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Genetic Analysis of Iron Ore Deposits in Pakke Region Bontocani District Bone Regency South Sulawesi

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ABSTRACT

Characteristics of iron ore deposits vary significantly from the physical properties of the ore carrier rock, the physical and chemical properties of the ore carrier minerals, and the geological conditions of an area, causing variations or types of iron ore deposits. Based on this, the research will focus on the characteristics of alteration or mineral alteration in iron ore deposits in the Pakke area, Bontocani District, and Bone Regency. This study aims to determine the type of alteration in iron ore deposits. The sampling process used chip sampling and grab sampling, where five samples were taken in the form of ore samples. The data analysis process from the samples obtained was analyzed using petrographic analysis, micrography, and XRD (X-ray diffraction). Petrographic analysis is used on altered rock samples to determine alteration mineral assemblages and rock names. Mineragraphic analysis was carried out on iron ore samples to determine the assemblage of iron ore carrier minerals and alteration characterizing ore minerals. XRD (X-ray diffraction) was conducted to determine the set of alteration minerals, iron ore carrier minerals, and alteration-characterizing ore minerals. The characteristic of skarn-type alteration is the type of alteration formed in the research area. Skarn alteration is characterized by the presence of the main characterizing minerals, namely garnet, epidote, diopsid, and wollastonite. The sequence of formation of the alteration of the curvature includes three stages, namely the first isochemical (600ºC), the second stage is metasomatism (600-400ºC), and the third stage is retrograde (400-200ºC).

Keywords: Alteration; Petrography; Mineragraphy; XRD; Skarn

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INTRODUCTION

Indonesia has an enormous potential to produce iron, which is spread across various regions. It also has diverse depositional characteristics in terms of quality, deposition type, and iron-bearing minerals (Kementrian Perindustrian, 2014). South Sulawesi Province is one of the areas that have potential sources of iron in Indonesia.

Iron ore (iron ore) is a natural resource used in various industries, including the steel industry. Indonesia's potential iron-producing resources are quite large, namely around 5,110 million tons. The potential for iron waste is spread in several areas in limited quantities (Kementrian Perindustrian, 2014).

Iron ore in South Sulawesi Province is found in Bone Regency. Bone Regency has resources of 116,682,200 tons spread across several areas, namely Bontocani District (Pakke Hamlet, Tanjung Hamlet, and Marara Hamlet), Kahu District (Matajang Village), and Libureng District (Malinrung Village) (Badan Pusat Statistik, 2021).

The iron ore in Dusun Tanjung has propylitic and skarn alteration types. This is based on a collection of alteration minerals found in the form of epidote, carbonate (sericite), and garnet minerals (Firdaus, 2020). Meanwhile, the iron-bearing minerals found in the Tanjung Region are magnetite, hematite, goethite, and sulfide group minerals, including pyrite and cuprite (Bakri, 2021). Pakke area iron ore is found in carbonate sedimentary rock (Wackstone), which is indicated as the source rock (Harwan, 2021).

The characteristics of iron ore deposits vary greatly, starting from the physical properties of the ore-bearing rock, the physical and chemical properties of the ore-bearing minerals, and the geological conditions of an area, causing many variations or types of iron ore deposits. Based on this, the research will focus on the characteristics of alteration in iron ore deposits (Figure 1).

This research aims to determine the type of alteration in iron ore deposits, which is one parameter for determining the type of iron ore deposits in the research area.

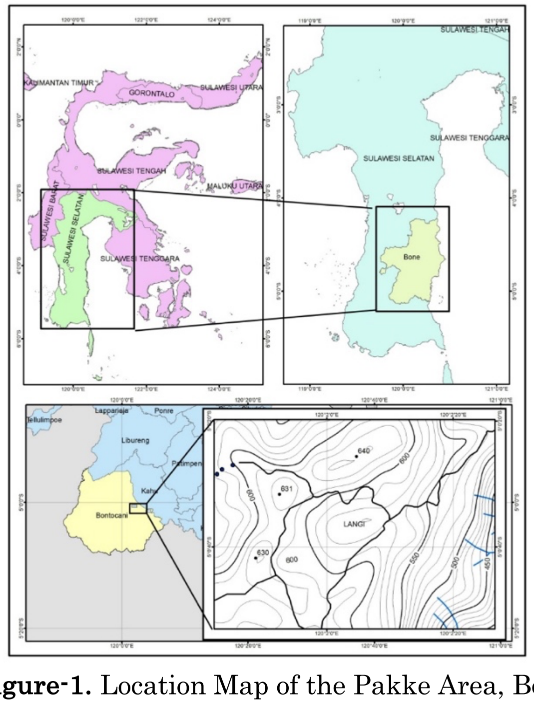

Figure-1. Location Map of the Pakke Area, Bone Regency

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METHODOLOGY

The research stages began with observing the research location, collecting field data, and taking samples of altered rocks and iron ore deposits.

Data Collection Techniques

The data collection process consists of primary data from altered rock samples and iron ore samples. The data collection method was carried out randomly according to representative field conditions for data collection. The sampling process uses chip sampling and grab sampling methods where the samples taken are five ore samples.

Data Analysis Techniques

Data analysis stages from samples taken in the field are processed using petrography and XRD (X-ray diffraction) methods. Petrographic analysis is carried out on rocks that are thought to have undergone alteration. XRD (X-ray diffraction) analysis was carried out to determine the set of alteration minerals (alteration minerals), iron ore-bearing minerals, and ore minerals characterizing alteration. Petrographic XRD (X-Ray Diffraction) analysis was carried out at the Minerals Preparation Laboratory, Department of Geological Engineering, Faculty of Engineering, Hasanuddin University.

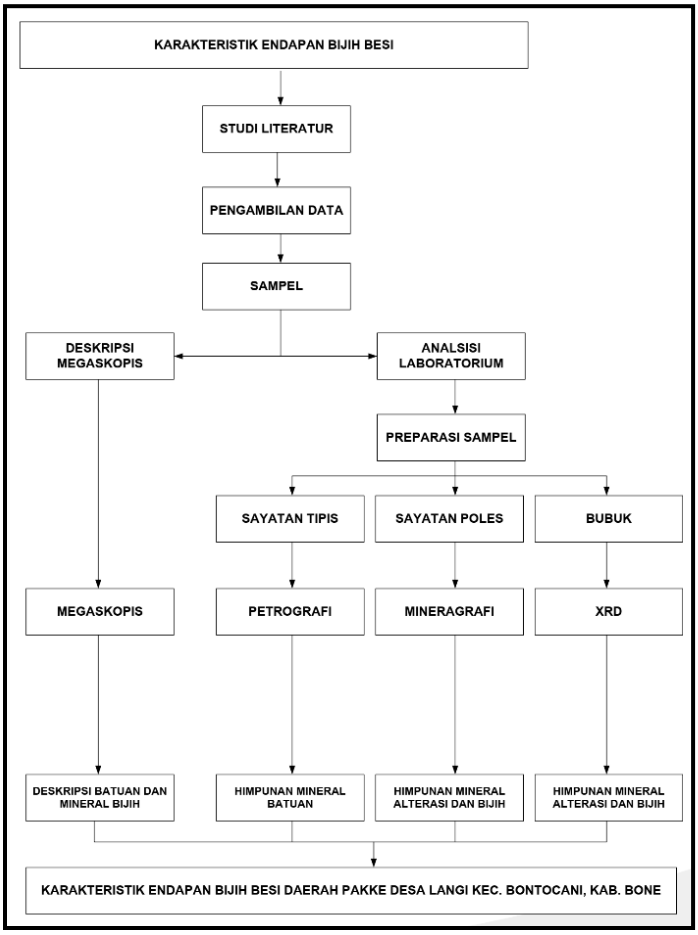

Figure-2. Research flow chart

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Research Result

Geological Conditions

The Bontocani area is in the Southwest part of Sulawesi, which is the southern part of the West Sulawesi Mandala. Based on its physiographic appearance, the Bontocani area consists of two mountain ranges that stretch relatively north to south, the Bone Mountains. The research area is at an altitude of between 2000 and 3000 meters, with a maximum altitude of 3495 meters (Sukamto, 1982).

Based on data from the Regional Geological Map of the Ujung Pandang, Benteng, and Sinjai Sheets (Sukamto, 1982), the sequence of rock formation in the Bontocani area and its surroundings consists of Langi Volcanic rocks (Tpv), Tonasa Formation (Temt), and the Granodiorite (gd) rock group.

Langi Volcanic Rocks (Tpv) are a group of volcanic rocks with a thickness of around 400 m. This rock is overlain unconformably by Tonasa Formation limestone and intruded by granodiorite (gd) rock. The results of dating based on radioactive analysis of tufa volcanic rock samples at the bottom of the rock formation indicate that the rocks' age was around 63 million years or Paleocene.

The Tonasa Formation (Temt) is a rock group consisting of limestone, which is divided into layered limestone and solid limestone, coral, bioclastic limestone, and calcarenite with marl inserts. The thickness of this formation is approximately 1750 meters and is unconformably overlain by the Langi Volcano Rock and is overlain by the Camba Formation (Tmc). In some parts, this formation is intruded by hacks, sills, and stock consisting of basalt with diorite, which formed around the Tonasa area in the Pangkajene Sheet and Western Watampone areas (Sukamto, 1982).

Granodiorite (gd) is a granodiorite breakthrough rock based on the visible, microscopic appearance of the minerals feldspar, biotite, and quartz. This intrusive rock appears on the surface in the Biru area through the Marada Formation (Km) and Propylized Volcanic Rock (Tpv).

Lithological Condition

The rock outcrops found in the research area do not have a large variety of rocks. Based on regional geology, altered rock samples are carbonate rocks (Sukamto, 1982). Altered rocks are iron ore host rocks. Apart from altered rocks, igneous rocks were also found, which are indicated as source rocks that carry iron ore.

The results of petrographic analysis of thin sections of the rock revealed that the type of rock formed was igneous rock, Porphyry Basalt, and carbonate sedimentary rock, Wackstone. Wackstone is indicated to be the host rock of iron ore deposits in the study area.

1. Porphyry Basalt

The results of the petrographic analysis of the igneous rock sections obtained have a gray absorption color, blackish gray interference color, igneous rock texture of hypocrystalline crystallinity, porphyroophanitic granularity, euhedral - subhedral crystal shape, inequigranular relations, massive structure, and a unique porphyritic texture. This rock consists of minerals with a mineral size of <0.02 – 2.2 mm and an elemental mass. The percentage of mineral presence in the rock section is labradorite, pyroxene, opaque minerals, and groundmass (plagioclase crystallites, pyroxene crystallites, and glass) with a color index of 50 (Figure 5).

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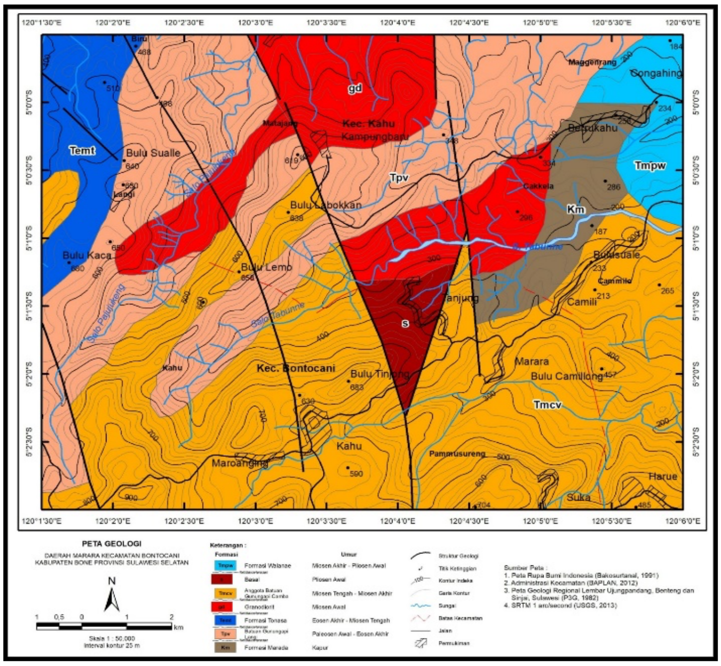

Figure-3. Geological Map of Research Area [6]

Figure-4. a. Photo of iron ore samples; b. Photo of the appearance of iron ore outcrops with carbonate sedimentary rocks; c. Photo of iron ore samples; d. Photo of the appearance of the iron ore outcrop.

2. Wackstone

The results of the petrographic analysis of carbonate sedimentary rock incisions show a brown absorption color with a reddish-brown maximum interference color. The texture of the clastic rock is rough, with a grain size of <0.02 – 1.6 mm. In this rock, the composition of the rock material consists of clay-sized grains, fine-sized calcite minerals, and opaque minerals (Figure 6).

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Alteration Type

Thin section analysis (petrography) and XRD are used on iron ore samples to determine the characteristics of altered or altered minerals. XRD analysis was carried out on three iron ore samples and two rock samples. The results of petrographic analysis (thin section) for the station 5 sample (ST.5.P) revealed the presence of garnet, epidote, and calcite minerals (Figure 7). Garnet is a mineral that forms at temperatures around 400-600ºC (Ugurcan, 2016).

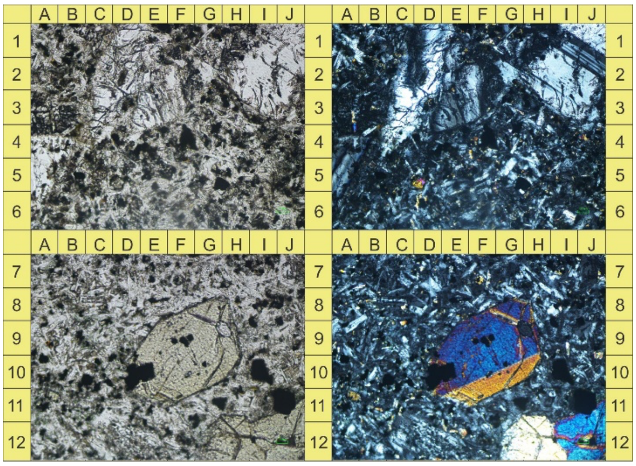

Figure-5. Photomicrograph of an igneous rock section showing the presence of the mineral Plagioclase (C3), Pyroxene (E9), opaque mineral (J11), and groundmass (C5).

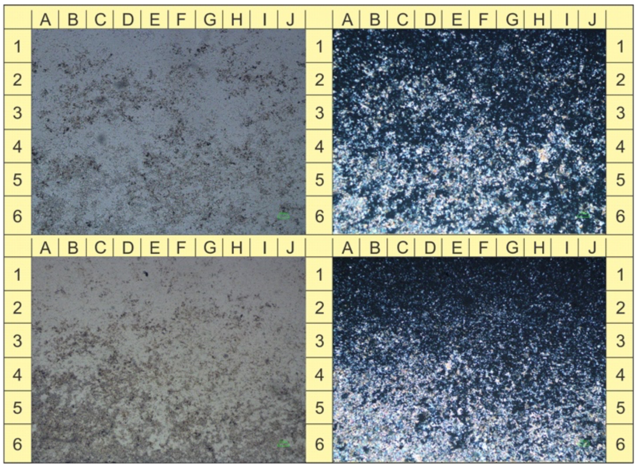

Figure-6. Photomicrograph of a section of carbonate sedimentary rock showing opaque minerals, grains, and mud (C3).

The XRD analysis yielded a range of results, each with its own significance. The main characteristics of skarn alteration, as revealed by the presence of characteristic minerals such as garnet (andradite), pyroxine (Diopsid), and pyroxinoid (wollastonite), were further illuminated. One of the key features of skarn alteration is the Diopsid mineral, a group of pyroxene minerals formed at a temperature of approximately 600ºC. In contrast, the pyroxinoid group, which appears to be the main characteristic of skarn alteration, is wollastonite, formed at the same temperature as Diopsid but with different mineral formation pressures (Hawkins, 2017).

The characteristics of skarn alteration in the research area were comprehensively understood through a combination of petrographic observation analysis and XRD analysis. The main mineral characteristics obtained from the analysis results allowed for the division of skarn alteration formation into three stages: the isochemical stage, metasomatism stage, and retrograde stage (Pirajno, 2009).

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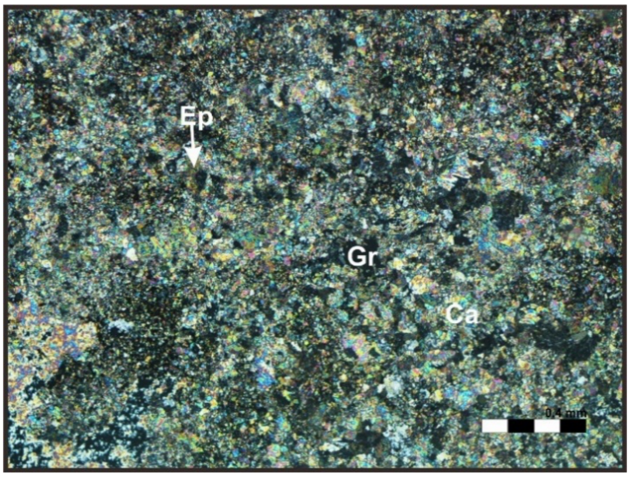

Figure-7. Photomicrograph of ST.5.P rock section showing the presence of garnet (Gr), epidote (Ep) and calcite (Ca) minerals.

The isochemical phase, serving as the foundational stage in skarn deposit formation, is initiated by the presence of liquid magma that penetrates the carbonate side rocks. In the Pakke area, this process occurs with the intrusion of magma fluid into limestone, a carbonate rock. The predominant influence of high temperatures marks the beginning of the isochemical stage. This phase commences with a recrystallization process, leading to the formation of non-hydrous minerals such as garnet (andradite), diopside, and wollastonite. The formation of garnet group minerals occurs at temperatures around 400-600ºC (Ugurcan, 2016). The pyroxenoid group mineral, diopside, is formed at a temperature of approximately 600ºC, while the pyroxenoid group mineral, wollastonite, is formed at the same temperature as diopside but under different formation pressures (Hawkins, 2017).

The metasomatism phase, a crucial stage in the transformation of skarn deposits, follows the isochemical phase. This stage is characterized by a decrease in the temperature of the magma liquid. The process of iron element enrichment occurs due to the significant pressure from the magmatic fluid, which is rich in the composition of the iron element (Pirajno, 2009). In the Pakke area, the metasomatism stage is identified by the presence of iron ore-bearing minerals in the form of magnetite. Magnetite mineral is formed at temperatures around 400-600ºC (Ugurcan, 2016).

The third and final stage, the retrograde phase, is a captivating part of the skarn deposit formation process. This stage begins with a gradual decrease in temperature as the liquid magma undergoes a cooling process. The intriguing aspect of this phase is the role of meteoric water, which enters and mixes with the liquid magma, causing the replacement of initially non-hydrous minerals (garnet, diopside, and wollastonite) with hydrous minerals. In the research area, the retrograde phase is characterized by the formation of epidote and chlorite minerals, which form at specific temperatures, between 272 to 412ºC (Ugurcan, 2016).

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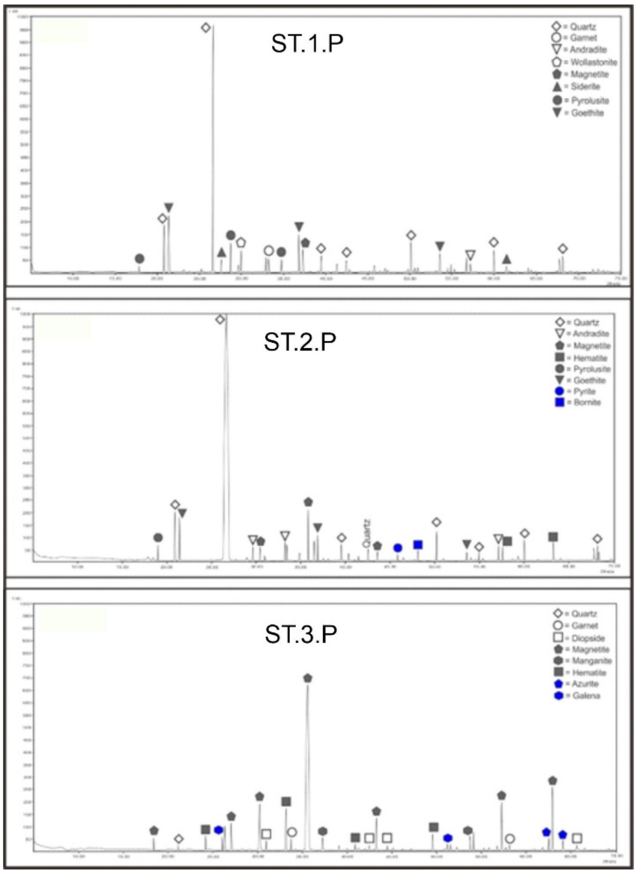

Figure-8. a. The XRD diffractogram of station 1 (ST.1.P) shows the presence of garnet minerals and wollastonite pyroxinoid group minerals; b. The XRD diffractogram of station 2 (ST.2.P) shows the presence of andradite garnet group minerals; c. The XRD diffractogram of station 3 (ST.3.P) shows the presence of pyroxy diopsid group minerals.

Table-1. The sequence of formation of alteration minerals.

Mineral	Prograde		
	Isochemical Stage	Metasomatism Stage	Retrograde Stage
Garnet			
Diopsid			
Wollastonit			
Quartz			
Calcite			
Epidote			

CONCLUSION

The characteristics of skarn-type alteration are the type of alteration that forms in the research area. Skarn alteration is characterized by the presence of the main characteristic minerals: garnet, epidote, diopsid, and wollastonite. The sequence of formation of current alteration includes three stages: the first isochemical (600°C), the second is metasomatism (600-400°C), and the third stage is retrograde (400-200°C).

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