Study on properties of gossan ore from zinc sulfide deposit

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Abstract: Because of its complex composition, low content of valuable metals and high development cost, the gossan ore has not been paid much attention by scholars at home and abroad. In this paper, the properties of gossan ore from zinc sulfide deposit were studied by the methods of mineralogical analysis, BET analysis and SEM/EDS analysis. The results show that the studied ore is typical zinc-bearing gossan type ore. The main elements in the gossan ore are zinc and iron, as well as a certain amount of silicon. The iron mineral of ore is limonite, most of which are monomers, a few connected with clay, dolomite and so on, and are closely adhered with some siderite, which generally contains zinc. Zinc minerals are mainly smithsonite and hemimorphite, a small amount of sphalerite, zinc mica, most of the siderite and limonite symbiosis. The nitrogen adsorption-desorption isotherm of the gossan ore is a typical type III isotherm, and the isotherm is concave and has no inflexion, which shows that the interaction of adsorbents is stronger than that of adsorbents and materials. The specific surface area of gossan ore is small, mainly composed of micro-pores, the smaller specific surface area and pore volume limit its adsorption capacity, which intimates that the untreated gossan ore is not a good adsorbent. The gossan ore particles are composed of many irregular crystal particles with uniform size and many large pore channels appear in the gossan ore particles. The particles are smaller and more dispersed, and that the interconnections between larger particles are mainly caused by the direct interaction of some smaller particles. This research will lay a theoretical basis for the follow-up development and utilization of the gossan ore.

1. Introduction

As a kind of mineral resource, the gossan ore has not been paid much attention by scholars at home and abroad because of its complex composition, low content of valuable metals and high development cost. The mineral composition and chemical composition of the gossan ore are related to the main metal composition of the primary sulfide deposit. Different types of primary sulfide deposits have different element combinations in the gossan ore formed by supergene oxidation\cite{1}. For example, the main valuable metals of the gossan ore formed in the sulfide deposit containing precious metal gold (silver) are gold (silver), iron, etc. The valuable metals of the gossan ore in sulfide copper deposit are copper and iron, and the valuable metals of the gossan ore in sulfide zinc deposit are zinc and iron and so on. Obviously, the gossan ore contains a large number of valuable metals, which are potential for development and utilization. From the point of view of sustainable development of mineral resources, with the continuous development and depletion of high quality resources, the low quality resources...
such as the gossan will have to be comprehensively utilized in the future to make up for the shortage of mineral resources and improve the self-sufficiency rate of mineral resources. Therefore, the gossan ore resources have an important potential recovery value. There are more valuable metals in the gossan ore. However, because of an oxidized ore with a lower metal content, it is difficult to break through the oxidized ore treatment technology, to develop and utilize it by using the traditional processing and metallurgy technology, and to effectively carry out the comprehensive recovery and utilization of resources. Therefore, there are few basic researches on its application by domestic and foreign experts and scholars, only can be seen to use it to judge the type and content of mineral deposit[2-4], the influence of heavy metals in the gossan ore on the surrounding environment[5-7]; and some research on high value-added precious metal (silver) gossan ore. Therefore, it is great practical significance and theoretical value to study the properties of the gossan ore.

2. Gossan ore sample
The sample is a zinc-bearing gossan ore from a mine. The ore collected from the mine is about 500kg. The ore is in an irregular block shape. The surface of the ore is mostly khaki and brown, and there are a lot of corrosion marks, and small irregular holes on the surface of the ore. It is consistent with the appearance of the classic gossan ore. Fig. 1 shows a representative collection of the gossan ore bearing zinc. The gossan ore was dried naturally, broken up and sieved, and then crushed to -1mm.

![Gossan ore sample](image)

Fig.1 The sample of gossan ore

3. Analysis of properties of gossan ore
3.1 Mineralogical analysis of gossan ore
It can be seen from the results of semi-quantitative multi-element analysis of the gossan ore in Table 1. From Table 1, the chemical element composition of the gossan ore is relatively simple, consisting mainly of zinc, iron, silicon, oxygen and aluminum, in addition to trace amounts of manganese, magnesium, calcium and lead. Zinc minerals, iron minerals, silicon dioxide and alumina are the main components in the ore, of which Zn8.99%, Fe2O368.32%, SiO210.32%, Al2O35.6%. The results of chemical quantitative analysis of zinc and iron, the main elements of the gossan ore, are Zn8.5% and Fe40%.

| Element | Zn   | Fe2O3 | SiO2 | Al2O3 | MgO  | CaO  |
|---------|------|-------|------|-------|------|------|
| Content/% | 8.99 | 68.32 | 10.32 | 5.6   | 1.35 | 0.56 |

Table 1 The multi-element semiquantitative analysis results of gossan ore.

| Element | Na2O | K2O | SO3 | TiO2 | Mn | Pb |
|---------|------|-----|-----|------|----|----|
| Content/% | 0.20 | 0.12 | 0.90 | 0.25 | 1.46 | 1.38 |

Table 2 shows the mineral composition and content of the gossan ore. It can be seen that the zinc minerals in the ore are mainly smithsonite and hemimorphite, the contents are about 8.73% and 3%, respectively. The iron mineral is mainly limonite, the content is about 57.44%. The gangue minerals are mainly illite, quartz and dolomite with contents of about 11.70%, 5.28% and 3.45%, respectively.
Table 2 Mineral composition and content of gossan ore.

| Mineral          | limonite | cerussite | galena | pyromorphite |
|------------------|----------|-----------|--------|--------------|
| Content/%        | 57.439   | 0.824     | 0.002  | 0.035        |

| Mineral          | hydrophotolite | hydrophobite | sphalerite | hemimorphite |
|------------------|----------------|--------------|------------|--------------|
| Content/%        | 0.083          | 0.128        | 0.235      | 2.999        |

| Mineral          | smithsonite | zinc mica | pyrite | acanthite |
|------------------|-------------|-----------|--------|-----------|
| Content/%        | 8.728       | 0.532     | 0.612  | 0.002     |

| Mineral          | quartz | albite | sericite | chlorite |
|------------------|--------|--------|----------|----------|
| Content/%        | 5.280  | 0.130  | 3.058    | 0.115    |

| Mineral          | stilpnomelane | tourmaline | illite | apatite |
|------------------|---------------|------------|--------|--------|
| Content/%        | 0.220         | 0.013      | 11.698 | 0.152  |

| Mineral          | calcite | dolomite | psilomelane | plumbarite |
|------------------|---------|----------|-------------|------------|
| Content/%        | 0.582   | 3.453    | 0.443       | 0.003      |

| Mineral          | jarosite | lead vitriol | rutile | barite |
|------------------|----------|---------------|--------|--------|
| Content/%        | 0.175    | 0.252         | 0.147  | 0.033  |

| Mineral          | gypsum | gibbsite | slag | iron filings |
|------------------|--------|----------|------|--------------|
| Content/%        | 0.011  | 0.177    | 1.743| 0.494        |

The mineralogical analysis of the gossan ore shows that the main mineral in the ore is iron mineral limonite with a content of about 57.44%, followed by zinc minerals, mainly smithsonite and hemimorphite, a small amount of sphalerite and zinc mica, and a variety of lead oxide minerals with the lower content, including cerussite, galena, pyromorphite, hydrophotolite, hydrophobite, lead vitriol and plumbarite and so on. The gangue minerals are mainly clay, illite, sericite, chlorite, followed by quartz, dolomite and so on. Most of limonite in ore is monomeric, a few limonite is associated with clay and dolomite, and some of siderite is closely associated with limonite. Limonite generally contains zinc with average Fe60.64% and Zn5.31%. The content of smithsonite is about 8.73%, which is the most zinc mineral. Smithsonite contains various amounts of iron and other impurities, with an average content of 44.17%Zn and 5.25%Fe. Most of the sphalerite are in the shape of crust and colloidal ring, and most of them are associated with limonite. Hemimorphite contains a small amount of iron, aluminium, potassium and titanium, with an average Zn content of 57.05%. It can be concluded that iron mainly exists in limonite, while zinc mainly exists in the form of minerals such as smithsonite and hemimorphite, and some zinc occurs in limonite in the form of dispersion.

3.2 BET analysis of gossan ore

The materials generally have pore structure, which can increase the specific surface area of the materials and obtain more surface activation energy and is beneficial to the adsorption and catalytic properties of the materials. The pore structure distribution and specific surface properties can effectively reflect the application potential of the materials. BET analysis was also carried out for the future application of zinc ferrite. The isotherms of nitrogen adsorption and desorption of the gossan ore bearing-zinc are shown in Fig. 2. It can be seen from Fig. 2 that the nitrogen adsorption-desorption isotherm of the gossan ore is a typical type III isotherm, and the isotherm is concave and has no inflexion, which shows that the interaction of adsorbents is stronger than that of adsorbents and materials. At the initial stage of relatively low pressure, the adsorption of the material was weak. With the increase of relative pressure, the adsorption velocity increased exponentially.
Fig. 2 BET isotherm adsorption and desorption curve of gossan ore

According to BJH model, the Pore volume-pore size distribution, total pore volume and average pore size can be obtained. Fig. 3 shows the average pore size distribution of the gossan ore. The specific surface area, pore volume and average pore size of the gossan ore is shown in Table 3.

Fig. 3 Pore size distribution of gossan ore

Table 3 Surface parameters of gossan ore.

| Specific surface area/m²·g⁻¹ | Pore volume/m³·g⁻¹ | Mean aperture/nm |
|-----------------------------|-------------------|------------------|
| 1.740                       | 0.002             | 1.348            |

As can be seen from Fig. 3, the pore size of the gossan ore is mainly between 1 and 20nm, most of which are in the range of micro-pore (<2nm). Table 3 shows that the specific surface area, pore volume and average pore diameter are 1.740m²·g⁻¹, 0.002m³·g⁻¹ and 1.348nm, respectively. Therefore, the specific surface area of gossan ore is small, mainly composed of micro-pores, the smaller specific surface area and pore volume limit its adsorption capacity, which intimates that the untreated gossan ore is not a good adsorbent.

3.3 SEM/EDS analysis of gossan ore

BET Analysis shows that the specific surface area of gossan ore is small and the main pore structure is micro-pore. In order to further understand the microstructure characteristics and main element composition of the gossan ore, SEM/EDS characterization was carried out. The SEM and EDS diagrams of the gossan ore are shown in Fig. 4 and Fig. 5.
From Fig. 4(a), it can be seen that the gossan ore with -0.074mm particle size has no obvious agglomerate, the size of agglomerate is 10μm. The further magnification of the gossan ore particles as shown in Fig. 4(b) shows that the gossan ore particles are composed of many irregular crystal particles with uniform size and many large pore channels (about 2.5μm) appear in the gossan ore particles. According to Fig. 4(c) and Fig. 4(d), it is more obvious that the particles are smaller (500nm) and more dispersed, and that the interconnections between larger particles are mainly caused by the direct interaction of some smaller particles. That is to say, when some small particles participate in the reaction, the small particles may agglomerate and grow to form larger particles. It can be seen from Fig. 5 that the main elements in quantitative analysis ore are zinc and iron, as well as a certain amount of silicon.

4. Conclusions
(1) The studied ores are typical zinc-bearing gossan type ores. The main elements in quantitative analysis ore are zinc and iron, as well as a certain amount of silicon. The iron mineral of ore is limonite, most of which are monomers, a few connected with clay, dolomite and so on, and are closely
adhered with some siderite, which generally contains zinc. Zinc minerals are mainly smithsonite and hemimorphite, a small amount of sphalerite, zinc mica, most of the siderite and limonite symbiosis.

(2) The nitrogen adsorption-desorption isotherm of the gossan ore is a typical type III isotherm, and the isotherm is concave and has no inflexion, which shows that the interaction of adsorbents is stronger than that of adsorbents and materials. The specific surface area of gossan ore is small, mainly composed of micro-pores, the smaller specific surface area and pore volume limit its adsorption capacity, which intimates that the untreated gossan ore is not a good adsorbent.

(3) The gossan ore particles are composed of many irregular crystal particles with uniform size and many large pore channels appear in the gossan ore particles. The particles are smaller and more dispersed, and that the interconnections between larger particles are mainly caused by the direct interaction of some smaller particles.

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