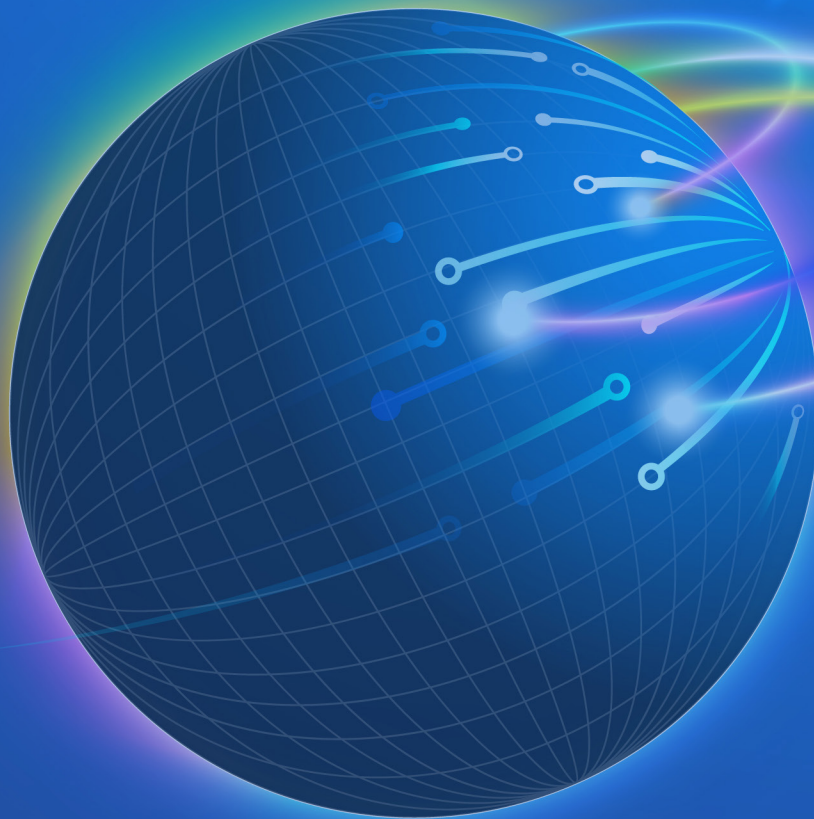




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The Minerals That Make Up the Eastern Part of the Balkhab Copper Mine and Its Nearby Rocks

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ABSTRACT

Balkhab copper mine is located in the Balkhab district of Saripul province in the Mir Sayed Murad region at coordinates E 66°46' and N 35°35'. It is approximately 150 kilometers away from the center of Saripul province and is one of the largest copper mines in the world. The studied area is depicted on the geological map of Balkhab, along with the locations of the collected samples. The purpose of this research is to determine the characteristics of the minerals comprising of the western part of the Balkhab copper mine and its neighboring stones. To write this article, In addition to field and laboratory analyses, a number of other resources mentioned in the references have been used to complete this article. The samples taken from the copper ores were subjected to mineralogical-petrographic and geochemical analysis. This research reveals that the fundamental minerals constituting the copper ore in this area include feldspar, quartz, copper, amphibole, plagioclase, pyroxene, and iron oxide. Additionally, trace amounts of other minerals, such as pyrite, biotite, and OPECs, are present. From the geochemical study, it is seen that in addition to copper, other elements such as Silicon (Si), Sulfur (S), Iron (Fe) and Aluminum (Al) are also included in the composition of copper ore, but their amounts vary. These minerals are predominantly associated with andesitic rocks, including rhyolite, basalt, and dickite. Furthermore, sedimentary rocks like sandstone, pyrite clay, and silicic clay also contain copper minerals. The results obtained from mineralogical-petrographic analysis consistently support the same findings across various studies.

INTRODUCTION

Mines represent national treasures and valuable economic infrastructure in every country. Their role in production and industrial development is crucial, contributing significantly to the national economy. Afghanistan, our dear homeland, boasts abundant natural resources that underpin the country's industry, agriculture, and economy. Despite its vast mineral wealth, much of Afghanistan's resources remain untapped and require further detailed study. Notably, copper mines have been identified in several provinces of Afghanistan, including Saripul, Logar, Herat, Farah, Kapisa, Kandahar, Zabul, and Kabul. Among these, four prominent mines, Ainak, Balkhab, Shida, and Zarkashan stand out as significant contributors to the country's mineral wealth (Abdullah, 1977).

LITERATURE REVIEW

The Balkhab copper mine, situated in the Balkhab district of Saripul province within the Mir Sayed Murad region, ranks as one of the world's largest copper mines. Its formation occurred during the Lower Carboniferous and Upper Triassic periods, resulting from the folding and deformation of the Harsin formations of the Kalchidani group and the massive sulphidic volcanic rocks, located in the northern Afghanistan base platform (Doebrich, 2006). Balkhab copper mine was discovered in 1972 by Afghan and former Soviet Union geologists and contains 1.66 percent pure copper. It spans 400 meters in width

and approximately 5000 meters in length, with estimated reserves exceeding 150 million tons of copper ore (Mikhailov, 1967).

The Balkhab mine has been studied by geologists of the Afghanistan Geological Survey (AGS) and the United States Geological Survey (USGS), which is very interesting and important in terms of geological structure (Kafarskiy, 1972). The mine was contracted to the US Geological Survey (USGS) in 2002 and, along with other mines in Afghanistan, was remotely surveyed and mapped (Orris & Bliss, 2002).

In 1972, 1973 and 1977, Soviet geologists conducted extensive research on the Balkhab copper mine and drew its geological sketch. Later, the Balkhab area was mentioned by Abdullah Sharq and others in 1977 as a copper mineral phenomenon. Subsequent research by the Economic and Social Commission for Asia and the Oceania in 1995, the Japan Metal Mining Agency, the US Geological Survey in 2002, and Doebrich and Peter in 2006 showed that the Balkhab copper mine has massive mineralized copper deposits of copper origin and is related to the origin of the Hydrothermal metasomatic subvolcanic formation and volcanogenic mineral rocks are massive sulphides.

The maps and reports of former Soviet experts show that the Balkhab area was formed in the Ordovician period ≈450 million years ago and contains sandstones and siltstones, and younger rocks were formed by unfavorable

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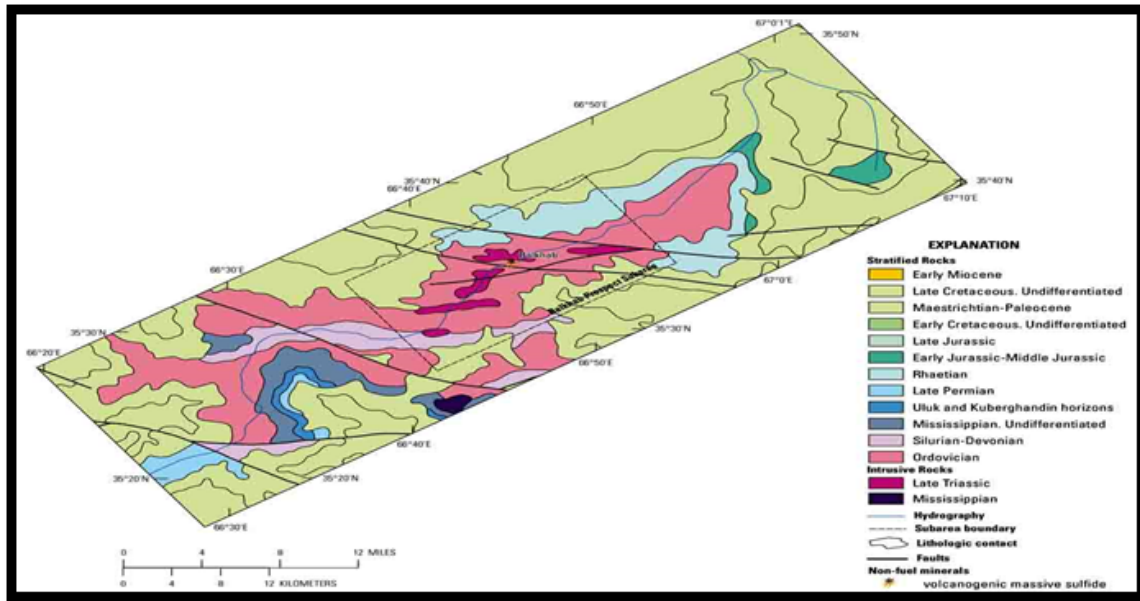


Figure 1: Geological map of Balkhab copper mine prepared by GIS program

layers of young sedimentary rocks of the Jurassic period 120-200 million years ago (Abdullah, 1977).

The research findings from samples taken at the Balkhab copper mine indicate the presence of several minerals in addition to copper. These minerals include feldspar, quartz, sulfur, amphibole, plagioclase, pyroxene, iron oxide, and trace amounts of other elements (referred to as OPECs) in varying percentages.

Research Topic

Petrography is the science of studying various rocks, focusing on the diverse rock types that constitute the Earth's crust. Petrography employs several methods to investigate stones, with thin section preparation being particularly significant. Further studies delve into mineral composition, including major, minor, accessory, and secondary minerals, as well as mineral size, mutual relationships, structure, texture, and microscopic characteristics.

Fourteen samples were collected from the study area to assess mineral composition. These samples were carefully

labeled, noting the sample's location, date, and purpose. Each sample was securely packed in specialized plastics and transported to the laboratory for thorough analysis. In different parts of the study area, specific samples were individually examined using specialized equipment to identify the minerals present. The results are detailed below.

METHODOLOGY

For this article, we employed library, field, and laboratory methods. In the library method, we utilized books, reports, and magazines available in the libraries of Jawzjan University and Saripul Higher Education Institution. The field method encompassed various tasks, including sample collection and the study of geological processes occurring in the field. Field research on the copper ore rocks involved the use of equipment and hand tools, such as GPS, tape measures, hammers, pens, and pre-prepared notebooks for note-taking. Additionally, we used a camera, loupe, sulfuric acid, and a mountain compass. The images below depict some of our field activities.

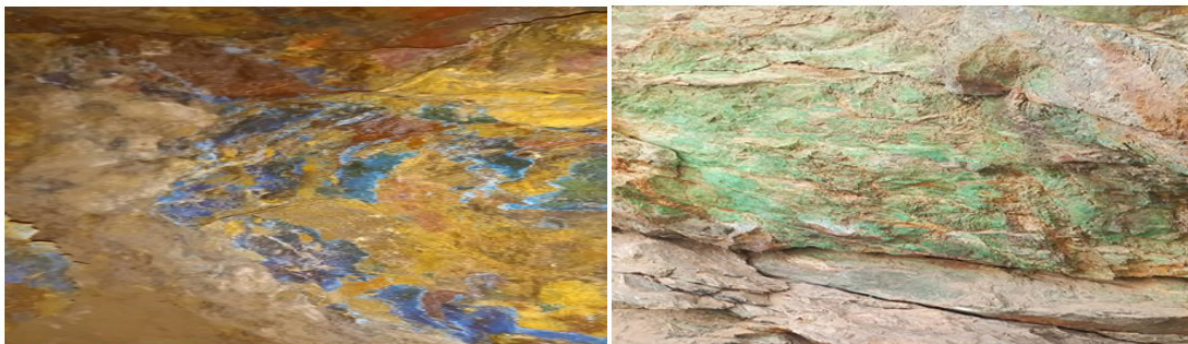


Figure 2: A view of the expansion of copper ore in the Mir Sayed Murad area of the Balkhab district

Laboratory Research Procedures

During laboratory research, the samples were systematically numbered and recorded in the database. Subsequently, each sample underwent thorough analysis and investigation.

For analysing by the device, 14 samples were transferred to the Geological Survey Department of the Ministry of

Mines and Petroleum on 1402/07/01 and were studied by petrographic and XRF methods and the results of all 14 samples were compared, the results of which were conducted by the analysis machine, indicating the conformity of the results and indicating the accuracy of the tests. Additional laboratory activities are depicted in the images below.



Figure 3: The flow of laboratory work on the copper sinks of Balkhab

Description of Sample Number (3)

The sample under study is copper, and it represents high-quality copper. Mineralogical studies reveal that the mentioned sample consists of approximately 90 percent copper, feldspar, quartz, and sulfur minerals, with less than 10 percent iron oxide minerals and other opaque minerals (referred to as OPECs). Structurally, the copper ore exhibits a slightly elongated form and a schist texture. The sample displays a pleasing color, and if cut and polished, it will yield a very high-quality stone.

Mineralogical-petrographic studies of copper minerals are essential to investigating, evaluating, and analyzing the relationship between copper minerals and nearby rocks. Accordingly, samples were collected from the

copper minerals and adjacent stones, and subsequently, the mentioned samples underwent mineralogical-petrographic analyses.

Microscopic observations were conducted using a petrographic microscope (Leica DM750P). An eyepiece with 63X magnification and an objective lens with 40X magnification were employed to assess the size of calcite particles and crystals. Additionally, two Nicols were used to detect minerals with high interference colors and enhance observations of mineral characteristics and torque angles. The slide prepared from the mentioned stone sample was examined using a Leica microscope manufactured in Germany, and its characteristics and results are outlined in the table below:

Table 1: The results of petrographic studies of sample number (3)

Microscopic characteristics					
Color	Degree of nerosion	Porosity	Cover	Against acids	
Yellow, gray, colorless, and brown	Does not have	Does not have	Does not have	Has resistance	
Mineral composition				Stone building	
Major minerals	Amount in percentage	Minor minerals	Amount in percentage	Structure	Slightly stretched
Feldspar, quartz, copper and sulfur	90	Iron oxide	7	Texture	Shale
		OPECs	3	Matrix	Does not have
				Vacuum	Does not have
The origin of the stone		Metamorphic			
Geological characteristics					

Asthma	Petrographic class
Shale with copper azurite and sulfur	Copper ore

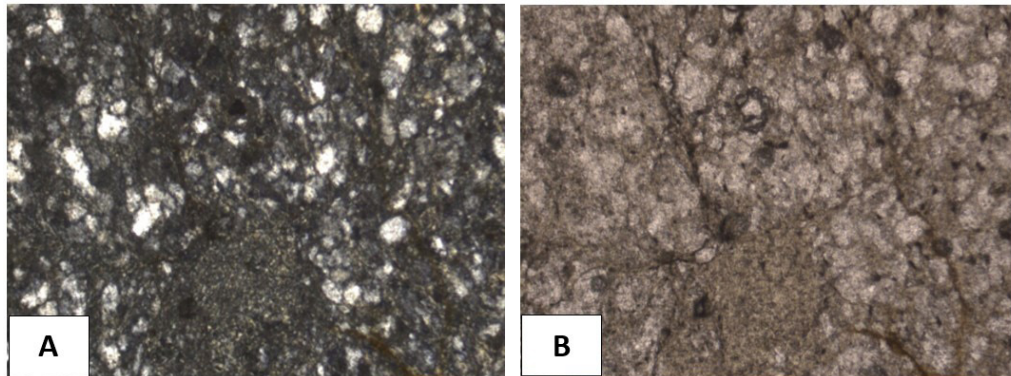


Figure 4: Petrographic characteristics of different sections of the sample (3) are shown in the figure

A: Under two Nicols (XPL) with a magnification of 40x, the diameter of the field of view is 2.5 mm.

B: under a Nicol (PPL) at 40x magnification, the field of view diameter is 2.5 mm.

Description of Sample Number (15)

The stone under study is copper, and it represents high-quality copper. Mineralogical studies show that

the mentioned sample is composed of approximately 90 percent quartz, iron oxide, and calcite, with less than 10 percent biotite and opac minerals seen in their composition.

Structurally, the copper ore exhibits a slightly elongated form and a Granoblastic texture. The mentioned sample has a very nice color, and if it is cut and polished, a very high-quality stone will be obtained from it. The slide

Table 2: The results of petrographic studies of sample number (15)

Microscopic characteristics					
Color	Degree of erosion	Porosity	Cover	Against acids	
Yellow, gray, and white	Does not have	Does not have	Does not have	Has resistance	
Mineral composition				Stone building	
Major minerals	Amount in percentage	Minor minerals	Amount in percentage	Structure	Slightly stretched
Quartz, iron oxide, and calcite	90	Biotite	5	Texture	Granoblastic
		OPECs	5	Matrix	Does not have
				Vacuum	Does not have
The origin of the stone		Metamorphic			
Geological characteristics					
Asthma			Petrographic class		
Quartzite with copper			Copper ore		

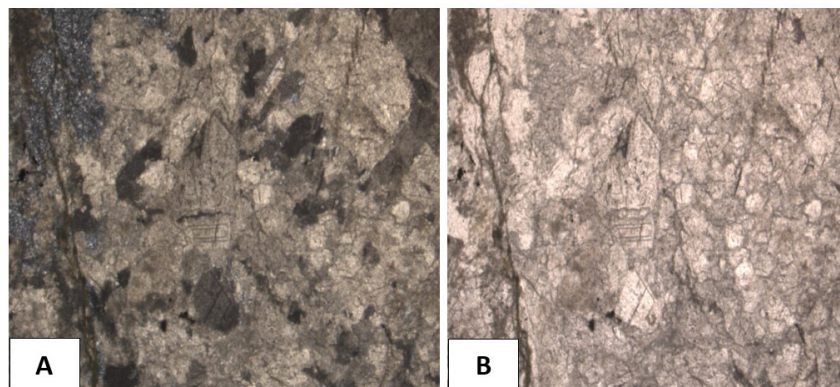


Figure 5: Petrographic characteristics of different sections of the sample (15) are shown in the figure

prepared from the mentioned stone sample was studied under a Leica microscope made in Germany, and its characteristics and results are outlined in the table below.

A: Under two Nicols (XPL) with a magnification of 40x, the diameter of the field of view is 2.5 mm.

B: under a Nicol (PPL) at x 40 magnification, the field of view diameter is 2.5 mm.

Description of Sample Number (13)

The sample under study is copper, and it represents high-quality copper. Mineralogical studies reveal that

the mentioned sample consists of approximately 85-88% amphibole, plagioclase, pyroxene, and quartz, with less than 12% pyrite, biotite, and opaque minerals. Structurally, the copper ore exhibits a slightly elongated form and a granoblastic texture.

The mentioned sample has a very nice color, and if it is cut and polished, a very high-quality stone can be obtained from it. The slide prepared from the mentioned stone sample was studied under a microscope, and its characteristics and results are detailed in the table below.

Table 3: Results of petrographic studies of sample number (13)

Microscopic characteristics					
Color	Degree of erosion	Porosity	Cover	Against acids	
Gray, colorless, and yellow	Does not have	Does not have	Does not have	Has resistance	
Mineral composition				Stone building	
Major minerals	Amount in percentage	Minor minerals	Amount in percentage	Structure	Slightly stretched
Amphibole, plagioclase, pyroxene and quartz	85-88	Pyrite	7	Texture	Granoblastic
		Biotite and OPECs	5	Matrix	Does not have
				Vacuum	Does not have
The origin of the stone		Metamorphic			
Geological characteristics					
Asthma			Petrographic class		
Amphibole			Copper ore		

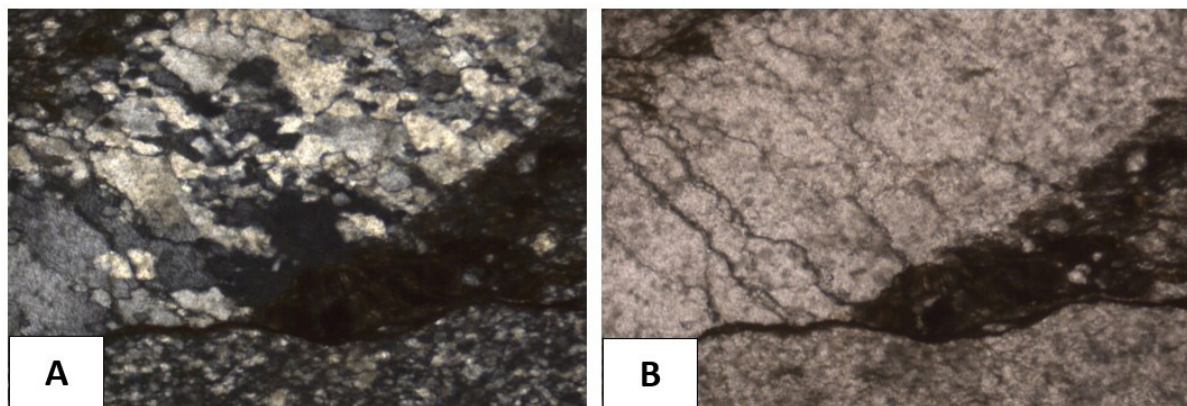


Figure 6: Petrographic characteristics of different sections of the sample (13) are shown in the figure

A: Under two Nicols (XPL) with a magnification of 40x, the diameter of the field of view is 2.5 mm.

B: under a Nicol (PPL) at 40x, magnification, the field of view diameter is 2.5 mm.

Geochemical Results

In this article, the results of the samples of different

types of copper ores collected from the area of Mir Seyed Murad Balkhab have been studied and geochemically analyzed. The geochemical results show that in the composition of minerals, in addition to copper, other compounds: silicon (Si) about 10.86 percent, copper (Cu) 10.63 percent, sulfur (S) 13.40 percent, iron (Fe) 5.04 percent and aluminum (Al) 8.47 percent.

Table 4: Geochemical Composition of Balkhab Copper Ores in Saripul Province

Al %	Fe %	S %	Si %	% Cu	Sample NO
0	4.26	9.68	5.31	20.45	1
0	1.42	18.94	2.42	27.73	2

0	2.91	17.48	12.43	17.74	4
0	5.39	5.8	14.73	4.05	5
0	4.25	22.7	6.04	25.49	7
0	0.29	4.66	40.37	0.13	8
10.07	5.13	11.27	11.22	0.4	9
2.74	5.13	13.13	6.88	8.67	10
9.42	10.46	19.36	4.76	7.65	11
13.19	14.24	4.98	13.67	0.31	12
6.93	2	19.45	1.63	4.39	14

The results of the samples collected from the field show that the percentage of copper is different in different samples and there is no single interval for them.

RESULTS AND DISCUSSION

The collected samples have been studied under a petrographic microscope. As evident, the evaluated samples predominantly consist of copper, feldspar, quartz, iron oxide, calcite, amphibole, plagioclase, pyroxene, and sulfur minerals.

Interestingly, when examining the results obtained from the mineral composition study, it becomes apparent that all the studies yield consistent outcomes. The mineral composition of the studied samples reveals the presence of various minerals, including copper, feldspar, quartz, iron oxide, calcite, amphibole, plagioclase, pyroxene, sulfur, pyrite, biotite, and opaque minerals, albeit in different proportions. From the geochemical study, it is seen that in addition to copper, other elements such as Silicon (Si), Sulfur (S), Iron (Fe) and Aluminum (Al) are also included in the composition of copper mineral stones, but their amounts vary.

Therefore, a comparative analysis of the petrographic study indicates that copper in the Balkhab area of Saripul province is not monomineralic; rather, it comprises a mixture of different minerals. Mineralogical studies involving nearby stones are essential to thoroughly investigate and evaluate copper. Consequently, samples were collected from the target area and subjected to mineralogical analyses.

This article delves into disputed copper samples and their petrographic analysis. The mentioned samples hold significant importance for petrographic studies, having been extracted from the expanding copper ore region.

Mineralogical studies demonstrate that the samples are primarily composed of approximately 90 percent copper, feldspar, quartz, iron oxide, calcite, amphibole, plagioclase, pyroxene, and sulfur minerals. In terms of overall volume, these minerals outweigh the presence of pyrite, biotite, and opaque minerals. The results obtained from the study of mineralogical composition can be seen that all the studies provide the same result.

CONCLUSION

Through the conducted research on copper in the Mir

Sayed Murad area of Balkhab District, Saripul Province, the general results of mineralogical-petrographic and geochemical analysis reveal that the primary minerals constituting the copper ore in this region include feldspar, quartz, copper, amphibole, plagioclase, pyroxene, calcite, sulfur, and iron oxide. Additionally, trace amounts of other minerals, such as pyrite, biotite, and opaque minerals (referred to as OPECs), are present in very low percentages. The host rocks for these minerals consist of andesitic rocks such as rhyolite, basalt, and dickite, which, in conjunction with sedimentary rocks like sandstone, pyrite-bearing clay, and siliceous clay, contain copper minerals.

Novelty of Research

From the geochemical study, it is seen that in addition to copper, other elements such as Silicon (Si), Sulfur (S), Iron (Fe) and Aluminum (Al) are also included in the composition of copper ore, but their amounts vary. These minerals are predominantly associated with andesitic rocks, including rhyolite, basalt, and dickite. Furthermore, sedimentary rocks like sandstone, pyrite clay, and silicic clay also contain copper minerals.

Contribution of Knowledge

The mineral composition of the studied samples reveals the presence of various minerals, including copper, feldspar, quartz, iron oxide, calcite, amphibole, plagioclase, pyroxene, sulfur, pyrite, biotite, and opaque minerals, albeit in different proportions. A comparative analysis of the petrographic study indicates that copper in the Balkhab area of Saripul province is not monomineralic; rather, it comprises a mixture of different minerals.

Fulfillment of Research Gap

For writing this article, the researchers faced some challenges such as; in our Higher Education Institute we do not have standard library in Geology and Mine field, as well as we do not have developed laboratory. And it is mentionable that, in our university as a researcher we do not have financial independence. Besides this, in this research the researchers used library method, we utilized books, reports, and magazines available in the libraries of Jawzjan University and Saripul Higher Education Institution.

RECOMMENDATIONS

To accurately explore the copper deposits in the Mir Sayed Murad area of Balkhab's creep copper mining region, a more precise study of its copper-bearing layers is essential. If modern equipment suitable for geophysical exploration is available and can be effectively used in metamorphic rocks, the exploration process for the copper-bearing mineral area should employ geophysical methods.

As the work of stripping and preparing the mine approaches its final stage, the exploitation phase (extractive operations) will commence. Based on the study of samples from the Mir Sayed Murad copper field, it is evident that they exhibit good quality. Additionally, apart from copper minerals, sedimentary stones such as gravel, pyrite-bearing clay, and silicified clay are present in the studied area. These materials can potentially be utilized for construction purposes.

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