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Mineralogical and Chemical Characterization of Disseminated Low-Grade Sudanese Chromite Ore in Gedarif State at Umm Saqata-Qala Elnahal

Mahmoud Motasim Hassan Al-Tigani[1*], Abdelshakour Awdekarim Mohamed[2] and Ahmed Abdullah Sadeek Seifelnasr[3]

[1]*Department of Mining Engineering, Faculty of Engineering, Omdurman Islamic University, Khartoum, Sudan*

[2]*Department of Chemical Engineering, Faculty of Engineering, University of Khartoum, Khartoum, Sudan*

[3]*Department of Mining Engineering, Faculty of Petroleum and Mining, Suez Canal University, Suez, Egypt*

[*]**Corresponding author:** Mahmoud Motasim Hassan Al-Tigani, Department of Mining Engineering, Faculty of Engineering Sciences, Omdurman Islamic University, Khartoum, Sudan, Tel: 00249960579034; E-mail: Mahmoudmotasim2018@hotmail.com

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Abstract

This study was carried out on the low-grade chromite, Gedarif state, Sudan, at Umm Saqata- Qala Elnahal to achieve full characterization for the ore via Microscopic studies for the polish section samples, X-ray diffraction analysis (XRD), X-ray Fluorescence Analysis (XRF), Scanning electron microscopic with Energy Dispersive X-ray Spectroscopy (SEM-EDX), and physical properties tests. Microscopic study revealed that the liberation size of chromite mineral is in the range (0.30-0.05) mm. also the X-ray diffraction, X-ray fluorescence and scanning electron microscope with the Energy Dispersive X-ray analysis showed that main gangue of the ore is mineral silicates as Antigorite and contains 21.58-19.60% Cr_2O_3. The physical tests (saturated density and dry density) demonstrated that ore has low density in range 2.54-2.38 g/cm^3 because it is low grade chromite ore, this can be attributed to the dominating mineral silicate (waste) which associated with chromite mineral.

Keywords: Characterization; Low-grade chromite; Microscopic; SEM; EDX; XRF; XRD

Introduction

Chromium (Cr) is one of the world's most strategic and critical materials having a wide range of uses in the metals and chemical industries. Alloys containing Cr enhance metal resistance to impact, corrosion, and oxidation. In addition, Cr is used primarily in stainless steel and noniron alloy production for plating metals, development of pigments, leather processing, and production of catalysts, surface treatments, and in refractories [1].

Characterization of the low-grade ore of minerals is very important because it considered the key of selection suitable method for treatment or processing (upgrading) via physical methods, chemical methods and physiochemical methods. Characterization for low grade of minerals widely obtained by using microscopic studies for thin or polish sections samples, X-ray diffraction (XRD) Analysis, X-Fluorescence Analysis, Scanning electron Microscopic studies, Energy Dispersive X-ray Spectroscopy (EDX), and physical properties tests (Natural density, saturated density, etc.).

Chromite ore deposits in Sudan mainly occur in the Ingassana Hills in the Blue Nile region. Other occurrences have been reported at Hammissana, Sol Hamid in the Northern Red Sea Hills, and the Nuba Mountains in Southern Kordofan, Jabal Rahib Northwest Sudan, and Jabal El-Tawil in Central Butana in Southern Sudan in Umm Saqta-Qala Elnahal [2].

The present investigated area covers part of Qala En Nahal and Umm Saqata area in the south-western part of Gedarif State near the border line between the Sudan and Ethiopia. The area investigated is about 2450 km^2 bounded by Long. 34º 35` and 35º13`E and Lat. 13º18` and 13º43`N Figure 1, the reserves of this study exceed 6,00,000 tons, some occurrence are not estimated [2,3].

Low grade chromite of Ingassana Hills was characterized by wet chemical analysis and microscopic studies for thin and polish section. Wet chemical analysis revealed that ore contains 24.9% Cr_2O_3; 8.6% Fe_2O_3; SiO_2% 24.2; 13.1% MgO; 0.02% CaO; Cr/Fe 2.9, this result explained that mainly gunge are silicate and it has low iron to chromium ratio. However, the examination of thin and polished sections revealed that the main minerals were chromite [$(Fe,Mg)O.(Al,Fe,Cr)_2O_3$] and serpentine [$(Mg,Fe)_3Si_2O_5(OH)_4$] [4].

Microscopic studies

Thin and polish section prepare from bulk samples and then study by using microscope (ore microscope, reflective microscope, nuclear microscope) to get information about the topography of minerals also to estimate the grain size and liberation size for desire mineral widely chromite mineral appears in Euhedral chromite (pure grey) in magnetite (brownish grey), hematite (light grey lamellae) or Anhedral chromite (medium grey) between silicates (dark grey), small pyrite grains (yellow) [5].

X-ray diffraction (XRD)

X-ray diffraction is a versatile analytical technique for examining crystalline solids, which include ceramics, metals, electronic materials, geological material, organic, and polymers. These materials may be powders or irregular shapes. X-ray diffractometers fall broadly into two classes: single-crystal and powder. Single-crystal diffractometers are most often used to determine the molecular of new materials. Powder diffractometers are mostly and routinely used for phase identification and quantitative phase analysis in mineral processing applications [6].

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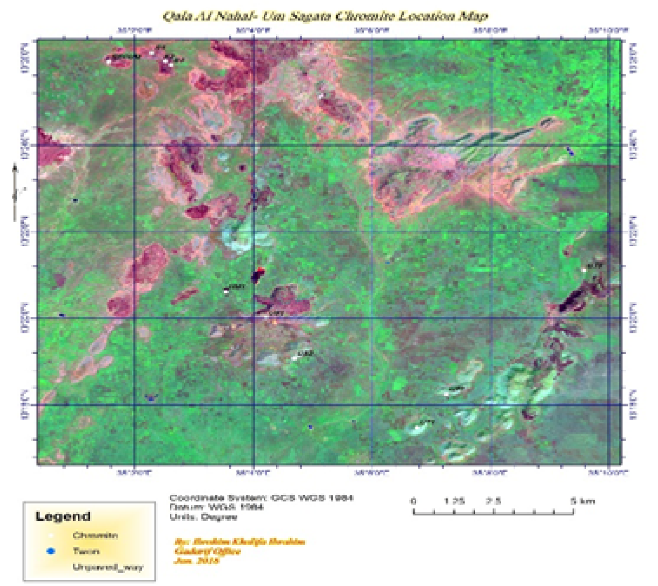

Figure 1: Chromite locations in Qala EL-Nahl and Umm Saqata.

X-Ray fluorescence analysis (XRF)

X-ray fluorescence (XRF) is the emission of characteristic "secondary" (or fluorescent) X-rays from a material that has been excited by bombarding with high-energy X-rays or gamma rays. The phenomenon is widely used for elemental and chemical analysis, particularly in the investigation of metals, rocks, glass, ceramics and building materials. In minerals processing applications X-ray fluorescence was used to evaluate the elements and mineral oxide in the ore [7,8].

Scanning electron microscopy (SEM) with the energy dispersive X-ray spectroscopy (EDX)

Scanning Electron Microscope with the Energy Dispersive X-ray Spectroscopy is commonly used to get information about the sample surface, topography and composition. A scanning electron microscope (SEM) produces images of a sample by scanning it with a focused beam of high energy electrons. The electron beam is scanned in a raster scan pattern, and the beam's position is combined with the detected signal to produce an image [9].

Materials and Methods

Materials

Chromite ore sample: Low grade disseminated chromite ore was collected from different interval locations through the lenses body in Umm Saqata. The samples were lumpy with a total collection weight about 100 kg, then were thoroughly mixed to be homogenous. Finally, thin and polish sections were made for mineralogical analysis from the lumpy samples.

Methods

Preparation of samples: A representative sample of the lumpy samples was taken (about 30 kg) with particle size of 10 cm. The sample was crushed by jaw crusher to -2 cm then by roll crusher to -2 mm in a closed circuit (Figure 2).

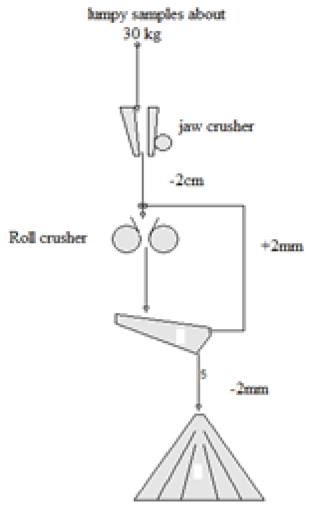

Figure 2: Sample preparation flow sheet.

Finally, a representative sample was taken for characterization by using coning and quartering method (Figure 3).

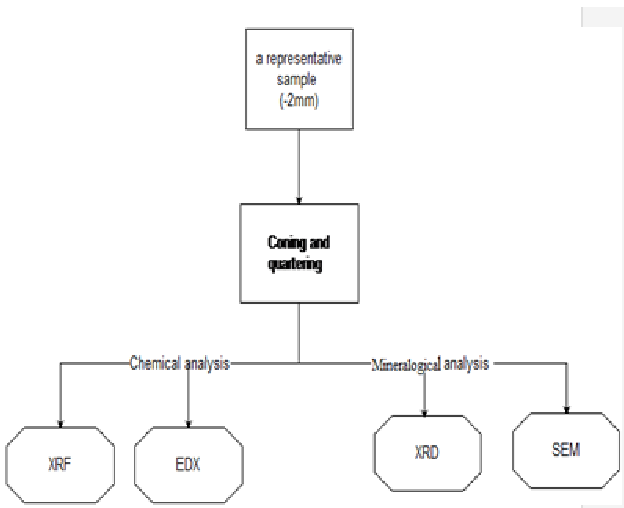

Figure 3: A representative sample for characterization.

Results and Discussion

Microscopic studies

Plate 1, Plate 2, Plate 3, and Plate 4 show that most of the rock matrix composed of the gangue minerals mainly (Antigorite) about 70% of the rock matrix. About 12% of magnetite is replaced by hematite, and most of the rest are chromite and ferrochrome 6% of the matrix, with minor amounts of native copper, Azurite, Malachite, Chalcopyrite, and Limonite.

Polish section plates revealed that chromite and magnetite particles appeared in euhedral shape. However, the liberation size of chromite was found in the range between (0.3-0.5) mm which will oblige that the size of the ground product should be between (-212+75) microns.

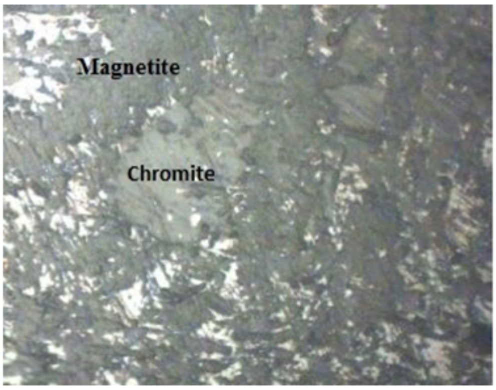

Plate 1: Chromite and magnetite under 20x.

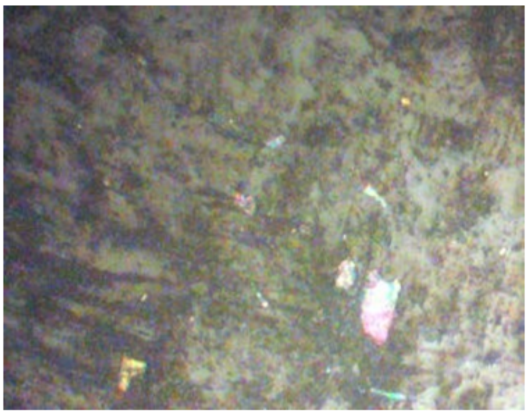

Plate 2: Native copper and chalcopyrite under 20x.

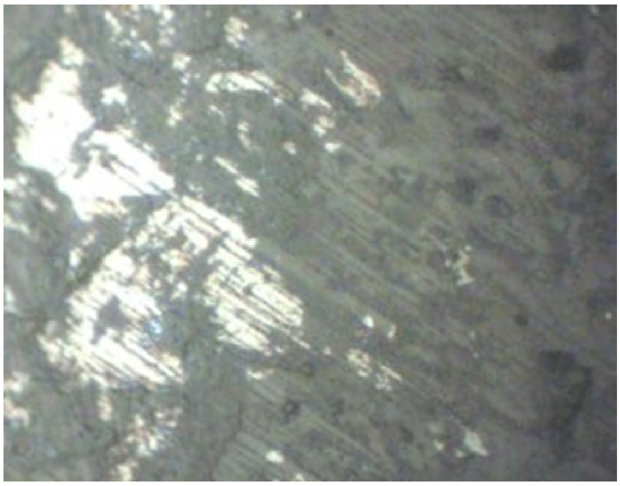

Plate 3: Hematite, antigorite, and small crystal of azurite 20x.

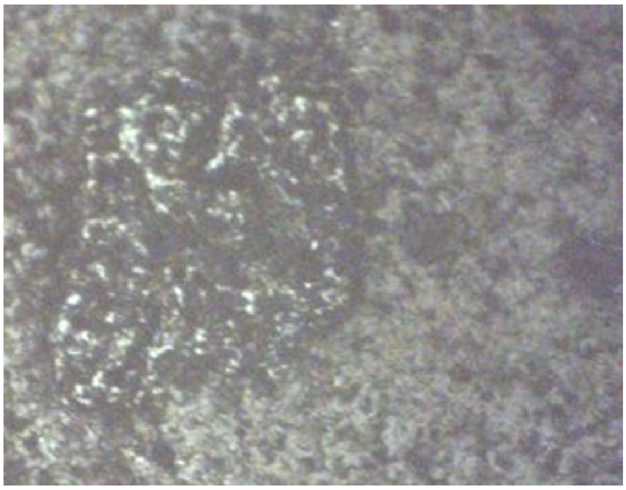

Plate 4: Relict of disseminated texture of chromite under 4x.

X-ray diffraction (XRD)

Figure 4 reveals that chromium element was located in spinel composition (AB_2O_4) with Ca and Fe (Chromtite $CaCrO_4$, Chromite $FeCr_2O_4$), as well as the Sample contained Antigorite ($MgO.SiO_2.H_2O$), Magnetite (Fe_3O_4), and Chabazite ($Ca_{1.85}$ ($Al_3.7Si_{8.3}O_{24}$)). Figure 5 shows that the highest peaks are the chromtite and antigorite indicating these two mineral are of high concentration.

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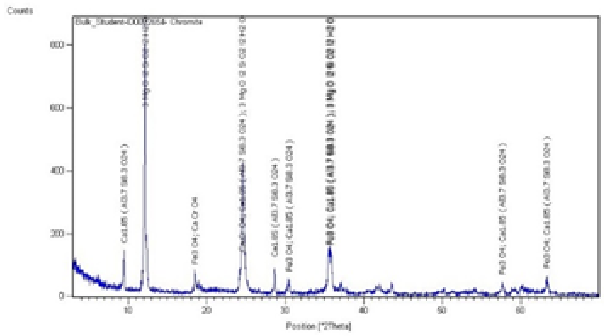

Figure 4: Chemical composition of the mineral phases.

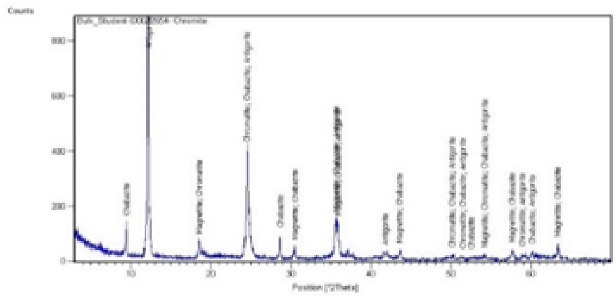

Figure 5: Pattern of the mineral phases.

SEM-EDX study

Figure 6 showed the pattern of the elements in EDX result. These elements are (Cr, Fe, Al, Si, Mg) and indicated to the presence of (Cr_2O_3, Fe_3O_4, Al_2O_3, SiO_2, MgO) respectively. These oxide minerals are considering the main content of the Chromtite, Magnetite, Antigorite and Chabazite minerals.

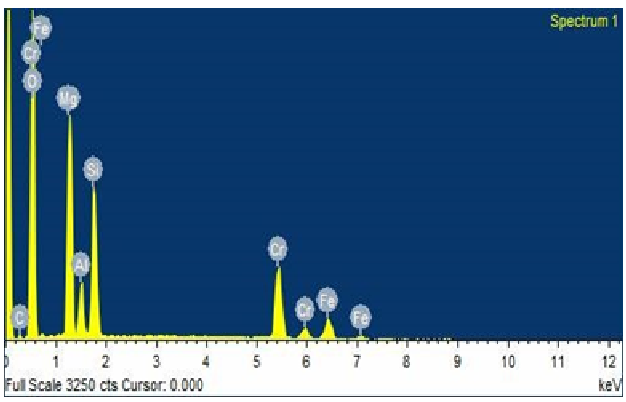

Figure 6: The pattern of the elements in EDX.

More over Figure 6 demonstrated that the Cr, Fe, and O elements existed in one peak that indicates to the spinel composition. Table 1 shows the percentage of the presence elements and their corresponding oxides.

Element	Weight (%)	Mineral Oxide	Weight (%)
Cr	13.37	Cr_2O_3	19.6
Fe	5.34	Fe_2O_3	7.628
Mg	16.11	MgO	26.85
Al	3.97	Al_2O_3	7.6918
Si	10.66	SiO_2	22.84

Table 1: Chemical analysis for the elements by EDX.

Plate 5 showed that the silicate minerals have a pastel grey color whereas chromite and Magnetite minerals have dark grey color.

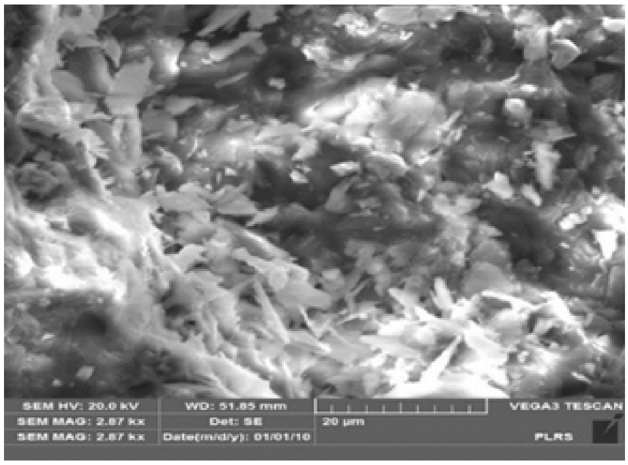

Plate 5: Chromite, magnetite, and silicates in Scanning Electron Microscope (SEM) image.

X-Ray fluorescence analysis (XRF)

Table 2 shows the chemical analysis of the head sample (-2 mm) via XRF and it revealed that the silicate mineral is mainly gangue in the ore.

Oxide	Cr_2O_3	Fe_2O_3	SiO_2	Al_2O_3	MgO
%	21.5	11.8	32.61	4.608	28.09

Table 2: Chemical analysis of the head sample.

Physical properties

Table 3 shows the calculated densities of the low grade chromite. It can be concluded that the ore is low density. This result can be attributed to the dominating mineral silicate (waste) which associated with chromite mineral.

Sample Name	Natural density g/cm^3	Dry density g/cm^3	Saturated density g/cm^3
SCR 1	2.43	2.41	2.56
SCR 2	2.28	2.26	2.46
SCR 3	2.41	2.41	2.56
SCR 4	2.4	2.39	2.53
SCR 5	2.38	2.36	2.58
Average	2.38	2.36	2.54

Table 3: The densities of low grade chromite ore.

Conclusion

The most of gangue mineral associated with tested chromite ore are silicates as the Antigorite mineral and other minerals (magnetite and chabazite). Microscopic investigations indicated that this ore was a low grade disseminated chromite ore and the liberation size in the range of (0.3-0.05 mm). X-ray diffraction administrated that the chromium element was located in spinel composition (AB_2O_4) with Ca and Fe (chromtite $CaCrO_4$, chromite $FeCr_2O_4$). Moreover, the Sample contained Antigorite ($MgO.SiO_2.H_2O$), Magnetite (Fe_3O_4), and Chabazite ($Ca_{1.85}$ ($Al_{3.7}Si_{8.3}O_{24}$)). Physical properties tests (Natural density, saturated density, and dry density) revealed that the ore of this research has low density and that is attributed to the dominating mineral silicate (waste) which associated with chromite mineral.

X-ray Florence's revealed that the ore of chromite is low grade contained 21.58% Cr_2O_3 and the silicate mineral is mainly gangue in the ore. Scanning electron microscope (SEM) with Scanning Electron Microscope with the Energy Dispersive X-ray Spectroscopy revealed the topography of the ore is mineral silicate witch is appeared in a pastel grey. However, the elements witch are appeared (Cr, Fe, Al, Si, Mg) and indicated to the presence of (Cr_2O_3, Fe_3O_4, Al_2O_3, SiO_2, MgO). Also it approved there are no precious metal in this ore.

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