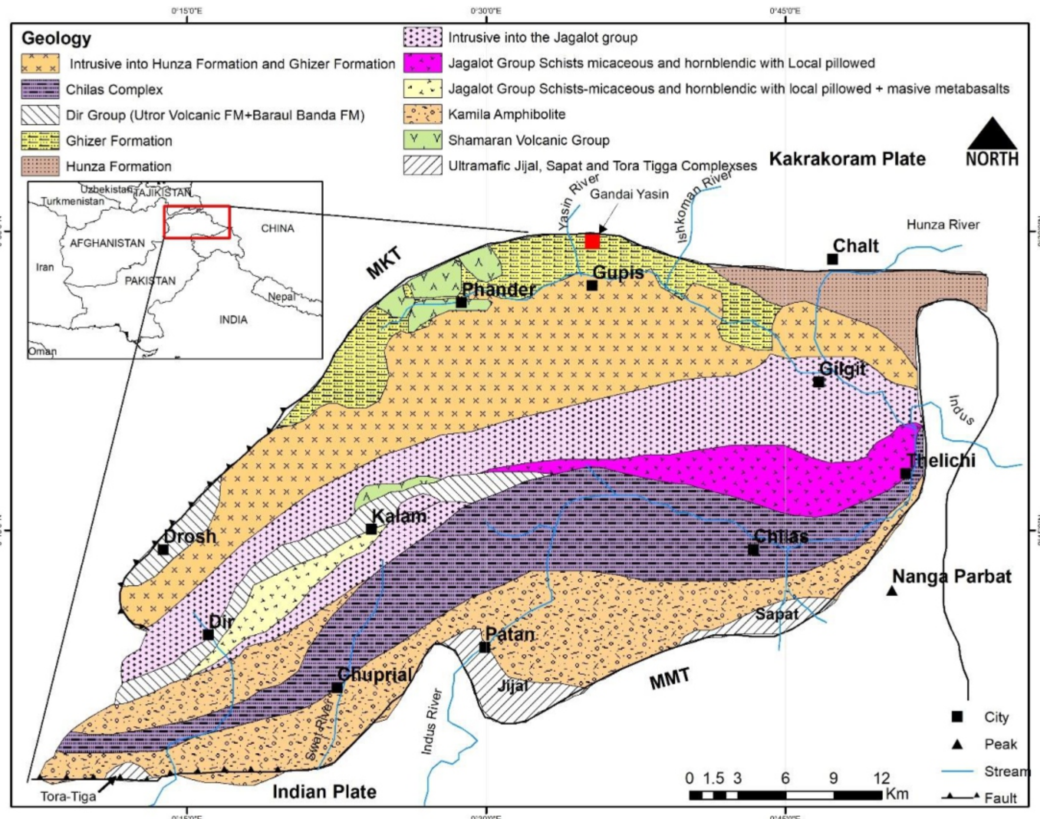

Fig. 1. Geological map of the Kohistan Island Arc (source: modified after Burg et al., 1998). The map showing Jijal ultramafic to mafic complex; Kamila amphibolite; intrusive Chilas Complex; Kohistan Batholith; Jaglot Group; Chalt Groups and Yasin group.

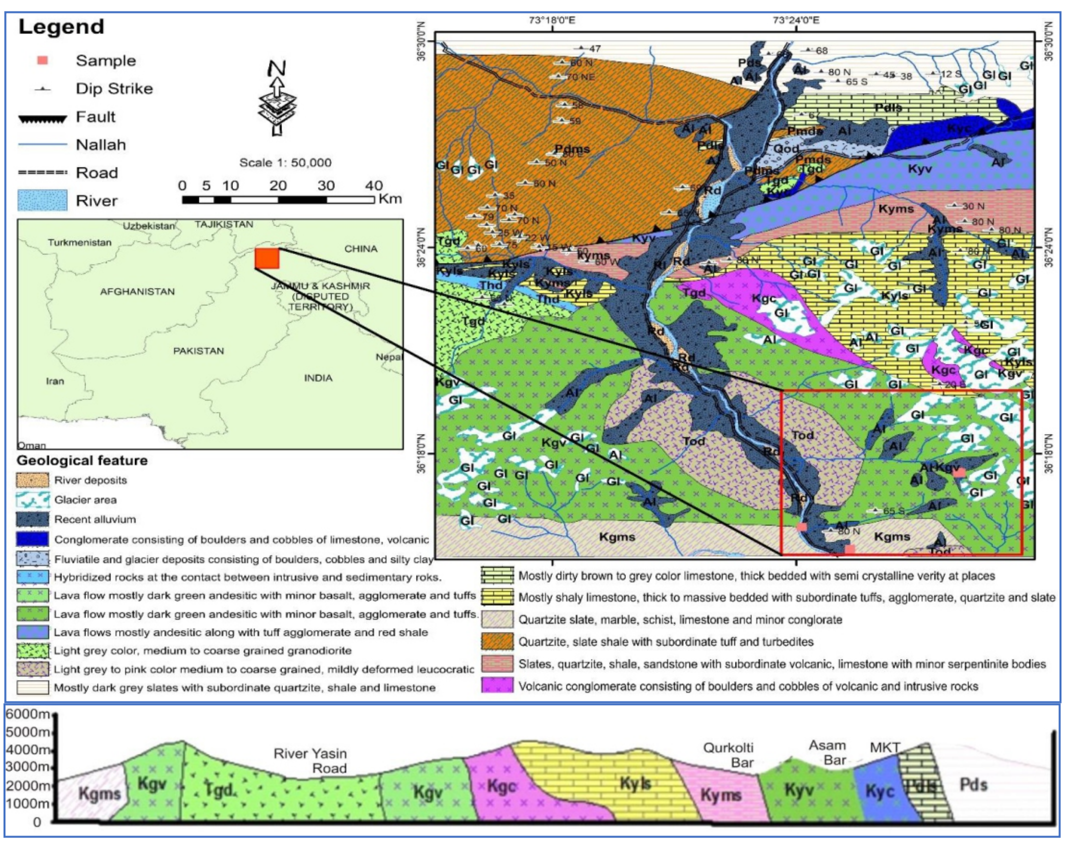

Fig. 2. Geological map of Yasin, Gilgit-Baltitsan, Paksitan. (Source: modified map from Geological map of Yasin quadrangle (42-H/7) scale 1: 50,000; Geological Survey of Pakistan).

Preparation of stock solution for gold is done by taking 1gm of the sample in Teflon beaker with 10 milliliter (ml) of Hydrofluoric Acid (HF). The solution was heated up to one hour and put into nature to cool down. The 20 ml of aqua-regia is to be mixed in a beaker to heat it until it dried. Then the solution is diluted by 50 ml using distilled water. Whatman no 42 filters were used for filtering the solution. To reduced evaporation from the solution, the test tube is covered by polyethene film. At the final sample is ready for further analysis in Atomic Absorption Spectrometer to measure the concentration of gold or desired base metals in the solution.

The geochemical data in the form of weight percentage for major elements oxides and parts per million for gold were analysed by using a different type of statistical analysis tools are called Softer Interpretation. Petrographic software tool was used to classify the rocks by using different type of variation diagrams, such as TAS, Harker, and AFM.

5. Results and discussion

Petrography of the selected rock samples indicates that the samples have been collected from hydrothermal alteration zone. Host rocks of the alteration zones are in the form of mafic in composition. Secondary mineralisation encountered during the optical study shows that these rocks had gone through extensive hydrothermal alteration.

Texturally rocks possess medium to coarse grains with anhedral to subhedral mineral crystals. Significant primary mineralisation includes olivine, pyroxene, amphibole and plagioclase, whereas the secondary mineralisation include calcite, serpentine, chlorite and ore bearing minerals include mostly pyrite, chalcopyrite, malachite and azurite (Fig. 3).

The alteration of olivine and pyroxene forms serpentine and chlorite. However, the presence of calcite and quartz along with metallic minerals indicates the hydrothermal solution has been initiated from a nearby sulfide body.

For the study of geochemistry (Fig. 4), nine samples were selected for lab analysis and classification of rock on the basis mineral composition for gold and copper, results are represented in Table 1.

Major Elements in mineralized zone: The range of SiO_2 is varied from 2.82-27.55 wt.%, TiO_2 has 0.10-0.34 wt.%, Al_2O_3 has 0.21-6.83 wt.%, Fe_2O_3 has 15.74-31.23 wt.%, MnO has 0.95-1.34 wt.%, MgO has 0.21-2.84 wt.%, CaO has 21.72-68.95 wt.%, Na_2O has 0.10-0.31 wt.%, K_2O has 0.03-0.13 wt.%, P_2O_5 has 0.008-0.14 wt.%, SO_3 has 2.88-8.83 wt.%, CuO has 3.36-12.35 wt.%, and LOI has 0.47-21.35 wt.%. The results of composition suggest that the primary mineralization includes olivine, pyroxene, amphibole and secondary mineralization include calcite, quartz, serpentine, chlorite and ore minerals include malachite and chalcopyrite, pyrite. The thin sections of the ore samples are studied under reflected light microscope/ ore microscope to identify the different types of base metals. The percentage of olivine, pyroxene and amphibole are more than other minerals and are the primary minerals depict that the rock samples are mafic to ultra-mafic in composition.

The major oxides against SiO_2have been plotted in Harker type variation diagram (Fig. 6) to analyze the variation during differentiation. The concentration of major elements in the samples ranges as SiO_2 is 53.31-63.1 wt.%, TiO_2 as 0.31-1.08 wt.%, Al_2O_3 is 13.2-21.33 wt.%, Fe_2O_3 range from 6.9-8.66 wt.%, MnO is 0.02-0.36 wt.%, MgO is 1.79-4.64 wt.%, CaO shows the percentage from 4.46-11.46 wt.%, Na_2O is 1.27-3.94 wt.%, K_2O has 0.54-2.75 wt.% and P_2O_5 has 0.11-0.39 wt.%. The results suggest that the major part of Shamaran volcanic are basaltic-andesite to andesitic in composition. The composition suggests that the volcanics are quartz-normative with a high concentration of plagioclase.

The TAS (after Le Bas et al.1986), diagram is used to classify the rocks by total alkali versus silica content. Before classification, the chemical analyses must be recalculated to 100% excluding water and carbon oxide. The rock samples fall in the field of basaltic-andesite to andesite, more samples are plot in dacite by total alkali versus silica diagram.

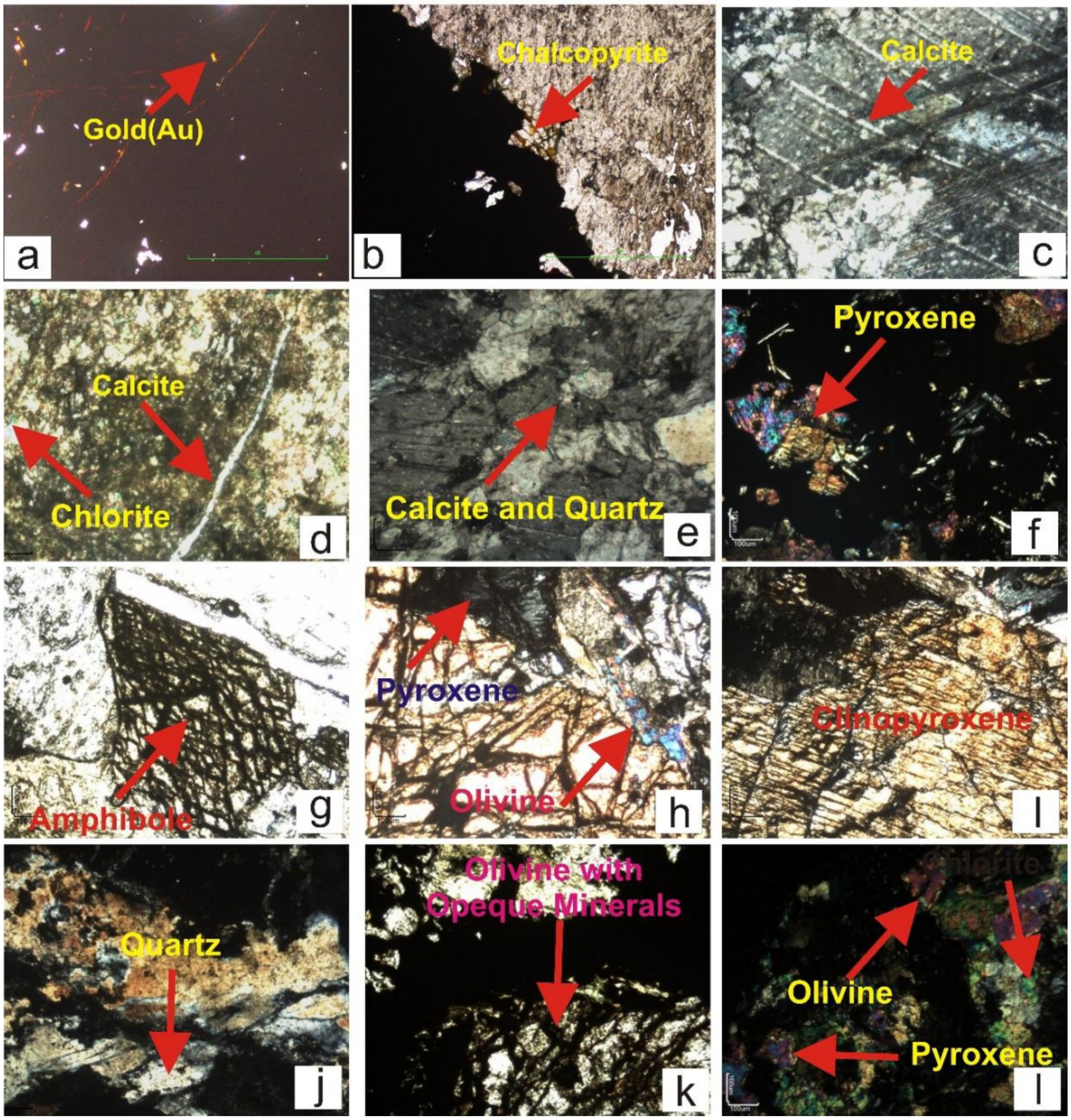

Fig. 3. Samples pictures of the thin sections (a) Gold (Au) represented in yellow color of thinsection (b) Chalcopyrite in yellowish color (c) Clear 120 angle cleavages in calcite an example of primitive cleavage because the polar cleavage plane of calcite consists of separate layers of Ca and carbonate ions. The basis vectors of the calcite cleavage plane span a primitive cel(d) Alteration of pyroxene into serpentine can see few unaltered grains like in the center-left a calcite vein is clearly visible in the centre of the image, (e) calcite along typical twins and a quartz grain in the center-right of the image, and (f) opaque material is of sulfide minerals mostly pyrite. A typical twin of pyroxene can be seen on the centre left of the image typical pyroxene interference colours are visible, (g) A large grain of amphibole with 120-degree cleavages in the centre, (h) olivine grain with fractures. Pyroxene grains are also present along with chlorite on the center top of the image, (i) A large grain of clinopyroxene with almost right-angle cleavage, (j) quartz grain indicating andalusite extension, opaque minerals are of sulfides mostly pyrite, (k) olivine along with opaque minerals and (l) olivine minerals with their typical 3rd order interference colour few pyroxene grains are also visible along with pyrite.

Table 1. Geochemistry of the rocks of mineralized zone and Shamaran Volcanics.

Sample	YN-1	YN-2	YN-4	YN-6	YNG-12	YNG-13	YNG-14	YNG-15	YN-4A
SiO_2	27.55	2.82	16.76	23.76	58.42	53.31	62.13	63.1	54.62
TiO_2	0.30	-	0.10	0.34	0.42	0.76	1.08	0.31	1.03
Al_2O_3	6.83	0.21	2.79	5.39	13.2	19.83	16.46	14.35	21.33
Fe_2O_3	31.23	15.74	23.83	22.39	8.35	8.66	6.22	7.5	6.9
MnO	1.23	1.16	0.95	1.06	0.36	0.18	0.11	0.2	0.13
MgO	2.02	0.21	2.01	2.84	3.94	4.65	1.79	3.96	2.22
CaO	21.72	41.96	31.91	30.09	11.46	5.66	4.46	7.22	7.76
Na_2O	-	-	0.31	0.10	1.27	3.94	3.82	1.3	3.56
K_2O	-	0.03	0.13	0.04	0.54	2.27	2.75	0.57	1.34
P_2O_5	0.14	0.01	0.03	0.10	0.11	0.27	0.41	0.12	0.12
SO_3	4.33	4.96	8.83	6.71	-	-	-	-	-
CuO	3.36	11.56	12.35	6.88	-	-	-	-	-
LOi	1.3	21.35							

According to TAS diagram sample number 4 and 13 rocks are basaltic andesite, sample 12 rock is andesite, and sample number 14 and 15 rocks are dacite (Fig. 5). Harker variations or bi-variant (x-y) diagram, represents the variations in two oxides of elements. This diagram gives the concept of the Bowen reaction series. Harker or Binary diagram for major elements has been plotted in (Fig. 6). In which we can see the variation trends of major oxides during differentiation of magma.

The samples of Shamaran volcanic are plotted in this diagram shows the decreasing trend of Fe2O3, MgO and CaO while Na2O, K2O and P2O5 show increasing with increasing SiO2. These characteristics are well-matched with calc-alkaline rocks. The sample plotted in Harker diagram represent that the Fe2O3, MgO and CaO show increasing trends while Na2O, K2O and P2O5 show decreasing with decreasing SiO2, which represent the rocks are tholeiitic. The nature of these rocks are also confirmed from the AFM diagram (Fig. 7).

This diagram is representing magmatic series which is further divided into tholeiitic and calc-alkaline series. These series are common in oceanic ridges and convergent margins. In this Fe increased while alkali decreases.

These series are mostly found in convergent margins, moderately alkaline, more magnesium. The samples of the mineralised zone are plotted in the region of both tholeiitic and calc-alkaline while the samples of Shamaran volcanic are plotted in the region of calc-alkaline series. It depicts that the rock type formed in the typical island arc type of setup related to subduction. The AFM ternary diagram is shown in (Fig. 7).

The mineralised zone in the study area is identified during fieldwork. Samples were collected for a geochemical concentration of gold and copper (Fig. 9), and finding outsources rock for these metals. Atomic absorption spectroscopy technique used to determine the concentration of gold and copper. The concentration of gold and copper are present in table 2. The concentration of gold varies from (2.43-4.76 ppm), and the concentration of copper varies from (26800-98600 ppm). The concentrations of gold and copper are also shown in the graph (Fig. 8).

Fig. 4. Samples pictures of shamaran volcanic for geochemistry.

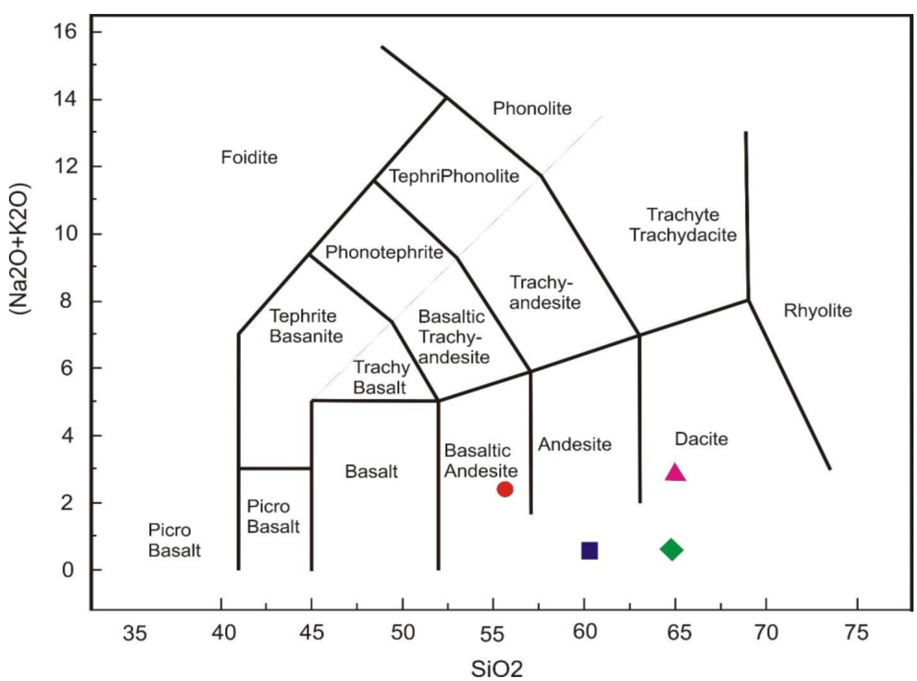

Fig. 5. TAS diagram (after Le Bas et al., 1986) for volcanic rocks of study area Andesite, Basaltic Andesite,Dacite, Dacite, Basaltic Andesite

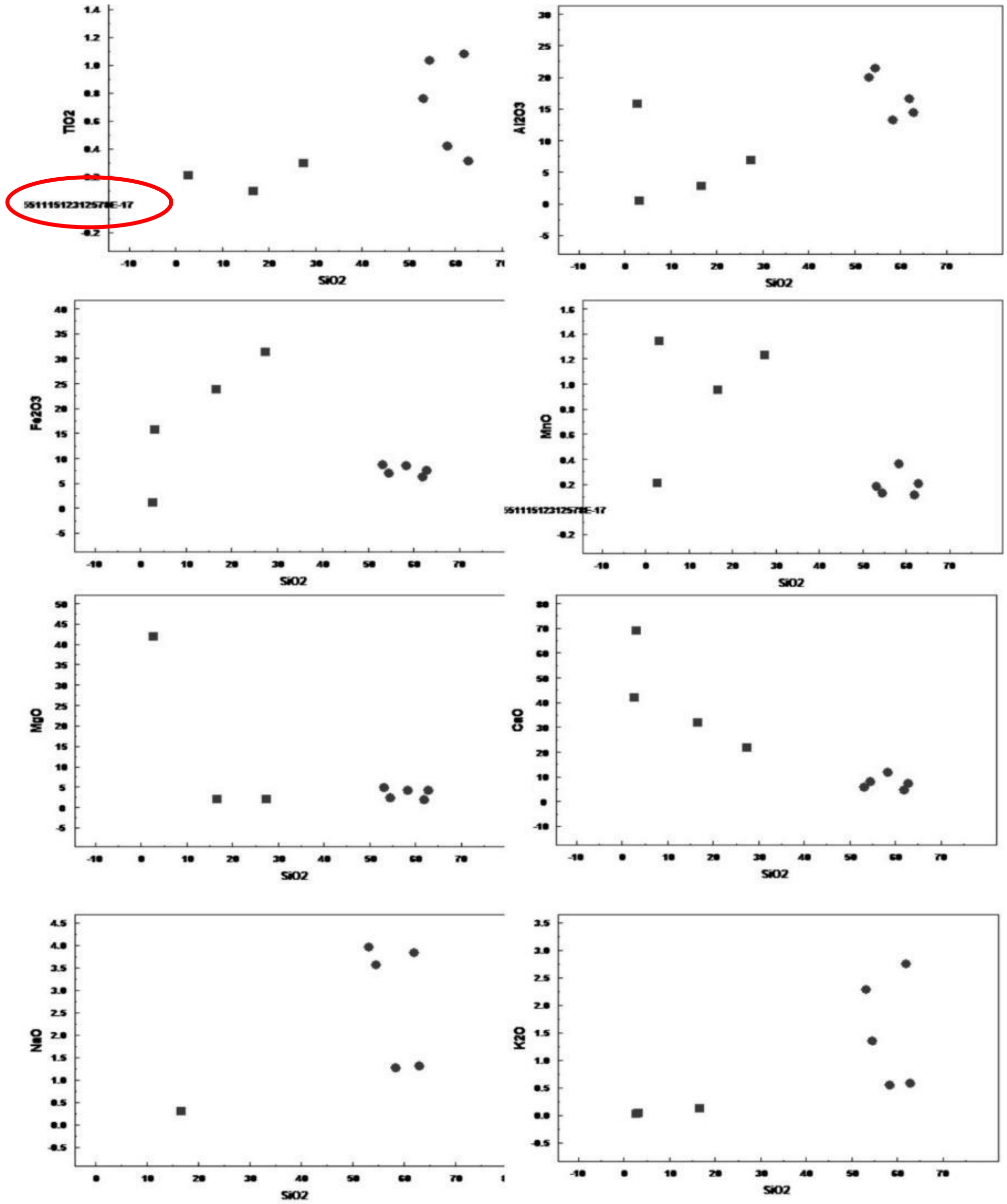

Fig. 6. Harker type variation diagrams for major oxides against silica showing fractionation trends in the volcanic rock of study area ■ = Mineralized zone ● = Shamaran volcanic.

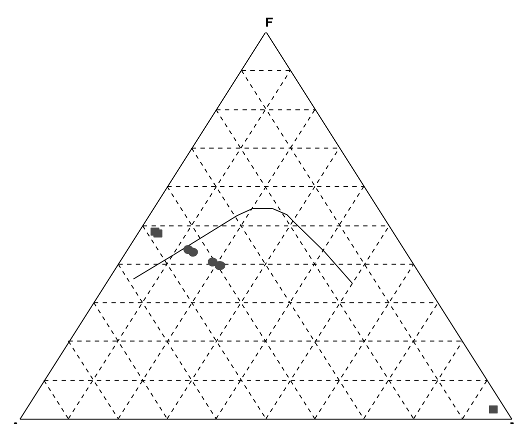

Fig. 7. Plotting of rocks of the study area in AFM (diagram after Irvin and Barager, 1971) discriminating between tholeiitic and calc-alkaline rock■= Parent ● = Shamaran volcanic.

Table 2. Gold and copper concentrations in the mineralised rock of the study area.

Sample No.	Gold (ppm)	Gold (%)	Copper (ppm)	Copper (%)
GY-1	3.15	0.000315	26841.86	2.68
GY-2	2.43	0.000243	92348.79	9.23
GY-3	4.76	0.000476	98659.83	9.87
GY-4	3.45	0.000345	95674.93	8.87
GY-5	2.65	0.000265	36841.67	9.20
GY-6	3.65	0.000365	98657.34	9.12

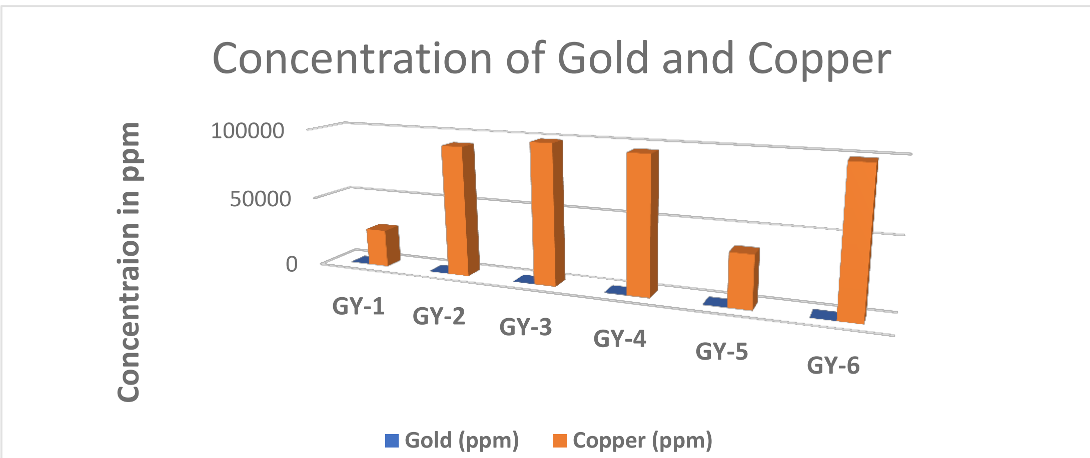

Fig. 8. Diagram showing the enrichment of gold and copper in the mineralised rock of the study area.

As the graph (Fig. 8) depicts that the concentration of gold in the mineralised zone is economically viable for mining. Therefore, the mineralised zone/hydrothermally altered zone in the study area is may the source rock for gold which was aimed in the proposed study.

Different discrimination diagrams ware plotted to find the petrogenesis of magma generation in a tectonic setting. The ternary plot is used to find out the difference between tholeiitic and calc-alkaline magma in AFM diagram (after Irvine and Barager 1971) shown in (Fig. 6), having the line divide between two environments. Major elements make this plot differentiation includes total alkalis, iron oxide and magnesium oxide. The samples from Shamaran volcanic were plotted in the field of calc-alkaline, which represent the rocks formed in typical island arc type setup related to subduction.

The samples from the mineralised zone were plotted in the field of tholeiitic environment. Which represent that the magma is formed in deep subduction zone due to the melting of ultramafic rocks.

Petrographic results of the collected samples are composed mostly of olivine and pyroxene, which implies that the rock is mafic to ultra-mafic composition and the geochemical results represent that rocks of Shamaran volcanic are basaltic andesite to andesite. The variation diagram was used to analyse the tectonic settings of magma generation. Gindai Gold and copper ranges are varying from 2.23-4.76 ppm and 26800-98600 ppm respectively. The rock formed in the subduction related environment are conducive for the formation of metallic mineral deposits.

Fig. 9. Gindai copper and gold deposit, secondary mineralization of malachite in fractures.

6. Conclusion

Mostly copper deposits are formed at convergent type boundaries at a depth of 1-4km. Here in Gindai gold and copper deposit in Tethys belt is due to the syn-collisional, post-collisional environment and the collision of the Indian plate with the Kohistan Island Arc, where the activity of oceanic subduction has disappeared ore-bearing magma, especially the required water, sulfur and metal sources for the ore-forming process cannot be migrated from the oceanic subduction traditionally. Geologically the area falls in between Kohistan Island Arc and Karakoram plate separated by Main Karakoram Thrust (MKT) fault. The area is mostly covered by the rock of Kohistan batholiths, Yasin group, Greenstone complex and Darkot group.

The results of the present study describe that,

i. The primary mineralization of the mineralized zone includes chalcopyrite, pyrite, olivine, pyroxene, amphibole, as well as the secondary mineralization includes calcite, quartz, serpentine, chlorite and malachite, and trace amount of gold particles were also found in the study area.
ii. The geochemistry of the Shamaran volcanic are classified into Basaltic-Andesite to Andesite in composition.
iii. The variation diagrams clear that the rocks of Shamaran volcanic are calc-alkaline; however the rocks of mineralised zone/hydrothermal zone are tholeiitic in composition.
iv. The concentration of the gold varies from 2.43-4.76 ppm; similarly, copper concentration varies from 26800-98600 ppm.
v. The study suggests that the concentration of these metals is economically minable.

Authors' Contribution

Javed Akhter Qureshi, developed main concept of research and supervised the whole study involved in writing manuscript. Kamran Ali, assisted in writing and establishing graphs and maps. Shukoor Murad helped in modification and editing of writing. Arif Ali, collected field data. Manzoor Ali did provision of relevant literature, and review. Garee Khan did mapping and graph designing. Muhammad Alam, did review before submission and proof reading of the manuscript.

References

Burg, J. P., Bodinier, J. L., Chaudhry, S., Hussain, S., Dawood, H., 1998. Infra-arc mantle-crust transition and intra-arc mantle diapirs in the Kohistan Complex (Pakistani Himalaya): petro-structural evidence. Terra Nova-Oxford, 10(2), 74-80.

Kazmi, A. H., Jan, M. Q., 1997. Geology and tectonics of Pakistan, Graphic publishers.

Khan, M. A., Jan, M. Q., 1991. An interpretation of the Himalaya-Karakoram region of Pakistan in the light of plate tectonics and rock ages. Pakistan Journal of Geography, 1.

Petterson, M. G., Treloar, P. J., 2004. Volcanostratigraphy of arc volcanic sequences in the Kohistan arc, North Pakistan: volcanism within island arc, back-arc-basin, and intra-continental tectonic settings. Journal of Volcanology and Geothermal Research, 130(1-2), 147-178.

Pudsey, C. J., Coward, M. P., Luff, I. W., Shackleton, R. M., Windley, B. F., Jan, M. Q., 1985. Collision zone between the Kohistan arc and the Asian plate in NW Pakistan. Earth and Environmental Science Transactions of The Royal Society of Edinburgh, 76(4), 463-479.

Searle, M., 1999. The tectonic evolution of the Kohistan-Karakoram collision belt along the Karakoram Highway transect, north Pakistan. Tectonics 18(6), 929-949.

Searle, M., Cox, J., 1999. Tectonic setting, origin, and obduction of the Oman ophiolite. Geological Society of America Bulletin, 111(1), 104-122.

Stauffer, P. H., Peng, L. C., 1986. Late Paleozoic glacial marine facies in Southeast Asia and its implications.

Tahirkheli, R. K., 1979. The India-Eurasia suture zone in northern Pakistan: Synthesis and interpretation of recent data at plate scale. Geodynamics of Pakistan: 125-130.

Tahirkheli, R. K., 1982. Geology of the Himalaya, Karakoram and Hindukush in Pakistan. Geological Bulletin, University of Peshawar, 15, 1-51.

Yigit, O., 2009. Mineral deposits of Turkey in relation to Tethyan metallogeny: implications for future mineral exploration. Economic Geology, 104(1), 19-51.