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| RESEARCH ARTICLE

Investigation of Sarodagh Valley Chromite, its Mineralogy and Geochemistry

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| ABSTRACT
This study examines the petrographic and geochemical characteristics of chromite in Sarodagh village, located in the Goshta district of Nangarhar Province, Afghanistan, highlighting the region's geological importance and mineral composition. The research clarifies the region, which is located along the Kabul-Kunar River route, around 45 kilometers from Jalalabad, at an elevation of 537 meters above sea level, using a combination of academic research, field observations, and laboratory analyses. The majority of the 455 square kilometer district's population are Pashtuns, mostly from the Momand tribe. After conducting macroscopic evaluations of chromite in the field, ten samples were gathered for in-depth laboratory examination where four samples were studied by petrographic microscope and ten samples powder were studied with geochemical (pXRF) Portable XRF. The petrographic analysis's findings indicate that the main minerals found in the chromite were olivine, pyroxene, and hornblende. Geochemically, a notable 45% reduction in silicon dioxide (SiO2) points to an ultramafic source for the chromite, which is just 0.4% of the total and has a limited distribution in the Earth's crust. By providing important insights into the geological origins and significance of the chromite deposits in Nangarhar Province, this research advances our understanding of these deposits. In order to assess these mineral deposits' economic potential, more research is recommended.

| KEYWORDS
Sarodagh, Chromite, Ophiolite, Goshta, Peridotite, Nangarhar, Jalalabad, Afghanistan

| ARTICLE INFORMATION
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1. Introduction
Chromite, the only commercial source of chromium, is a spinel group mineral that occurs in ultramafic igneous rocks and further occurs exclusively in rocks formed by the intrusion and solidification of molten lava or magma, which is very rich in the heavy iron-containing minerals such as pyroxenes and olivine. In addition, it is also found in metamorphic rocks such as some serpentinites. Pure chromite is a double oxide of iron and chromium with the formula FeO. Cr_2O_3. Considerable variation in composition occurs, however, due to partial substitution of divalent iron by magnesium and trivalent chromium and iron by aluminum. The chromium spinel may be described as (Fe, Mg) O. $(Cr, Fe, Al)_2O_3$. The chromium spinel is a heavy mineral and it is concentrated through gravity separation from most of the other molten material in the magma during the crystallization. Commercial chromite deposits are found mainly in two forms namely stratiform and podiform. (C. Raghu Kumar, 2023).

Chromite, relatively hard, metallic, black oxide mineral of chromium and iron (FeCr2O4) that is the chief commercial source of chromium. It is the principal member of the spinel series of chromium oxides; the other naturally occurring member is magnesiochromite, oxide of magnesium and chromium (MgCr2O4). Chromite is commonly found as brittle masses in peridotites, serpentines, and other basic igneous and metamorphic rocks; an unusual occurrence is as a crystalline inclusion in diamond. The earliest worked deposits were those in the serpentine of the Bare Hills near Baltimore, Md., U.S. The principal producing areas of chromite are South Africa, Russia, Albania, the Philippines, Zimbabwe, Turkey, Brazil, India, and Finland. For detailed physical properties, see oxide mineral. (Tikkanen., introduction to chromite, 2023).

Chromium is a relatively abundant element in Earth's crust; the free metal is never found in nature. Most ores consist of the mineral chromite, the ideal formula of which is FeCr2O4. It is widely dispersed in natural deposits, which are usually contaminated with oxygen, magnesium, aluminum, and silica; their chromium content varies from 42 to 56 percent. One of the chief uses of chromium is in ferrous alloys, for which the pure metal is not required. Accordingly, chromite is often reduced with carbon in a furnace, producing the alloy ferrochromium, which contains iron and chromium in an atom ratio of approximately 1 to 2. (Tikkanen., Chromite occurence and uses, 2023)

2. Literature Review

Ophiolites are remnants of oceanic crust that have been thrust onto continental crust due to tectonic processes. They are composed of mostly mafic and ultramafic rocks, which are genetically associated with gold, silver, platinum group element (PGE), chrome, manganese, titanium, cobalt, copper, and nickel deposits. (et@ll, 2023).

Ophiolites are the distinctive assemblage of mafic to ultramafic rocks and represent the abducted remnant of oceanic crust that was overthrust onto continental crust. Such types of rocks are rare around the world. One of the largest mafic–ultramafic complexes with an apparent area of about 2000 km^2 is in the southeast of Afghanistan between two active sinistral strike-slip faults within Logar and surrounding provinces. (Kalkan, 2021). During the tectonic history of Afghanistan, the successive accretion of Gondwana-derived fragments to the active margin of Laurasia since the end of the Paleozoic is evidenced by the emplacement of the ophiolites along distinct suture zones (all A. Y., 2023).

Most magmatic chromite deposits, particularly those in stratiform layered ultramafic-mafic intrusions, are interpreted to have formed by processes that decrease the solubility of chromite. (et@all M. L., January 2019).

chromite (Fe,Mg)Cr O is an oxide mineral in spinel group. It is one of metallic mineral which classified in to alloy and ferro alloy metallic mineral group along with iron, nickel, titanium, manganese, cobalt, and bauxite. Chromite is the only ore mineral of metallic chromium and chromium compounds and chemicals. Because of this fact, chromites and chrome ore are used synonymously in trade literature. It is used for refractory material, because it has high heat stability. (Ernowo, May 2010).

Podiform chromitite bodies occur in highly serpentinized peridotites at Dobromirtsi Ultramafic Massif (Rhodope Mountains, southeastern Bulgaria). The ultramafic body is believed to represent a fragment of Palaeozoic ophiolite mantle. The ophiolite sequence is associated with greenschist-lower-temperature amphi-bolite facies metamorphosed rocks (biotitic gneisses hosting amphibolite). This association suggests that peri-dotites, chromitites and metamorphic rocks underwent a common metamorphic evolution. (et@all J. M.-J., 4, December 2009)

Most of the chromite deposits occur in a section of Logar Valley in northeastern Afghanistan starting 33 km south of Kabul and extending 15.5 km southward into the valley (Volin, 1950). The Logar River traverses the valley south to north before it joins the Kabul River east of Kabul. The occurrences lie mostly in the hills on the western side of the valley and occur in two groups about 9 km apart. The northern group is on or near Kuh-e-Mohammad Agha; the southern one is on Kohe Saymahmude Ghazi west of the Logar River. Chromite is also found in small quantities at locations in Kandahar, Paktia, and Parwan Provinces. Most of the names of geographic features are from Google Earth. (Abullah, 1980)

3. Methodology

Library Method : This method was considered an initial part of the research, relevant literature was reviewed using research and review articles, theses, textbooks and authoritative websites. This method intent to determine the weak and hidden points of previous studies on the Nahartangi nephrite deposit and to select the correct analytical method for the mineralogical, and geochemical characterization of the nephrite The method provides general information, including the geological and tectonic context of the study area.

Field observation method: Field work and sampling are important such research. Therefore, the fieldwork for this study consisted of Several geological transects to study and collect macroscopic properties. A sample of the selected points. Collection of samples for laboratory analysis. Two phases of fieldwork were carried out in the study area this samples were taken at random and analyzed according to physical, morphological and structural changes in nephrite. Five samples and their associated coordinates were collected.

Laboratory method: The purpose of this method is to carry out mineralogical, chemical and petrographic analyzes on the collected samples in order to show decided on properties of nephrite. Samples are sent to the Mineralogy Laboratory of Ministry of mine & petroleum Kabul, Afghanistan for reliable outcomes The samples have been subjected to X-ray fluorescence and mineralogical analysis of chemical and mineral composition.

3.1 Objective of the research

This research sought to understand the geological systems, geochemical analysis and determination of mineral composition, petrological characteristics of Sarodagh Chromite.

3.2 Importance of research

The studies became conducted through comprehensive fieldwork and sampling of chromite massess. The translation and outcomes of this examine can effectively serve as a mandated reference for the Afghanistan Geological Survey (AGS) and related research devices.

3.3 Research question

I. What are the adjacent rocks Sarodagh Chromite field ?
II. What is the geochemistry of Sarodagh Chromite ?
III. What is the mineralogy of Sarodagh Chromite in the study area ?
IV. Does the Sarodagh Chromite have economical value ?
V. What is the origin Sarodagh Chromite ?

3.4 Research limitation

Each study has its own limitations and risks. In this case, safety concerns arise from the lack of previous mining activities and the loss of geological information in the area. The brief geological training from the government was not enough to conduct thorough investigations, making it difficult to collect important samples and apply different analysis in the Ministry of Mines & Petroleum and private companies. Additionally, the absence of modern equipment and well-equipped labs at Kabul Polytechnic College poses a major obstacle to progress.

3.5. Study area

The Sarodagh area, which hosts chromite deposits, is situated in the Goshta district of Nangarhar Province, Afghanistan. This district serves as a border region, sharing an eastern and northeastern boundary with Pakistan along the Durand Line, while it is bordered by Lal Pura district to the south, Kama district to the west, and Batikot district to the southwest, as well as Kuz Kunar district to the northwest. The district is positioned along the Kabul-Kunar river route, at an elevation of 537 meters above sea level and approximately 45 kilometers from Jalalabad. Covering an area of 455 square kilometers, the population is primarily composed of Pashtuns, with the majority belonging to the Momand tribe. The Geographic coordinats of the area is 34 23 44.2"N

70 45 23.8"E.

The region is marked by various mineral deposits, which are indicative of a rich geological landscape, yet the local population faces significant economic challenges. The geographical coordinates of the chromite deposit in the Goshta district are approximately 34 degrees, 23 minutes, and 44.1 seconds north latitude, and 70 degrees, 45 minutes, and 23.8 seconds east longitude. The chromite deposits at Sarodagh have been identified based on geological excavations conducted by local inhabitants. The Goshta district features a mountainous terrain characterized by a Mediterranean climate, typified by hot and arid summers, with precipitation occurring primarily in the winter months. Summer temperatures can reach up to 47 degrees Celsius, while winter temperatures can drop to around 3 degrees Celsius (Obaidi, 2022).

Throughout the year, particularly during winter, precipitation levels range from 350 to 400 millimeters. The average annual temperature in Jalalabad is approximately 21 degrees Celsius, with rainfall varying between 240 and 390 millimeters. The precipitation in this region predominantly falls as rain, while snowfall is rare, except in higher altitudes above 900 meters where snow may accumulate on rugged terrain. The southern mountains of Jalalabad (known as Spin Ghar) and those in Laghman, Nuristan, and Kunar are often seen blanketed in snow.

It is noteworthy that the Spin Ghar and the mountains in Kunar and Nuristan are influenced by seasonal monsoons from India during summer, while in winter, cold Siberian winds affect the area, contributing to both snow and rainfalls at higher elevations, along with rainfall in the lower areas. Summers in Jalalabad tend to be quite hot, with dry winds referred to locally as "Barho" blowing from Torkham towards the region. The Mediterranean climate provides favorable conditions for the growth of various flora, notably citrus trees and date palms, which thrive abundantly in this climatic zone (Jilani, 1388).

3. Geological Setting

1) 3.1 Tectonic

Jalalabad tectonic zone is located in the eastern part of Afghanistan and the SE part of Nuristan block. It was first identified in 1969 by Prof. Slavin as called the Tectonic Zone of Jalalabad, which is located and named Block of Nuristan. Correspondingly, the zone is related to the upper Cambrian or younger Cambrian. The basic metamorphic rocks are exposed in the Spinghar Mountains. They can also be observed in the eastern part of that zone, southeastern parts of Jalalabad city on the left bank of Kabul and Kunar River. In the central part of this zone, the Neogene sediments have been positioned in the new tectonic depression. In the tectonic map of 1976, in this area, sub-zones are isolated, which are called Kunar, Spinghar and Jalalabad depressions. (Peters, 2011)

The Nephrite of mineralization includes a group of actinolite and tremolite deposits that have formed as a result of the contact metasomatic impact of ultra-acidic mafic rocks with adjacent rock, such as phyllite and serpentinite metamorphic rock, upon Precambrian carbonate rocks in the Nurestan block. The nephrite occurrences are confined to a unit of calcite _ dolomitic marble beds occurring in serpentinite and phyllite. A group of unique nephrite deposits is located in the Nuristan Block. Nephrite deposits and occurrences have been found in the areas that extend in veins and lens shapes for more than a few meters and 10 meters. And underlain by phyllite, calcite and dolomitic marbles and hornblende and biotitegarnet schists, garnet amphibolite and skarns. Nephrite is subdivided into Jade, which is a semi-precious gemstone that is further classified into two categories named Jadeite and Nephrite, divided into two groups of actinolite and tremolite deposits (Minerals in Afghanistan: Rare-Metal Deposits. British Geological Survey, Afghanistan project. Available from https://www.bgs.ac.uk/afghanminerals/ last, 13 May 2019)

The stratigraphy of the Jalalabad zone is different in terms of age and composition; the oldest sediments are related to the Archean (Proterozoic) period, and the youngest to the Quaternary period, which means that there are sediments of all periods in this zone. Magmatic rocks are vastly developed in the Jalalabad zone, and they are outcropped along Kunar Valley and the Spinghar Mountain series. In the Jalalabad zone, the following magmatic complexes can be separated:

I. Granites and gabbro amphibolite complex, Upper Proterozoic (PR3)

II. Granite and granodiorites complex, Upper Paleogene (PZ). (all A. U., 17, October, 2023).

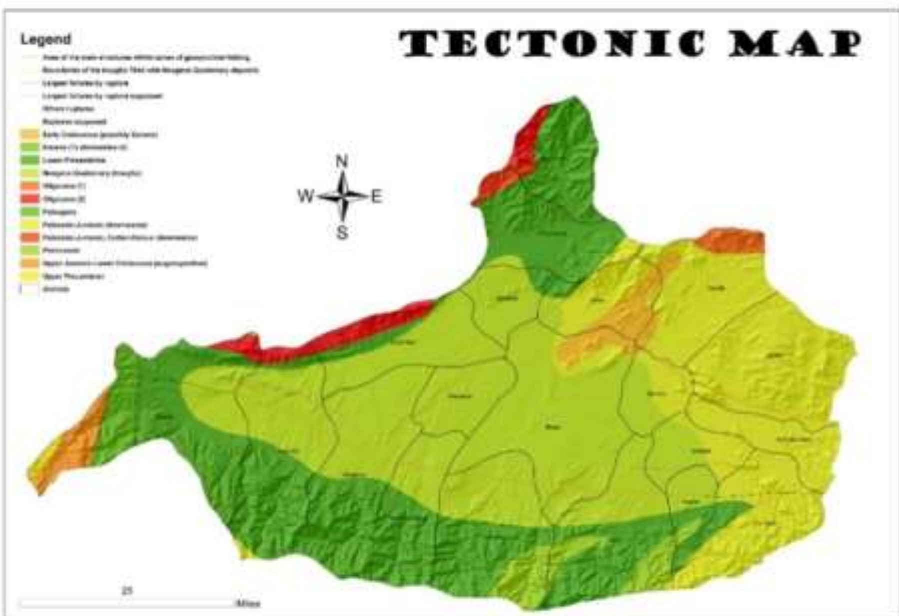


Figure 2.1: Tectonic map of the Sarodagh

3.2 Mineral Deposit

In the context of Afghanistan's geology, chromite is found in the Sarodagh village of the Goshti district in Nangarhar Province. This area is associated with an ophiolite complex, which has formed in a podiform manner, and the primary rock type related to the chromite deposits is dunite, an ultramafic rock. Other associated rocks with dunite include harzburgite, pyroxenite, and wehrlite. The term "ophiolite" refers to a geological formation that occurs when oceanic crust is situated above continental crust as a result of tectonic movements (Huda & Panezai, 2022). The concept of ophiolite first emerged in early 19th-century Europe and has undergone several developmental phases (Ahmadi, 2021). The Logar chromite complex is located approximately 30 kilometers south of Kabul, where the ophiolite is presented in an elliptical shape, extending toward the north and northwest over an area of around 2,000 square kilometers, with a length of 65 kilometers and a width of 45 kilometers. The formation of chromite in Logar has a long history, and previous studies have heavily focused on chromite in this province. It is believed that the ultramafic complex has a pre-Cretaceous age, with its upper formations dating from the early Cretaceous and the lower formations from the late Cretaceous period. The main component of this ultramafic complex consists predominantly of dunite and harzburgite, while smaller portions include wehrlite, lherzolite, serpentinite, and serpentinized breccias (Petterson, 2009).

Various mineral findings suggest that if a detailed geological survey is conducted in Nangarhar Province, there may be additional occurrences of chromite in other districts. Afghanistan is rich in many economic minerals, and its mineral wealth has recently been the topic of several studies. The country has large mineral deposits that have been known for a relatively long time (Coats & Garry, 2010). Chromite deposits, in particular, are found in various provinces of Afghanistan, including Logar, Wardak, Khost, Zabul, Baghlan, Kunar, and Nangarhar.

Afghanistan is a resource-rich country, and these natural resources play a crucial role in its national economy. Unfortunately, it should be noted that no precise studies have been conducted yet to determine the size of Afghanistan's chromite reserves. However, according to geological surveys by the United States Geological Survey (USGS), the total chromite reserves in Afghanistan are estimated to be around 6,000 metric tons. Additionally, untrained individuals are extracting these resources using non-professional methods, and due to a lack of modern technology and insufficient government oversight, they are often illegally transported to neighboring countries. The goal of this research is to conduct geochemical and petrographic studies of chromite in Sarodakh village of the Goshti district in Nangarhar Province. Since no studies have been conducted in this area regarding chromite, it is deemed important to address the lack of information about these deposits and to facilitate further research. Relevant authorities should also pay special attention to this area.

4. Material and Methods

The study was conducted in the Sarodagh area of the Gostha district in Nangarhar province, Afghanistan, renowned for its rich chromite deposits. Samples were collected from ten distinct points within the mining area, which is currently being exploited by local inhabitants using local equipment, and geographical coordinates for each sampling location were recorded. To create geological and tectonic maps of the area, Geographic Information System (GIS) tools were utilized, integrating the collected coordinates. The chromite content in each sample was analyzed using X-ray fluorescence (XRF) testing conducted in a laboratory. Additionally, thin sections of the samples were prepared for examination with a petrological microscope to study the mineralogy in detail. All data, including the XRF results and mineralogical observations, were compiled for comprehensive analysis and interpretation.

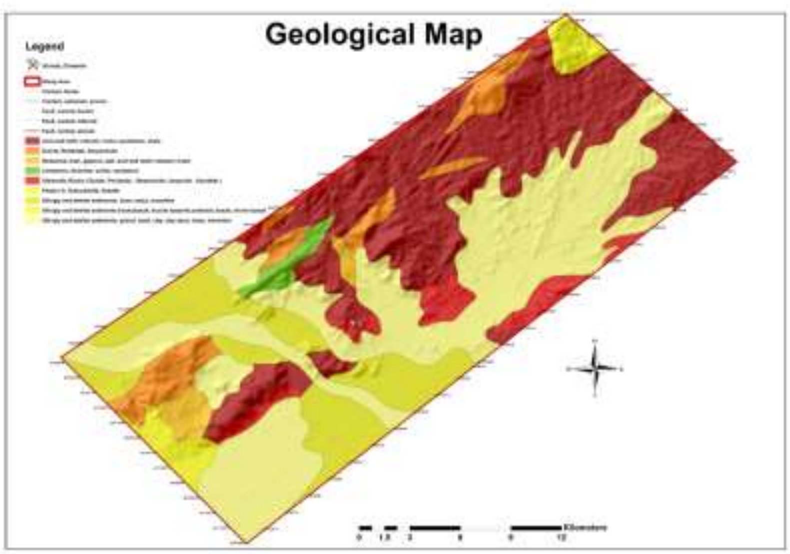


Figure 3.1: Geological map of the Sarodagh area.

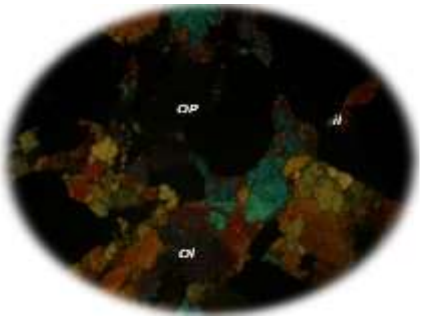
No	Name of rocks	Mineralogy	Geographic Coordinates
1	Peridotite (Verlite)	/ Olivine, Orthopyroxene, Ilmenite	34 23 44.2"N 70 45 23.8"E
2	Peridotite (Dunite)	/ Orthopyroxene, Olivine, Pyroxene	34 23 45.5"N 70 45 18.7"E
3	Peridotite (Harzburgite)	/ Pyroxene, Hornblende, Magnetite	34 23 44.1"N 70 45 19.4"E
4	Peridotite (Dunite)	/ Hornblende, Olivine, Pyroxene	34 23 49.7"N 70 45 19.6"E

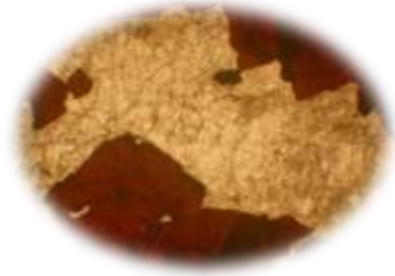
5. Results

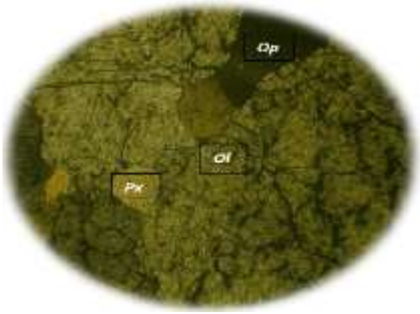
5.1 Petrographic analysis

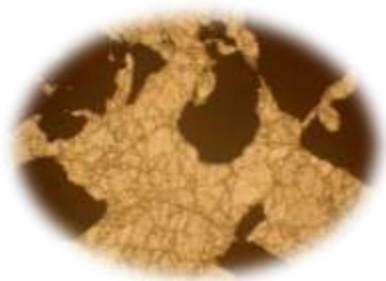
The Petrographic analysis shows that the samples are checked under a petrographic microscope and the pictures are below in PPL and XPL situation.

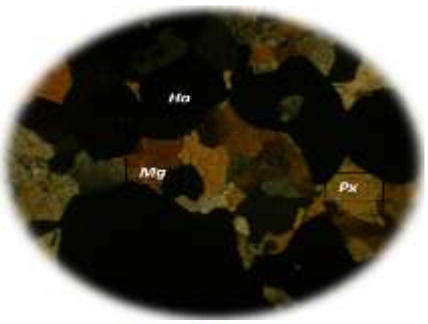
XPL	PPL

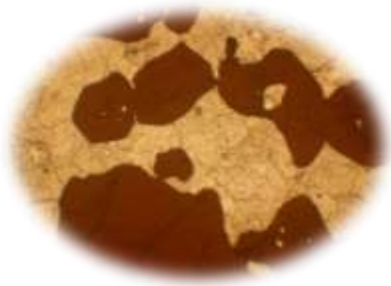


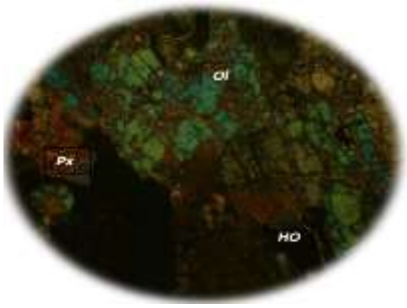












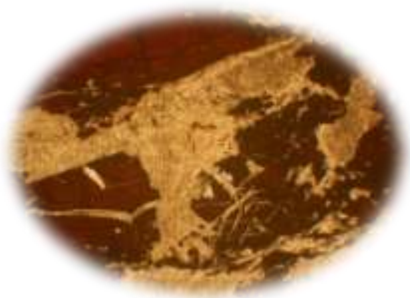


Figure 4.1: Photographic images **($XPL - PPL$).**

5.2 Chemical analysis

The Chemical analysis include two kinds of results the first table shows the percentage of the elements and the second table shows the result of the oxides in Chromite samples below.

Elements	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Bal	48.265284	51.5845	49.813	74.5418	39.2096	38.7928	66.5059	42.9803	61.491	61.0844
Mg	13.631172	8.8179	9.7372	5.4317	17.8954	15.7831	13.5169	15.6943	8.3616	8.737
Al	4.7934504	4.9261	0.4713	0.1473	0.7313	2.4593	0.1961	3.4412	0.4171	1.1699
Si	10.0929	6.5621	18.1971	17.0691	29.1097	19.995	14.0667	17.1091	21.3244	20.0577
P	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.0626
S	0.0673874	0.1325	0.1796	0.1021	0.1735	0.1617	0.1082	0.1392	0.0999	0.15886
Cl	0.1003512	0.2563	0.1607	0.3807	0.1817	0.105	0.1101	0.1571	0.1447	0.283
K	0.0555396	0.085	0.0523	< LOD	< LOD	0.0607	< LOD	< LOD	0.0386	0.1651
Ca	0.1318102	0.381	6.6289	0.3256	0.4309	3.8556	0.6446	7.1478	1.7242	1.7321
Ti	0.0964886	0.0849	0.0176	< LOD	0.0353	0.0387	< LOD	0.0505	0.0093	0.0195
V	0.0451183	0.0599	0.023	0.0051	0.0185	0.0428	0.0055	0.0289	0.0084	0.008
Cr	**15.243095**	**19.896**	**6.3425**	**0.0437**	**6.7003**	**12.67**	**0.0637**	**8.5859**	**0.998**	**0.1253**
Mn	< LOD	< LOD	0.4792	0.068	0.323	0.1733	0.1751	0.2392	0.138	0.1144
Fe	7.0735992	6.8629	7.3749	1.7519	4.7989	5.5151	4.376	4.0675	5.2177	6.0142
Co	< LOD	0.0446	0.0714	< LOD	0.0391	0.0233	0.0258	0.0562	< LOD	0.0238
Ni	0.3630791	0.2679	0.4071	0.063	0.3288	0.2867	0.1393	0.2707	0.0158	0.194
Cu	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.0068
Zn	0.0121272	0.0154	0.0165	0.0011	0.0118	0.0126	0.0035	0.0091	0.0026	0.0053
As	< LOD	< LOD	0.0012	< LOD	0.0009	0.0011	0.0005	< LOD	< LOD	0.0008
Sr	< LOD	< LOD	0.0059	0.0034	0.0003	0.0053	0.0003	0.0023	0.011	0.0003
Zr	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	0.0005	< LOD	< LOD
Nb	0.0008776	< LOD	0.0004	< LOD	0.0004	0.0004	< LOD	0.0003	0.0002	< LOD
Mo	0.0012509	< LOD	0.0004	< LOD	0.0005	< LOD	< LOD	0.0005	0.0004	< LOD
Ba	0.0233678	0.0202	0.0165	0.0083	< LOD	0.0139	0.0147	0.0141	0.0075	0.0196
Pb	< LOD	< LOD	0.0022	< LOD	< LOD	0.0019	< LOD	0.0009	< LOD	0.0007

Table 2.1: geochemical elemental composition of all samples.

Oxides	1	2	3	4	5	6	7	8	9	10
MgO	22.62774	14.637725	16.1639094	9.0166734	29.7064313	26.2001	22.4381906	26.05254	13.8803	14.5035
Al2O3	9.05962	9.3104984	0.8908457	0.2784733	1.3822815	4.64815	0.3707085	6.504005	0.788405	2.21127
SiO2	21.59891	14.043014	38.9418563	36.527875	62.2949313	42.7893	30.1027781	36.61354	45.63442	42.923
Fe2O3	10.11524	9.8140148	10.5461578	2.5052211	6.8624617	7.8866	6.2577113	5.816529	7.461446	8.60032
Cr2O3	**22.25492**	**29.048228**	**9.2601602**	**0.06389**	**9.7825617**	**18.4983**	**0.0931139**	**12.53545**	**1.457114**	**0.18305**
CaO	0.18453	0.5335007	9.2805977	0.4558487	0.6033816	5.39797	0.902546	10.00703	2.414015	2.42505
TiO2	0.16113	0.1419247	0.0284815	0	0.0589671	0.06473	0	0.084455	0.015643	0.0327
K2O	0.0672	0.1028896	0.0633574	0.0132356	0	0.07353	0	0	0.4677	0.19987
SO3	0.16846	0.3313853	0.4490948	0.2553814	0.4338186	0.40433	0.2706197	0.348189	0.249796	0.39665
P2O5	0	0	0	0.0623174	0	0	0	0	0	0.14348

Table 3.1: geochemical oxides composition of all samples.

4. Results and Discussion

The petrographic and geochemical analysis of the Sarodagh Chromite samples reveals diverse mineralogical compositions and variabilities in elemental concentrations. The primary rock types identified include Peridotite (Verlite, Dunite, and Harzburgite), each exhibiting a massive structure and granular texture, suggesting a uniform crystallization process under high-temperature conditions typical of ultramafic environments. Whereas the geochemical analysis of the Sarodagh Chromite reveals significant variability in elemental concentrations, with notable differences in chromium content across samples. The samples exhibit a wide range of oxides, reflecting a complex composition indicative of diverse geological processes. High magnesium and chromium values suggest a potential for economic mineralization, while the presence of silica indicates varying degrees of alteration. Overall, the geochemical data underscores the heterogeneous nature of the chromite deposits, highlighting their economic potential and the complexity of their formation.

5. Conclusion

The analysis of the Sarodagh Chromite's petrographic and geochemical properties highlights a complex interplay of mineral composition and textural characteristics. The significant variation in chromium and magnesium content reflects the geological diversity within the region and hints at potential sources for economic exploitation of chromite deposits. Future studies could focus on the geological contexts influencing these variations to better understand the formation mechanisms of these ultramafic rocks.

6. Suggestion

Based on our findings from the geochemical and petrographic study of chromite in the Sarodagh area of the Gostha district in Nangarhar province, I would like to make the following recommendations:

1. We urge the relevant authorities to take serious action to conduct detailed research, assessment, and mapping of the chromite deposits in the Sarodagh area.
2. It is essential to establish a domestic market and sales center for chromite to counter the ongoing illegal exports to other countries.
3. It is recommended that the leadership of Nangarhar University address the needs of geology and mining students by developing fieldwork opportunities and equipping laboratories for petrography, thin section preparation, and spectrometry analysis.
4. Considering the significant revenue potential of minerals and gemstones, I believe that relevant authorities must take practical measures to legalize mining operations throughout the country.

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