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Research Article

Ore Composition of Lege Worke - Dasu Blocks of Iron Mineralization, Northern Ethiopia

Belayneh Digafe Tulu*

Mineral Exploration and Evaluation, Geological Institute of Ethiopia, Addis Ababa, Ethiopia

Abstract

Iron existed in the form of oxides and also, it is mostly abundant as well as the dominant resource of the Earth for the constrictive industries of the world. The iron ore mineralogy of iron is mainly concentrated as hematite, goethite and magnetite oxides minerals. Beside those oxides the siderite, illmenite and many other are common iron ores. The Lege Worke -Dasu blocks of iron found in the Northern and northwestern part of Ethiopian plateau. This research study holds the main objective of determining the mineralogical composition and mineral assemblage of the iron ore mineralization of the Lege Worke - Dasu blocks. The geological field work with lithological mapping, reflected microscope (ore) petrographic study, mineralogical study using (XRD), and geochemistry of major and other elements were the most applied methodologies for this study. The mineralogical study of the Lege Worke - Dasu iron mineralization result shows that the iron ore body samples were characterized in terms of their mineralogical composition. The outcome result indicates that the ore body consists mainly hematite and goethite iron ore minerals are the dominant compositions documented from the polished section and XRD result. The outcome results of analyzed chemistry and ore study from the polished section studies are shows that the layered (laminated) and pisolitic textures of hematite ore, goethite ore compositions are the main outcomes of this research study. In addition to those ore mineralogy kaolinite gangue, anatase minerals are common constituents including quartz as a gangue mineral. Major oxide analyses for systematically selected samples were characterized by SiO_2, Al_2O_3 and Fe_2O_3 and others. The whole rock chemistry of iron ore and surrounding rock of Lege Worke - Dasu blocks of iron mineralization were used to determine the iron mechanism of the current research area.

Keywords

Iron Ore, Geochemical, Mineralogy, Lege Worke – Dasu Iron Blocks

1. Introduction

The north and western Ethiopian sedimentary basin (Blue Nile) is the target area for this research is conducted [2, 3]. This basin is the main evolved from the history of East African sedimentary basins were a number of industrial and metallic mineral resources are found [25, 32]. In addition to the Mekele, Ogaden, Gambela and Rift a basin of Ethiopia in the north western Ethiopian basin (Blue Nile) is among the five sedimentary formations exist in Ethiopia according to [10, 11, 16, 41]. Its geological formation is unconformable overlain by the volcanics formation of Ethiopian plateau [20, 21, 24]. The basin is well known by umber of economic minerals that exposed by erosion and cross cuttings of the thick sediments of

*Correspondence: Belayneh Digafe Tulu (belaydigafe21@gmail.com)

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the area [1, 12, 28]. The Lege Worke- Dasu iron mineralization is located in the northwestern Blue Nile Basin. The study area is characterized by Mesozoic sediment and Cenozoic volcanic rock varieties [14]. The sandstone, limestone, basalt and pyroclastic tuff are the main lithologic formation of the basin and current study area. Iron is an observable occurrence mineralization in the upper Blue Nile basin [26, 27, 40]. The mineralization of iron in those localities was typically surface occurrence. In its geochemical formation iron forms Fe^{2+} and Fe^{3+} complex ions and colloidal particles due to the fluide circulation and geochemical reactions [5, 13, 17, 18, 29, 31, 33, 35, 36]. According to the iron is concentrated in the oxide form of the magnetite (Fe_3O_4), the hematite (Fe_2O_3), the siderite ($FeCO_3$), an illmenite ($FeTiO_3$), the goethite ($FeO(OH)$) or limonite ($FeO(OH)*H_2O$) and other different sulfides ores [4, 6-10, 15, 22, 23, 30, 39]. In addition to this formation the ferruginous sediment and the chemical precipitated sediments of the ironstone formation and the banded iron deposit (BIFs) were largely used as archives of the geochemical signatures of Fe [19, 34, 38].

1.1. Location and Accessibility

The current research work site is found in the northwestern part of Ethiopia. It is the southwest of Wollo zone. The study area was accessed through the asphalt road of Addis Ababa - Mertule Mariam and about 60km away to all weathered gravel road to arrive the Lege Worke - Dasu site.

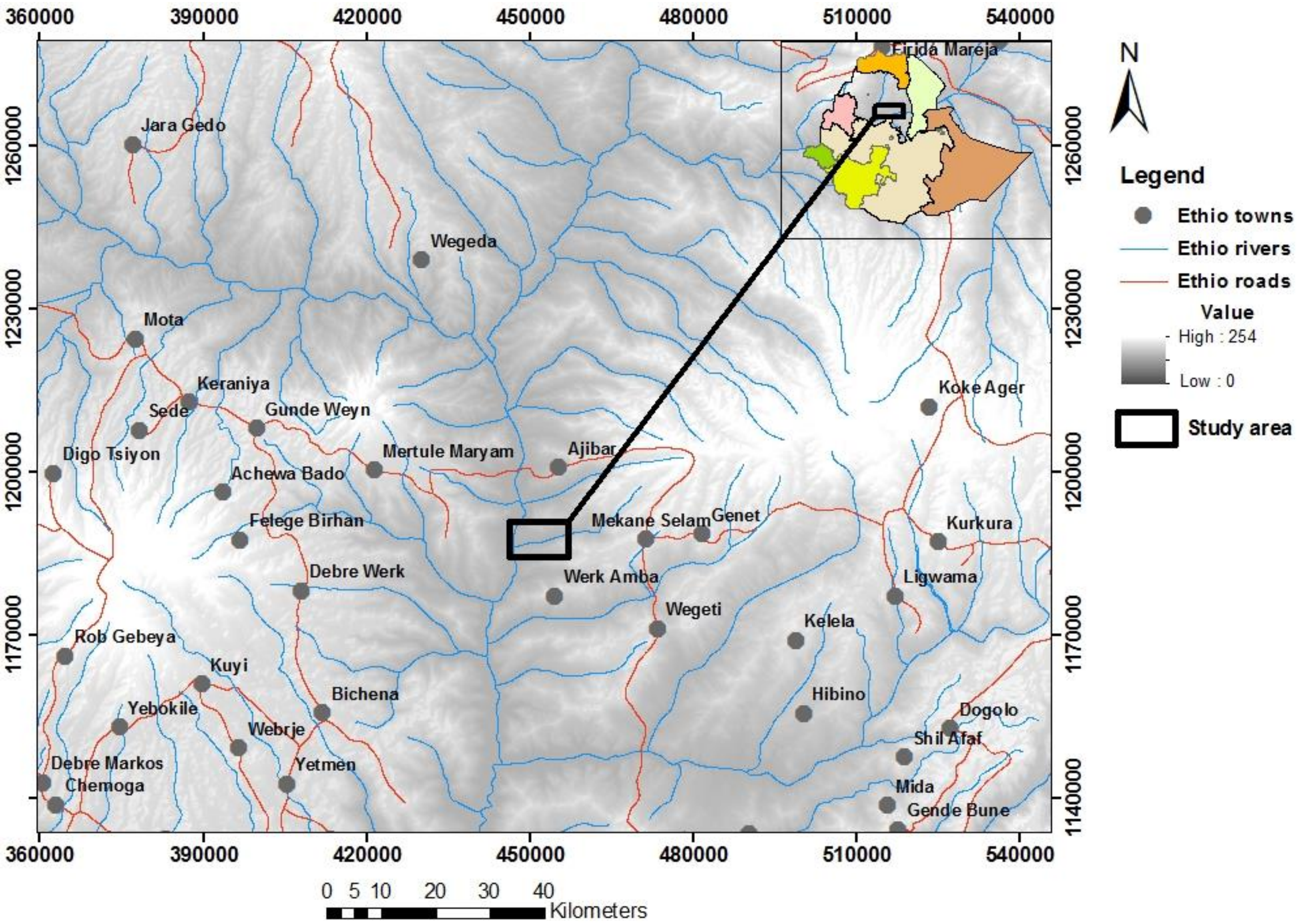


Figure 1. Location and accessibility map of the area.

1.2. Physiography of the Research Area

The Lege Worke -Dasu are found in the Ethiopian highlands which is described by the ragged topographic gorges and valley cuts exposed due to seasonal streams.

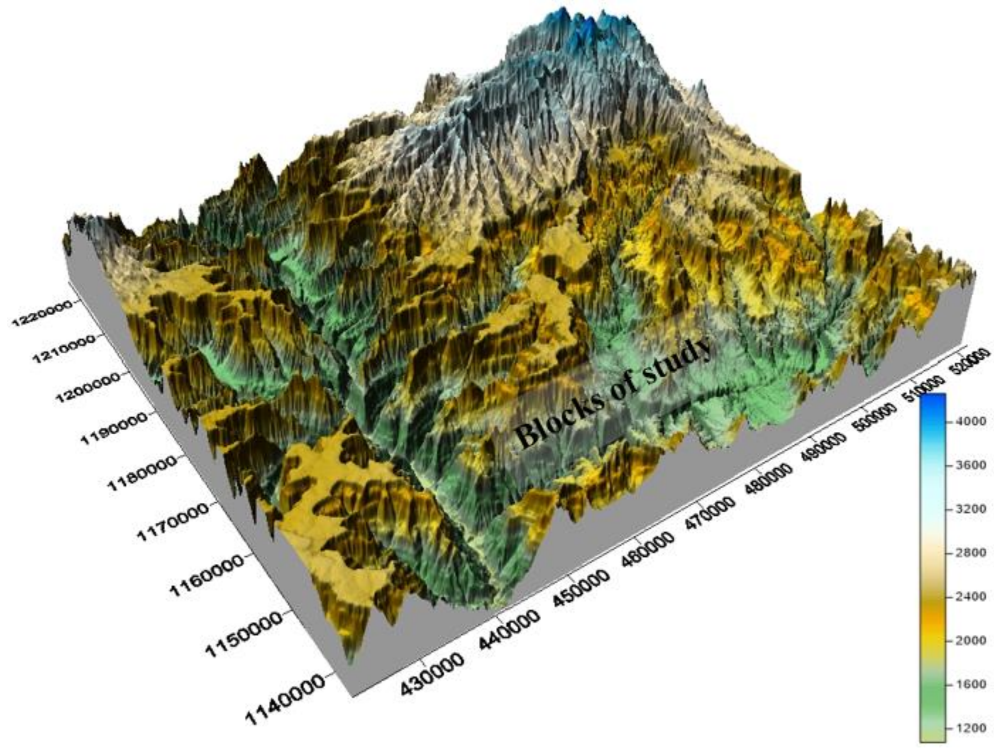


Figure 2. Dem physiographic map of the study and surrounding area.

1.3. Drainage

The water flow pattern of this research area (Lege Worke -Dasuu) and its surrounding area are southward flow to the main river (Abay basin). The drainage condition of the area is mainly dendritic, radial to centripetal types of arrangement in the basin.

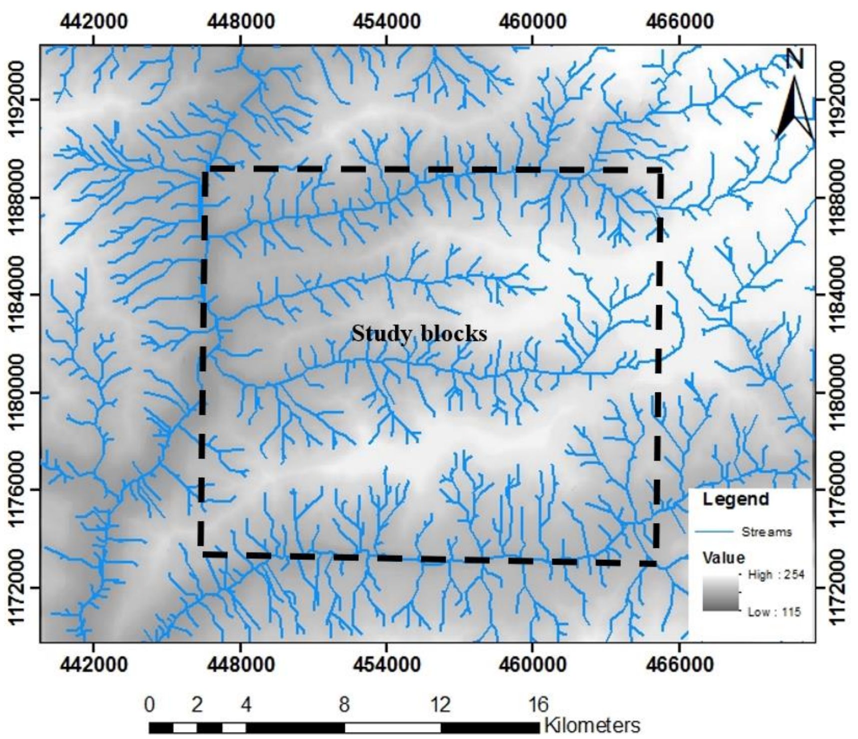


Figure 3. Dranage pattern of the study and surroundings.

2. The Research Goal

This research work has an objective of determining the ore mineralogical assemblage for the Lege Worke -Dasu iron mineralization.

Methodology

To achieve the objective the main applied methodologies are Geological, mineralogical, geochemical laboratory and petrographic study and assisted by:-

(i) Pre field work

Desk work study, literature review, and image analysis and interpretation and base map preparation.

(ii) Field work

Traverse line selection across the strike of the local geology, host and iron ore body systematic sampling, delineate the iron ore body and surrounding host rock and producing geological map of the area.

(iii) Post field work

Field data compilation and organization, geological report writing, preparation of samples for the laboratory analysis, data synthesis and interpretation accordingly the field and outcome results.

2.1. Field Investigation with Geological Maps

This research work contains field work investigation prior to the laboratory analysis and study. The geological mapping work for the site is done by scale of 1: 25,000. The dominant geological units and the iron ore mineralization were delineated by indicated scale.

2.2. (XRD) Study

The mineralogical study for the (quantitatively and qualitatively) analysis were conducted using XRD. The study were includes the geochemical analysis of different element concentration during the study. Some selected iron ore samples were sent to laboratory for mineralogical study. The X-ray diffraction method (XRD) is applied for the iron ore study. For this method of study collected ore samples of the sample (MS-B1), the sample denoted by (MS-DB3), the sample denoted by (MS-B5), the sample denoted by (MS-B10) and the sample denoted by (MS-LW) are the analyzed samples. Those selected iron ore samples were studied at Czech Republic laboratory.

2.3. Geochemistry

This study were mainly use (ICP -MS) and (ICP-AES) for the major oxide and trace element study. The major oxide and trace element analysis are studied by this method. Analyzed samples are denoted by the sample code of MSd1, by the sample code of MSd2, MSd3, by the sample code of MSd4, by the sample code of (MSd8) and by sample code (MSd11) for the surrounding rock. by the sample code of (MSB3), by the sample code of (MSB4), by the sample code of (MSB6), by the sample code of (MSB7), by the sample code of (MSB11), by the sample code of (MSB12) and by the sample code of (MSB15) are for iron ore. The chemistry is done in Belgium.

2.4. Thin Section

11 systematically collected samples were study by thin section. MSd3, MSd5, MSd6, MSd8, and MSd10, MSh1, MSL4 and MSL6 and MSh2 are the studied samples using thin section. The thin section samples were analyzed to determine their, modal composition.

2.5. Reflected Light (ore) Polished Section

The collected iron ore body samples were prepared and studied by reflected light microscope for the polished section. The iron ore sample of (MSB2, MSB8, MSB9, MSB13, MSB14 and MSB16) collected from Lege Worke - Dasu iron ore samples and surrounding ferruginous were studied by ore microscope. The ore body samples were prepared for the polished section at Ethiopian Geological Survey laboratory.

3. Geology of the Research Area

Geological formation for the current research work contains the Mesozoic sediment, continental clastics and other carbonate rock formations and tertiary basalts. Beyond those lithological units other associated pyroclastic deposits are common. The area is dominantly consists of the fossiliferous carbonated rock (limestone), thin beds of mudstone with intercalated shale lamination, coarse and medium grained lenses sediment and conglomeratic with gravel sandstone units. The iron ore bed that sandwiched with these upper and lower sandstone units is the common formation of the site. This geologic formation of the area is clearly understood from the stratigraphic section observed by the cutting of upper Blue Nile River.

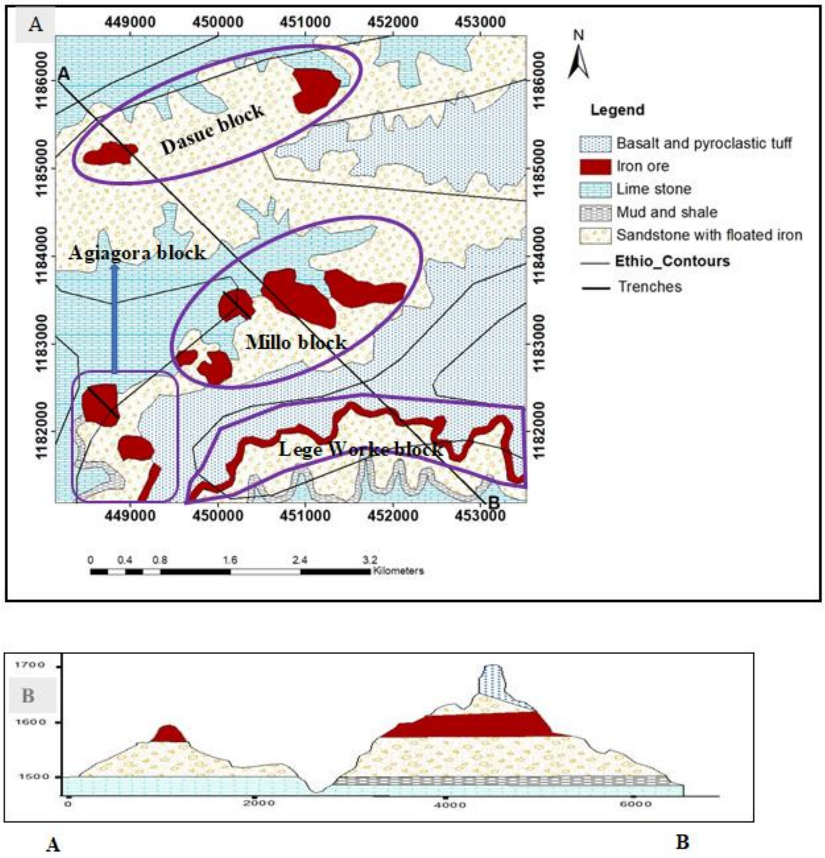


Figure 4. *Lithological map of the upper blue nile basin see picture (A) and geologic cross section along A-B see (B). [37].*

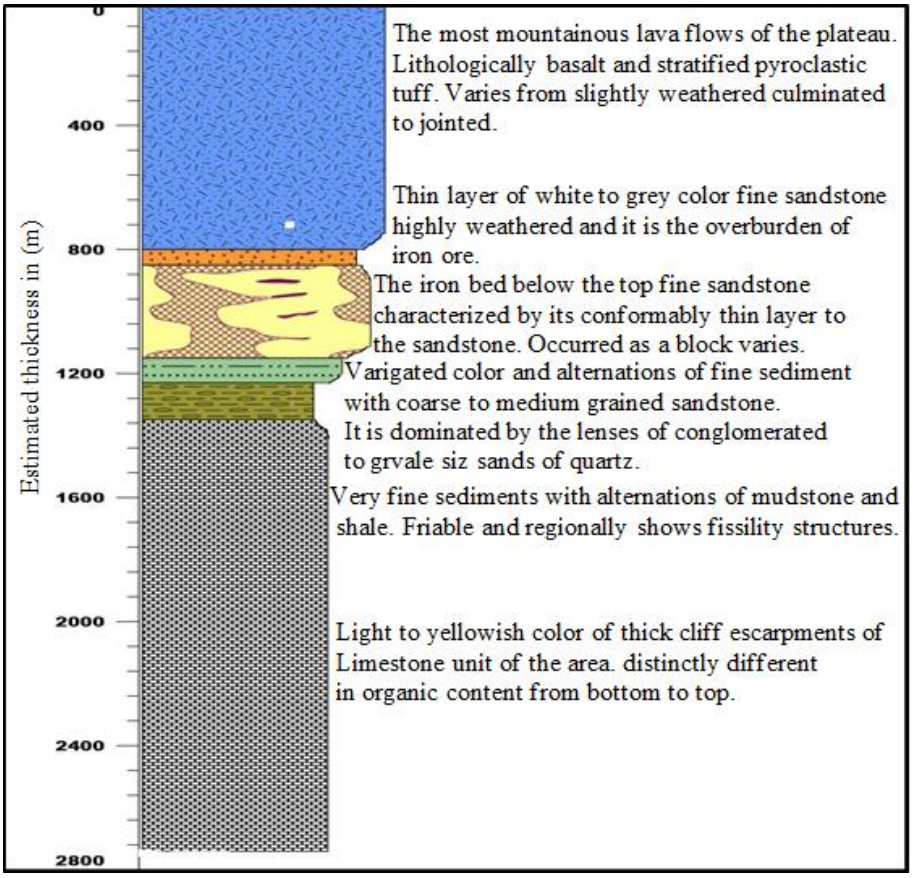


Figure 5. *General local stratigraphy of the study area [37].*

4. Results and Discussion

4.1. Iron Occurrence of Lege Worke - Dasu

The mineralized zone is classified to a number of iron blocks. These iron ore mineralized body zones are known by the Lege Worke - Dasu localies. The iron ore mineralization blocks are Dasue and Lege Worke. The Lege Worke -Dasu blocks of mineralization are the dominant inclusive of all blocks. Iron mineralization of the LEGE Worke - Dasu blocks contains oolitic occasionally with the absence of lateritic clasts of iron fragments within the sediments formation. Therefore, the iron ore body formation of the site is texturally characterized by both massive and oolitic iron formations.

A B C

Figure 6. Field photographs of laterite related iron ore body (A), massive type iron ore body and altered - oolitic to fragementations of iron ore body (B) and inter bedded (C) iron ore of the study area.

4.2. Ore and Gangue Mineralogy

The Lege Worke - Dasu iron ore body blocks samples composed of mainly the hematite ore mineral and the goethite ore minerals are the dominant compositions. The dominant ore constituents of the ore mineralogy are described quantitatively as the hematite about (30-60%), about goethite (8-59%) and magnetite about (0.5-3%) assembeledge. while the main gangue minerals of kaolinite about (11-23.5%), quartz about (1-21%) and anatese with small concentration about (1%) [37]. The ore microscopic study for mineral paragenesis and the goethite ore mineral replacement for the hematite mineral within the polished section study of iron ore minerals shown by the sketched diagram below (Figure 7).

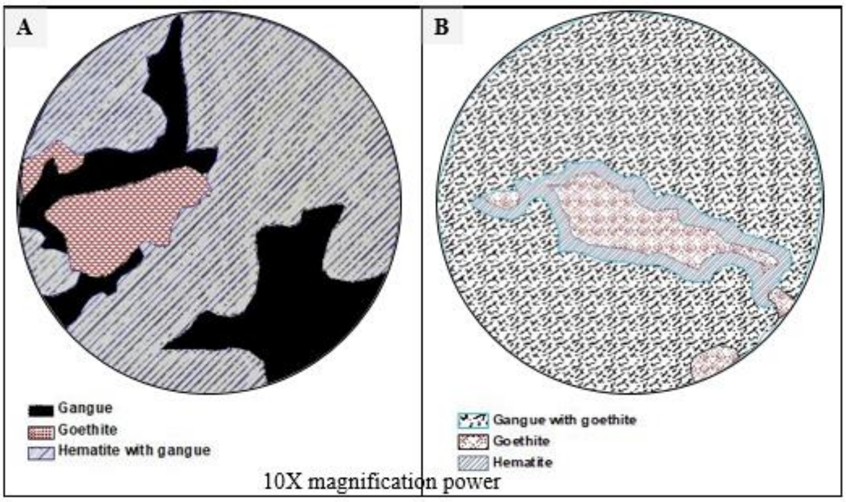


Figure 7. Sketched diagram of MSB13 (A) and MSB16 (B) showing mutual grain boundary and replacement relationship of goethite with hematite and the gangue [37].

(i). Mineralogy of iron ore body

The mineralogical composition of the Lege Worke - Dasu blocks iron ore body are mainly characterize by studied polishes sectioned samples using reflected light (ore) microscope for collected iron ore samples. The selected and prepared cutted ire samples were manually identified the dominant constituent minerals as illustrated from the polished iron ore samples below. The ore is transparent and shine where the gangue minerals are duel and opaque under the light reflected microscope as shown below.

(ii). Polished section mineralogical constituent

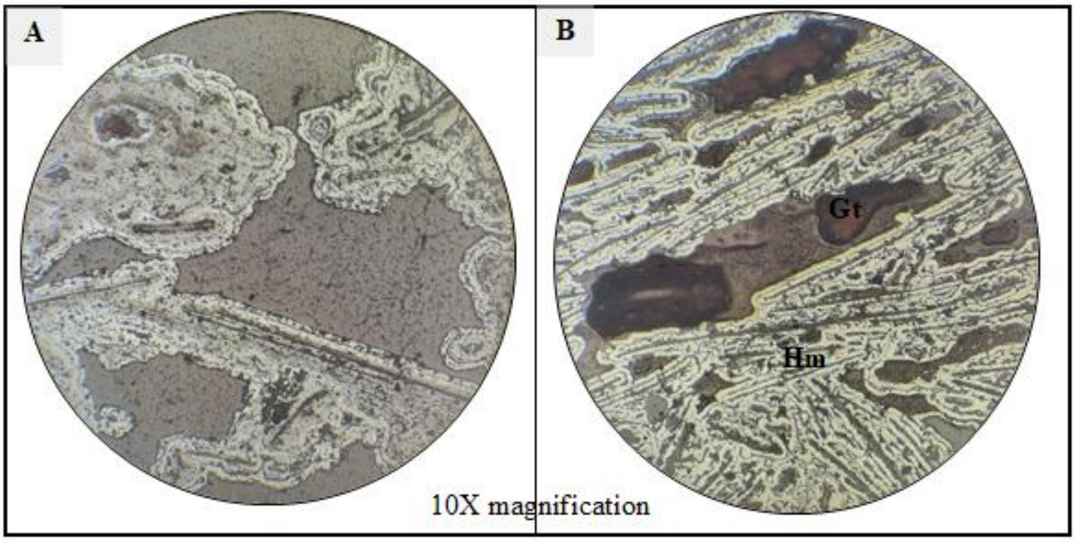


Figure 8. *Photomicrographs of platy type of -hematite iron ore crystals seen (MSB2) (A) and (MSB13) (B) oolith texture and botryoidally alteration of goethite ore form and features and interlayered bedded hematite ore iron mineralization [37].*

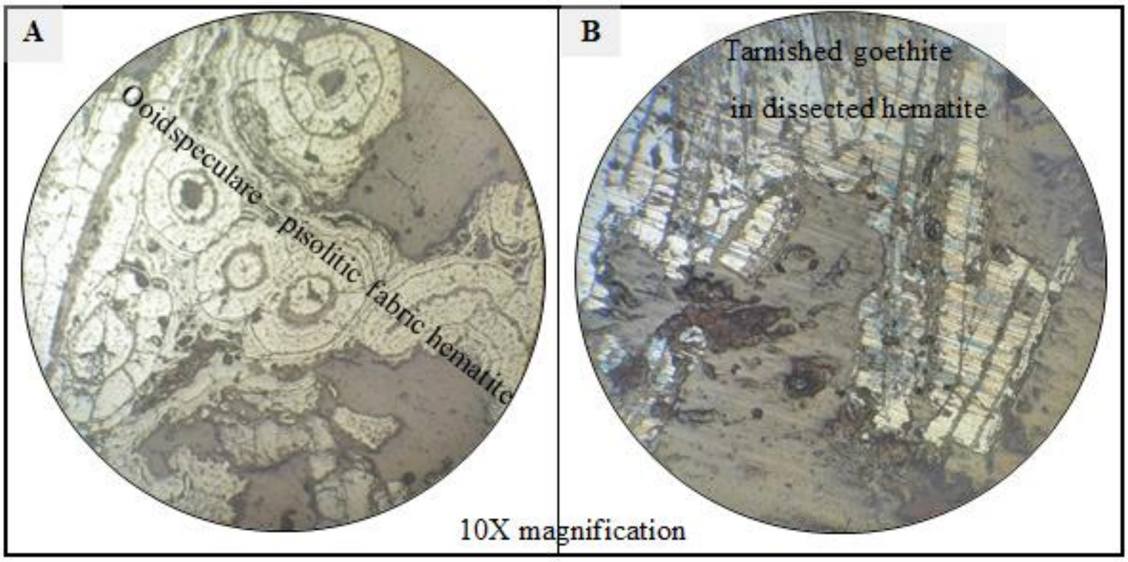
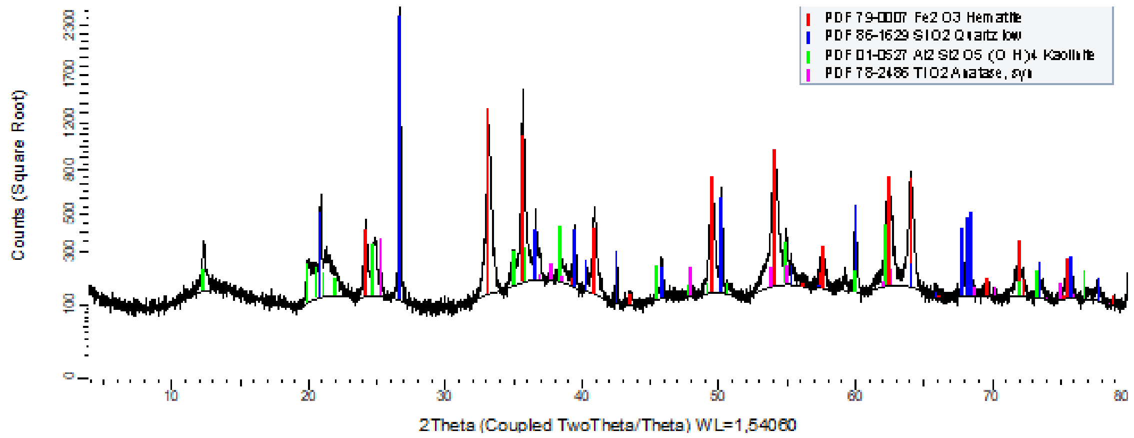


Figure 9. *MSB16 ooids (spherical grains) and specular – Pisolitic or pisoliths (pea-sized mineral grains) fabric (A) and acicular or laths crystals fill voids or fractures regular reflections of hematite and bluish tint of goethite iron oxides (B) [37].*

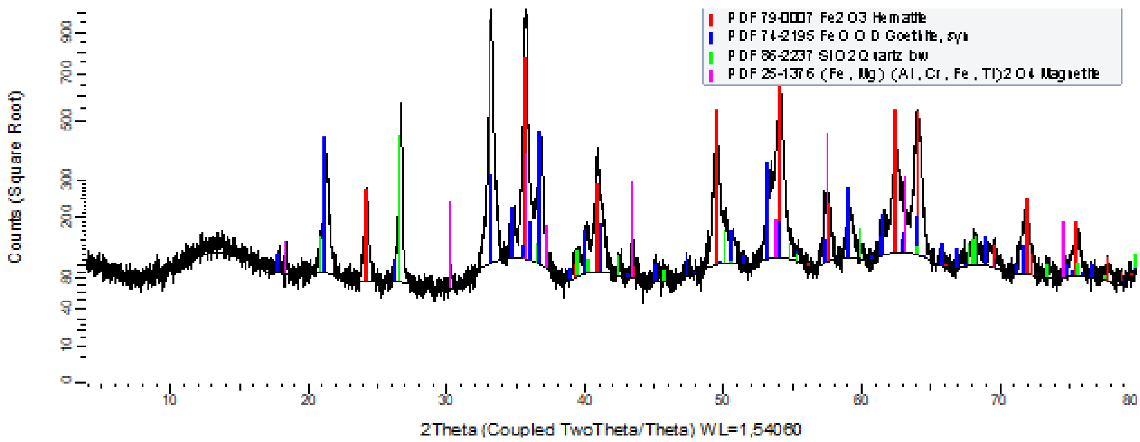
Iron ore mineralization of Leg Woeke - Dasu block iron compositions are studied by the XRD. The XRD results of iron ore samples were interpreted from the relative high to low picks of the constructed graph. As the picks of the graph shows the dominant ore composition of the blocks are hematite and some extent of goethite mineralogy as shown from the XRD picks of some selected samples below.

(iii). XRD mineralogical constituent



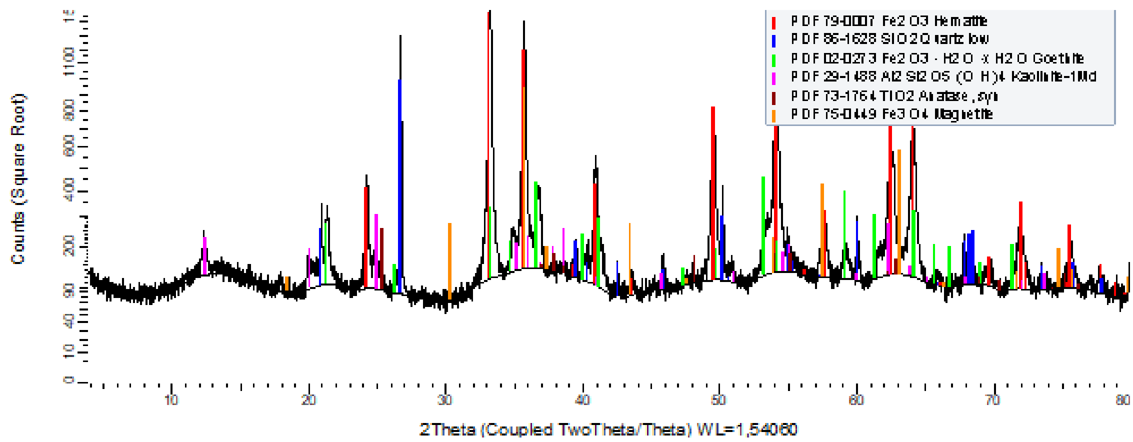
Obr 4. XRD difrakční záznam vzorku MS-B10 s vyznačenými píky od detekovaných fází.

Figure 10. XRD diffraction of iron ore sample denoted by the (MSB-10) characterized by iron ore stratified and bound with the hosted sand-stone and intercalated layer of mudstone [37].



Obr 5. XRD difrakční záznam vzorku MS-B5 s vyznačenými píky od detekovaných fází.

Figure 11. XRD diffractions graphs of iron ore body sample labeled by (MSB-5) interlayered and needle like silica associated with massive iron ore formation [37].



Obr 6. XRD difrakční záznam vzorku MS-DB3 s vyznačenými píky od detekovaných fází.

Figure 12. XRD diffraction value for the analyzes iron ore body sample of (MS-DB3) characterized as weathered and consists of secondary minerals fill the open space through precipitation within iron ore [37].

***Table 1**. The results of xrd studied iron ore body samples show mineralogical assemblage in average% and other associated percentage of gangue minerals (belayneh, 2020).*

Minerals content in wt%		**Iron Ore sample symbols**				
Iron ore minerals	**Gangue minerals**	**MS-B1**	**MSB-10**	**MS-B5**	**MS-DB3**	**MS-LW**
		1%	21%	12%	12%	13%
Hematite	Quartz	40%	46.5%	50%	60%	30%
Goethite		59%	8%	32%	16%	57%
Magnetite		-	-	3%	0.5%	-
	Kaolinite	-	23.5%	-	11%	-
Anatas		1%	-	-	1%	-

5. Discussions

Field work investigation for the Lege Worke -Dasu blocks of iron conclude that the formation mechanism of iron ore in the area and ground ore body shape of the ore body as well as the depth continuity. Mineralogical assemblage under study by ore microscope of iron ores consisted rivals that the kaolinite as a gangue mineral, the magnetite as miner ore mineral, hematite as the dominant iron ore minerals, the goethite moderate constituent of ore mineral and the anatase as miner composition of ore are the main mineral compositions of the iron ore body of the Lege Woeke- Dasu blocks (Figures 8-9). The anatase mineral is documented from XRD mineralogical study of the Lege Worke - Dasu iron. The hematite ore mineral is mainly occurred as layered (bedded form) as well as distributed as cementing in the iron ore body. Whereas the goethite mineral and associated gangues observed from the XRD result are exist in the form of botryoidally and altered ooide textures. The hematite ore mineral assemblage and the goethite ore that recorded from the XRD analysis it is paragenetically characterized under reflected light (ore) microscopic study were shows gradual and systematic replacement of the goethite ore mineral by the hematite ore mineral (Figures 11 and 12). This iron ore mineral assemblage analysis was interpreted for the [42]. The sedimentary replacement reaction of hematite ore mineral through the rock fractures or the cleavage surface of exited minerals by secondary goethite iron ore minerals [37].

6. Conclusion

Hematite, goethite, magnetite and anatase are the common mineralogical composition of the Lege Worke - Dasu iron blocks. Gangues minerals of the ore body in the blocks are quartz and kaolinite from the XRD result. The dominant compositions of investigated site iron ore body of each block are Hematite and goethite. The mineralogical characteristic of the ore body of Lege Worke blocks tells the felsic continental crust is the parent rock for the laterized and deposition of iron.

Abbreviations

MS-B1	Mekaneselam Block1
MS-DB3	Mekanselam Dasu Block3
MS-LW	Mekaneselam Lege Worke

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Author Contributions

Belayneh Digafe Tulu: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Software, Visualization, Writing – original draft

Data Availability Statement

The data is available from the corresponding authors generated during the field investigation work.

Conflicts of Interest

The authors declare no conflicts of interest.

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