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Research Article

Geochemical Characterization of Sedimentary Materials (Limestone, Gypsum, Coal, and Iron Ore) along the Nile River Basin, South Wollo, Ethiopia

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Sedimentary rocks are produced by the weathering of preexisting rocks and the subsequent transportation and deposition of the weathering products. Among the sedimentary rocks, especially limestone is a crucial raw material for cement production. The purpose of this study was to characterize the valuable industrial raw materials, limestone, gypsum, clay, coal, and iron ore, along with the Nile River basin. For sample collection, a random sampling method was applied. Different analytical methods were carried out for complete oxide analysis such as $LiBO_2$ fusion, HF attack, and gravimetric, calorimetric, and atomic absorption spectroscopy (AAS). The percentages of oxides detected in this study are in the range of acceptable values (high content of CaO ranging from 47.3 to 50.4% and less content of SiO_2 ranging from 8.72 to 11.24%) for good proposal as a potential raw material for cement production. The most dominant and wide-range coverage of limestone along with the Nile basin, particularly near Arsema Monastery, was found as matured limestone. The petrographic analysis of gypsum, sandstone, and clay samples indicated that all the samples taken from Wegidi revealed that the high percentage of gypsum ranges from 90 to 95%. Sandstone is dominantly preset in Kelala to Jamma road along with Beto River with high content of SiO_2 ranging from 61 to 95%. The results of this study indicate that the treated coal samples are relative to high calorific value, fixed carbon, and low ash content. Coal and iron ore from Jamma revealed that high calorific value is 4929.24 and hematite content is 52.2, respectively. The result of this study revealed that a huge amount of limestone reservoir is detected in Borena Wereda, Amhara, Ethiopia.

1. Introduction

Amhara regional state of Ethiopia is rich in mineral resources, particularly the Nile River basin is rich in industrial natural resources [1]. There are abundant utilizable mineral resources including limestone, gypsum, coal, sandstone, clay, iron ore, and gemstone in the basin [2]. Almost all the above valuable minerals are commonly found in the sedimentary part of the earth's surface. The chemical and mineralogical composition of sedimentary and metamorphic rock is determined by the composition of the sediments and rocks from which they have originated [3]. Those minerals are vital for the industrial and economic development of the countries [4, 5].

Limestone, a sedimentary calcareous rock, is mostly composed of calcite with some gangue minerals such as quartz, feldspar, and mica [6]. The major industries that consume limestone have cement production, metallurgy, manufacturing, agriculture, and construction purposes [7, 8]. Limestone is the lifeline for any cement plant because it constitutes the major raw material component [8]. In this rapidly developing world, cement plays a significant role in

the construction industry of a country. Therefore, the need for and use of cement are increasing day by day. In Ethiopia, new cement plants are being set up at a very rapid speed [9].

Raw materials of carbonate character, raw materials of acid character, and corrective raw materials which include silicate character and high content of iron oxide are the raw materials for cement production [10, 11]. The basic raw materials for cement production are limestone and clay. The limestone comprises the predominant portion, typically 75%, while the remaining 25% of the raw blend consists of clay and other corrective raw materials [10–13]. Other minerals such as gypsum, sandstone, clay, iron ore, and coal are equally important in the development of a country either by direct use as raw materials in the industry or as export items for dollar exchange.

Especially in Amhara region, the mining sector is too poor even if the resources are available at exposure, they are not utilized well [14]. Even though a huge deposition of limestone is found along with Nile Valley, which is the most important component of cement, there is no cement factory in the region. Nowadays, the price of cement in the region is increasing from time to time (18 Birr/kg), which affects the construction sector of the region. The availability of limestone resources and its chemical composition have not yet been studied. One of the combustible fossil fuels from sedimentary rock is coal [15]. It is mined in more than 50 countries and used by 70 countries [16]. The world's annual consumption of coal is about 5,800 million tons per year [17]. The available coal resource in Ethiopia is estimated to be around 300 million tons in the study area [18]. An important aspect in metallurgical, geochemical, and petrochemical investigations is the determination of iron content in rocks and minerals [19]. Iron is the least expensive and most widely used metal, which is extensively used for infrastructure development works, heavy machinery tools, agricultural tools, and household utensils. Hematite and magnetite are commonly exploited iron-bearing ores among the various minerals of iron [20].

In general, this study was conducted to investigate the availability of sedimentary resources such as limestone, gypsum, sandstone, clay, coal, and iron ore, suggesting their economic value to the concerned bodies working in the sector and how to commercialize the resources. Moreover, both physical and chemical characteristics were assessed. The physical characteristic of the rocks is determined by simple observation of their hardness, and the chemical characteristic of the rocks was determined at the National Geological Survey of Ethiopia using complete silicate analysis.

2. Materials and Methods

2.1. Description of Study Area. The study area covers about five weredas of South Wollo which are found along the Nile River basin and nearby Mehal Sayint, Borena (Mekane Selam), Wegidi, Kelala, and Jamma (Figure 1). All are near to Kombolcha, which is one of the industrial zones in the country.

2.2. Sample Collection and Sampling Techniques. Investigators followed a random sampling technique [21]. Limestone, gypsum, and sandstone samples were taken at different layers in the study sites that helped to estimate the depth and the coverage of the resource [22]. Moreover, sandstone samples were collected from different sites of a road (under construction) between Kelala and Jamma. Clay, coal, and iron ore samples were purposively collected based on the recommendation of the Wereda administrative officers. Thirty limestone samples were collected at different cliff levels along and near the Nile River basin of each wereda of South Wollo based on the lithological arrangements of the rock. Based on the physical observation, representative samples from each location were submitted for analysis. Some layers of Mekane Selam are shown in Figure 2.

2.3. Description of Samples. Sample collection sites and descriptive codes are presented in Table 1 (limestone), Table 2 (gypsum, sandstone, and clay), Table 3 (iron ore), and Table 4 (coal).

2.4. Methods of Analysis. All the analyses were carried out at the Laboratory of Geological Survey of Ethiopia. Representative samples were submitted for determination (analysis) of gypsum, limestone, sandstone, clay, iron ore, and coal (Figure 3).

2.4.1. Methods of Limestone and Iron Ore Analysis. To determine major and minor oxides, complete oxide analysis was carried out using different analytical methods such as $LiBO_2$ fusion, HF attack, and gravimetric, calorimetric, and atomic absorption spectroscopy (AAS). The particle (mesh) size was prepared as 200.

(1) Limestone Sample Preparation. To crush the limestone rock samples, mortar and pestle were used, and 50 g of each sample was weighed using an analytical balance and placed in a clean platinum crucible covered by a platinum lid. To avoid loss by decrepitation, the crucible was ignited for 1 hour at 1000°C slowly. The ignited residue was then cooled in a desiccator and was weighed again. The ignited residue was transferred into a 300 mL porcelain casserole, and 10 mL of water was added to the ignited residue and mixed with a glass rod.

Concentrated hydrofluoric acid (HF) (5 mL) was added to the porcelain casserole and was gently heated to facilitate the breakdown of the Si-O bond in silicate. The mixture was then dried for 1 hour in an electric oven at 150°C. The mixture was then cooled at 40°C for 30 minutes in the electric oven. 5 mL of concentrated hydrochloric acid was added to the mixture of solids, followed by adding an amount of water equal to the HF.

Then, the porcelain casserole was covered by a porcelain lid. The sand bath was heated, and then, the porcelain casserole was placed in the sand bath and heated for 10 minutes. The mixture was then filtered through filter paper, and the residue was

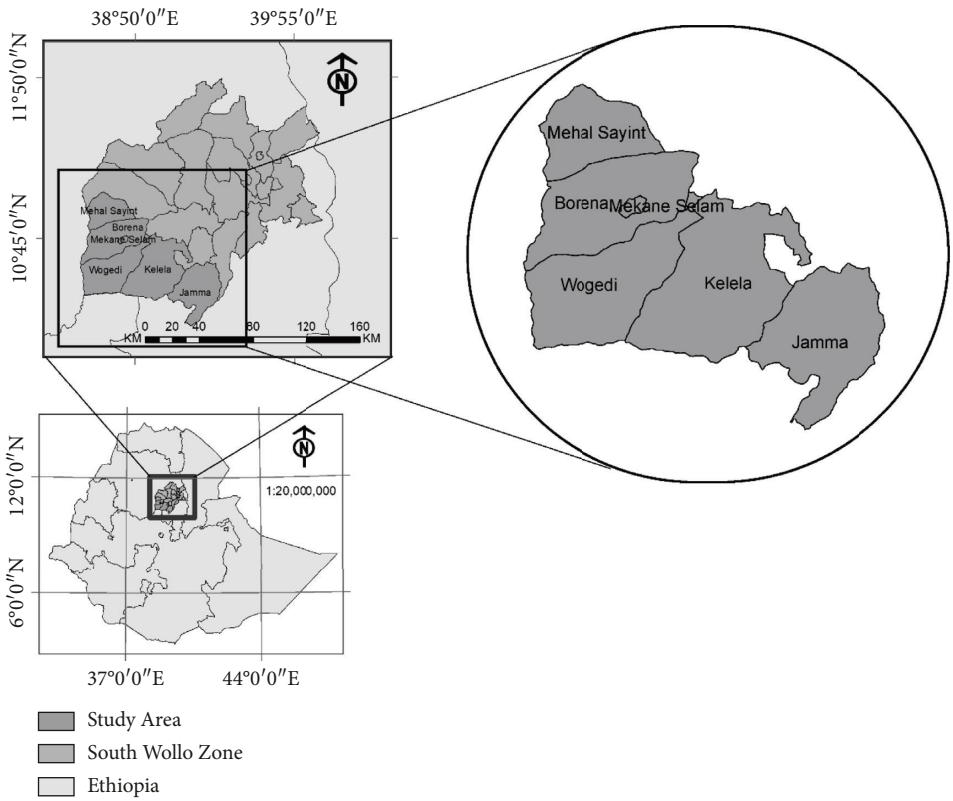

Figure 1: Map of the study area (Sayint, Mekane Selam, Wegidi, and Kelala).

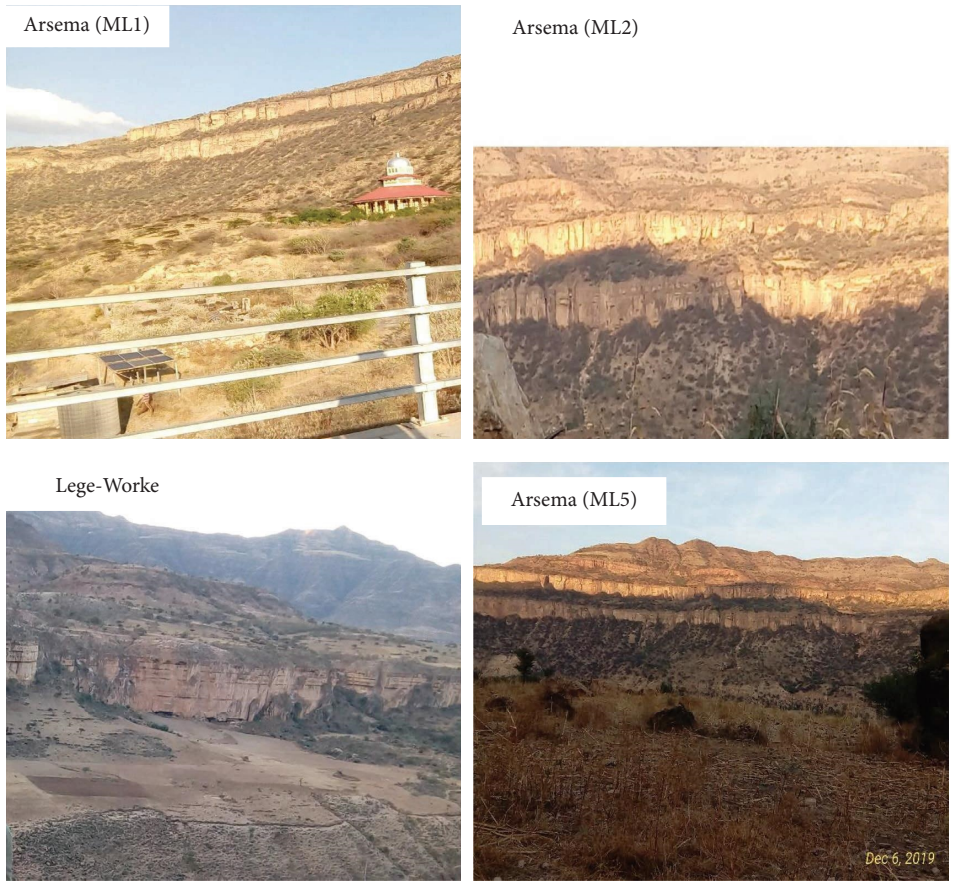

Figure 2: Some layers of limestone samples.

Table 1: Description of limestone samples.

	Limestone samples	Location	Code
1	Mekane Selam (layer 1)	Arsema Monastery	ML-1
2	Mekane Selam	Lege-Worke	ML-2
3	Mekane Selam (layer 2)	Arsema Monastery	ML-3
4	Mekane Selam (most upper)	Lege-Worke	ML-4
5	Mekane Selam (layer 3)	Arsema Monastery	ML-5
6	Kelala (018)	Nech-Afer	KL-1
7	Kelala	Beto River	KL-2

Table 2: Description of gypsum, sandstone, and clay samples.

	Gypsum, sandstone, and clay samples	Location	Code
1	Woleqa left to the main road (Etan trees)	Wegidi	WG-1
2	Woleqa upper layer	Wegidi	WG-2
3	Wegidi 015 Kebele (Gindo)	Wegidi	WM-1
4	Kelala near to Beto River	Kelala	KS-1
5	Kelala transported for road construction	Kelala	KS-2
6	Near to Beto clay (red color)	Kelala	KC-1
7	Dessie-Harego (red color)	Harego	DC-1
8	Jamma Pumis	Jamma	JP-1

Table 3: Description of iron ore sample.

	Iron ore samples	Location	Code
1	Mekane Selam (red shell)		MI-1
2	Mekane Selam (granular)		MI-2
3	Kelala		KI-1
4	Sayint	Kotet	SI-1
5	Jamma (016)	Kebele 016	JI-1

Table 4: Description of coal samples.

	Coal samples	Location	Code
1	Jamma		JC-1
2	Jamma	06	JC-2
3	Were Ilu		WC-1

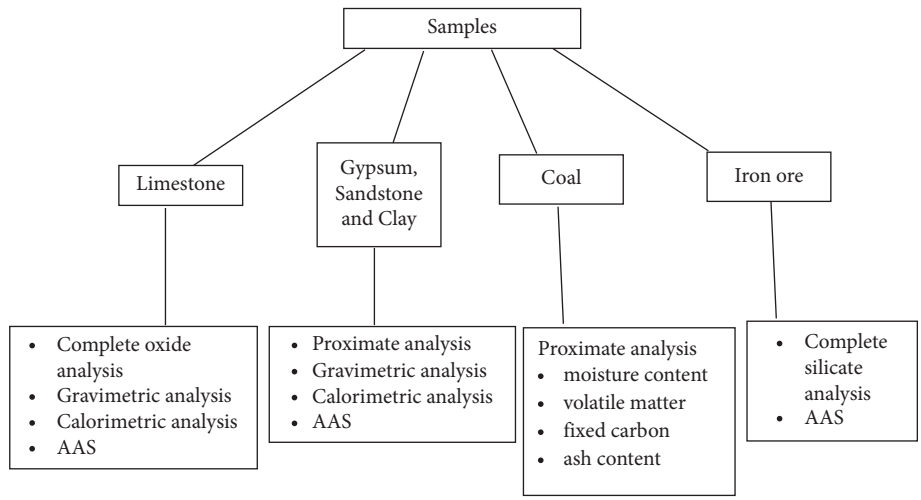

Figure 3: Flowchart of the geochemical analytical procedure.

washed with concentrated HF (1 : 10). Next, the porcelain casserole and the filter paper were washed twice with hot water (about 60–90°C). The solution of limestone filtrate was then transferred into a clean glass Erlenmeyer flask and covered. Limestone filtrate was analyzed by AAS at a specific setting to determine the percentage of metallic oxides and silicon dioxide.

(2) Acid Decomposition (HF Attack). Determination by decomposition with HF left a large amount of non-degradable fraction after decomposition [23]. The smallest insoluble fraction was obtained by using aqua regia (HCl/HNO_3, 3/1) followed by the addition of HF. After 1 hour of decomposition, the mixture was filtered, diluted with water, and then analyzed.

(3) Melting into Liquid. Determined samples were transferred to the solution by picking in platinum crucibles. The optimal melt ratio of $Li_2B_4O_7$ to $LiBO_2$ is 3 : 1. The melt thus formed was poured into dilute HNO_3 and boiled at 70°C with constant stirring and then determined by AAS.

2.4.2. Methods of Coal Analysis. Different analytical protocols were applied to analyze coal samples [24]. Proximate analysis was used to determine moisture content, volatile matter, fixed carbon, and ash content. The coal samples were analyzed for physical and chemical tests. An adiabatic calorimeter was used to measure the calorific value (cal/gm). Gravimetric method was used to measure the sulfur content. For proximate analysis, an Indian Standard IS: 1350 (Part-I) 1984 was followed. The experimental procedure we followed in coal analysis was reported by Rao et al. [8].

(1) Moisture Content Determination. Powdered (1°g) dried coal sample (212 μm size) was weighed into a silica crucible and heated within an oven at 110°C for 1.5 h [8, 25, 26] and after cooling percentage was calculate using the formula dividing the difference of initial weight of the sample and weight of the dried sample divided by the initial weight of the sample and multiplied by 100.

(2) Volatile Matter Determination. A special silica crucible was used for determining the volatile matter [8, 27]. The empty silica crucible was heated at 800°C for 1 h in a furnace. 1°g of coal in the crucible was placed inside the muffle furnace at 925°C for 7 minutes, cooled in desiccators, and weighed to calculate the percentage of volatile matter by dividing the weight of the coal sample after heating to the weight of the coal sample before heating.

(3) Ash Content Determination. An empty silica crucible was first heated in a muffle furnace for 1°h, cooled to room temperature, and weighed as mentioned by the authors of [8, 28]. 1°g of coal sample was weighed into the crucible and heated in a furnace at 450°C and 850°C for 30 minutes and 1 hr, respectively. The ash content (AC) was calculated from the residue on a percentage basis by subtracting the weight of the coal sample after heating from before heating and multiplying by 100.

(4) Fixed Carbon Determination. Fixed carbon (FC) is determined on an air-dried basis by subtracting the sum of all the above parameters (moisture, volatile matter, and ash content) from 100 as reported by Rao et al. [8, 29].

2.4.3. Methods of Gypsum, Sandstone, and Clay Sample Analysis. In addition to complete oxide analysis, petrographic analysis was used for the analysis of gypsum [30], sandstone [31], and clay [30] samples.

3. Results and Discussion

3.1. Results

3.1.1. Limestone Sample Analysis. The results obtained from the complete silicate analysis using $LiBO_2$ fusion, HF attack, and gravimetric, calorimetric, and atomic absorption spectroscopy (AAS) analytical methods are presented in Table 5.

3.1.2. Gypsum, Sandstone, and Clay Sample Analysis. The determination of the rock type through petrographic analysis using thin sections of sample preparation is presented in Table 6.

3.1.3. Coal Sample Analysis. The result obtained from the proximate analysis, calorimetric analysis, and gravimetric analysis for the determination of moisture content, volatile matter, fixed carbon, ash content, calorific value, and sulfur content is presented in Table 7.

3.1.4. Iron Ore Sample Analysis. For the analysis of iron ore, complete silicate analysis and atomic absorption spectroscopy (AAS) were used, and the result is shown in Table 8.

3.2. Discussion

3.2.1. Chemical Characterization of Limestone. Gravimetric and AAS methods were carried out for the chemical characterization of limestone samples. The range of parameters determined in percentages was reported as follows: loss on drying (0.10–1.68), loss on ignition (40.97–47.24), insoluble matter (1.4–2.7), SiO_2 (0.9–2.5), Fe_2O_3 (0.18–0.62), MnO_2 (0.0–0.3), Al_2O_3 (0.0–0.2), TiO_2 (0.0–0.1), K_2O (0.05–0.27), Li_2O (0.05–0.16), Na_2O (0.01–0.29), $CaCO_3$ (82.24–96.68), CaO (46.08–54.85), MgO (0.44–10.92), CO_3^{2-} (59.62–62.18), and CO_2 (43.72–45.61) [32]. The chemistry of the cement in general and Portland cement in particular largely depend upon the geochemistry of its raw materials, i.e., limestone. Lime (CaO)-bearing material is approximately 75% in Portland cement raw materials [33]. The high composition of CaO in the research area makes the potential and prospect of using this limestone as a Portland raw material [34].

As presented in Table 5, the Mekane Selam limestone (ML) samples showed less content of SiO_2 compared to other samples. The SiO_2 content in limestone varies widely ranging from 8.72 to 65.48%, which is contributed by quartz

Table 5: Geochemical analysis of limestone samples (wt%).

Code	SiO_2	AL_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	MnO	P_2O_3	TiO_2	H_2O	LOI
ML-1	11.24	<0.01	0.22	48.08	0.82	<0.01	<0.01	0.08	0.04	0.02	0.41	40.32
ML-2	9.49	<0.01	<0.01	50.40	0.24	<0.01	<0.01	0.04	<0.01	<0.01	0.34	41.08
ML-3	10.14	<0.01	0.34	48.44	0.74	<0.01	0.06	0.02	0.03	0.03	0.28	39.63
ML-4	10.92	<0.01	<0.01	47.30	0.34	<0.01	<0.01	0.02	<0.01	0.03	0.09	39.95
ML-5	8.72	<0.01	<0.01	50.02	0.50	<0.01	<0.01	<0.01	<0.01	<0.01	0.11	41.47
KL-1	65.48	11.22	0.16	3.98	1.14	<0.01	0.30	<0.01	0.10	0.18	4.66	11.91
KB-1	65.10	21.88	<0.01	2.18	0.16	<0.01	<0.01	<0.01	0.14	0.91	0.19	8.69

Table 6: Petrographic analysis of gypsum, sandstone, and clay samples (wt%).

Code	Gypsum	Opaque Fe_2O_3	Clay	Volcanic glass	Quartz	Plagioclase	Sanidine
WG-1	95	5	nd	nd	nd	nd	nd
WG-2	90	3	7	nd	nd	nd	nd
WM-1	95	3	2	nd	nd	nd	nd
KS-1	nd	7	10	nd	85	nd	nd
KS-2	nd	5	4	nd	91	nd	nd
KC-1	nd	5	30	nd	65	nd	nd
DC-1	nd	10	75	nd	6	10	nd

Table 7: Proximate, calorimetric, and gravimetric analyses (%, KJ/kg).

Code	Moisture	Volatile matter	Fixed carbon	Ash	Calorific value	Sulfur
JC-1	8.97	20.37	38.92	23.74	4929.24	4.17
JC-2	0.45	5.85	<0.02	93.85	ND	0.08
WIC-1	3.96	13.83	33.19	49.01	3278.96	<0.02

Table 8: Complete silicate analysis of iron ore samples (wt%).

Code	SiO_2	AL_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	MnO	P_2O_3	TiO_2	H_2O	LOI
MI-1	19.94	3.52	49.80	6.58	0.08	<0.01	<0.01	0.08	3.32	0.46	1.50	10.51
MI-2	24.04	10.69	37.28	3.90	0.34	0.80	<0.01	1.82	0.10	0.61	2.00	19.55
KI-1	65.34	15.13	4.08	2.98	0.44	4.86	2.68	0.16	0.16	0.33	0.62	1.93
SI-1	47.30	11.88	27.56	9.44	1.76	1.46	0.44	0.24	0.31	0.28	0.22	<0.01
JI-1	31.23	6.84	52.20	7.40	0.40	1.50	0.32	0.40	0.43	0.25	0.15	<0.01

(SiO_2). Due to the calcite (CaO) present in the limestone, the lime content of ML samples varies between 47.3 and 50.4%. A strong correlation between CaO in limestone and LOI may be due to the reason that LOI is contributed mainly by the carbonate content of calcite.

To judge the quality of limestone, the correlation between CaO and SiO_2 is useful because of the fact that the CaO and SiO_2 are from two different mineral phases, and they are not related. CaO shows a very strong negative correlation with that of silica. Alumina (Al_2O_3) in these samples ranges from 0.01 to 0.34%. The negative correlation of both SiO_2 and Al_2O_3 with CaO could be due to the clay material present in the limestone samples [35]. Among other constituents that are commonly important is MgO (0.16–1.14%) which might have been derived either from the magnesium-containing skeletal debris or due to post-depositional additions or during diagenesis [35]. A comparison with each sample indicated that there are variations in the chemical compositions existing between them. From Table 5, the predominant oxide compositions were CaO followed by SiO_2, MgO, and then Fe_2O_3 in that order ML samples. The minor oxides included Fe_2O_3, Na_2O, K_2O, MnO, TiO_2, P_2O_5, and SO_3.

The compositions of the various oxides in the analyzed samples shown in Table 5 fall within the requirements of limestone compositions provided [36]. However, two samples, KL-1 and KL-2, showed less content of CaO and high content of SiO_2 and Al_2O_3 which are the characteristics of quartz. The limestone samples taken from Lege-Worke (ML-2) and Arsema 3rd layer (ML-5) showed a high content of CaO compared with other locations, 50.40% and 50.02%, respectively. High content of MgO was detected in the samples of ML-1 and ML-3. The percentages of oxides detected in this study are in the range of acceptable value for a good proposal as a potential raw material for cement production. The most dominant and wide-range coverage of limestone along with the Nile basin, particularly near to Arsema Monastery, was found as matured limestone.

In all cases of Mekane Selam, the CaO/SiO_2 ratio is greater than 4 (standard is >2). For a good candidate for cement, the amount of MgO should not exceed 5%. However, the data in this study showed less than 1% in all limestone samples. As

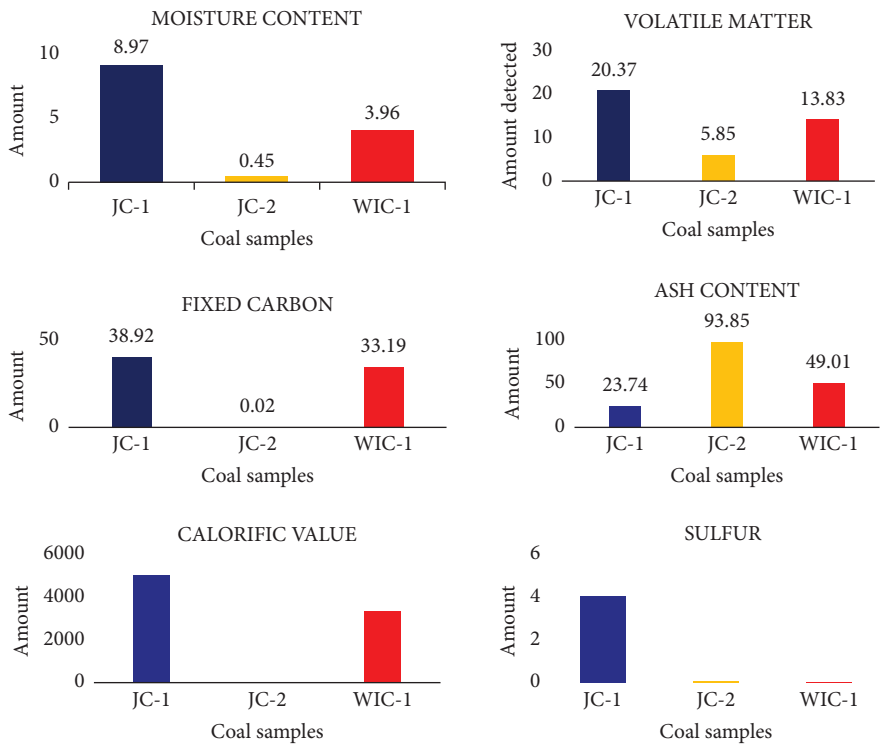

Figure 4: Coal sample graphical analysis.

shown in Table 5, KL-1 and KB-1 were analyzed as high content of SiO_2 which is not a characteristic of good limestone. The results also indicated that most of the limestone samples were found to meet some industrial raw material specifications used in the cement, agriculture, ceramics, glass, silica bricks, pharmaceutical, coal dust fire dampener, paint, poultry, and metallurgical purification processes in the steel industry and some other filler applications. Even though these samples were all sourced from South Wollo along with Nile basin, variations still existed between them because of the complex composition of the solutions from which they must have crystallized as there is ample opportunity, during their growth for the composition of mineral crystals to vary [37, 38]. It has been noted that compositional variation occurs not only between crystals of a given mineral from different localities and between different crystals of the same mineral from one locality but also within a single crystal variation that is evident [39].

3.2.2. Chemical Characterization of Gypsum, Sandstone, and Clay. Gypsum mineral occurs naturally as a soft rock in association with limestone, silica, clays, and a variety of soluble salts as impurities. Geologically, it is formed from super-saturated aqueous solutions in shallow seas which evaporate and deposit carbonates, sulfates, and chlorides among others in the order of increasing solubility [7].

The calcination or dehydration processes carried out on three samples collected from different sites were successful. The whiteness, fineness, and rheological properties of water matched the available standard. The densities, porosity, and other physical characteristics were found to be in agreement with standard ranges (2.1–2.8 g/cm^3) [40]. To assess the material yield and shrinkage characteristics, the percentage weight loss during calcination or heat treatment showed weight loss that increases with increasing calcination time. This is due to the loss of combined water and carbonaceous matter. As shown in Table 6, petrographic analysis of gypsum, sandstone, and clay samples indicated that all the samples taken from Wegidi revealed that high percentage of gypsum. Samples labeled as WG-1, WG-2, and WM-1 were found to be of high-quality gypsum compared with reported standards (>90%) [41].

On the other hand, sandstone and clay samples were analyzed using the same analytical procedure as limestone. High contents of quartz (SiO_2), which is the characteristic of high quality of sandstone, were recorded in KS-1 (85%), KS-2 (91%), and KC-1 (65%) samples. Moreover, as shown in Table 6, high contents of SiO_2 were analyzed in the samples of KL-1 (65.48%) and KB-1 (65.10%), thus indicating that the two samples expected to be limestone were analyzed as sandstone. As depicted in the table, the sample taken from Dessie, along with Haregaon Road, was analyzed as a good quality clay.

3.2.3. Chemical Characterization of Coal. One of the most basic parameters, which can evaluate coal economic value and effects of coal procession, is moisture in coal. The moisture content of the coal is an inherent parameter and undesirable component that reduces the calorific value and increases the weight of transport costs. The high content of moisture is characteristic of the lower-range coals, while the reduced values of this parameter are typical for the higher-range coals [9].

According to Table 7 and Figure 4, the moisture in coal JC-1 and WIC-1 was measured as 8.97 and 3.96%, respectively. However, the moisture content of JC-2 is 0.65%.

As shown in Figure 4, the calorific value is the amount of heat generated by burning a kilogram of coal and measured with a calorimeter. In the study area, because of low moisture and ash in lignite, the calorific value is relatively high. The calorific value of JC-1 and WIC-1 was recorded as 4929.24 calories per gram (20623.94 Joules) and 3278.96 calories (13719.17 Joules). However, the calorific value of JC-2 was not detected or measured. The factors on calorific value are organic elements, moisture, minerals, degree of coal transmutation, and types of forming and petrological composition [13, 26, 42]. Low-quality coal with a calorific value between 3000 and 5500 cal/gm is classified as lignite to subbituminous, whereas coal with a value between 6500 and 8500 cal/gm is classified as bituminous to anthracite [43]. All the samples taken from the study area are grouped in the first category.

Ash is a nonflammable residue that is produced when coal's organic and inorganic materials are burned. Depending on the mineral and organic constituents, the chemical composition of coal ashes varies widely with studied coal [28]. According to the samples collected, the yields of ashes are 23.74, 49.85, and 93.85%, respectively, for JC-1, WIC-1, and JC-2. As shown in the table, the ash contents of JC-2 are higher than the other two which indicates that this sample is not coal because any calorific value of it is not recorded.

Pyritic and organic sulfates are the major forms of sulfur in coal which accounts for the bulk of sulfur in coal [7]. The highest sulfur content was detected in the sample collected from Jamma wereda (JC-1). However, in the sample obtained from Wore Ilu (WIC-1), the amount of sulfur detected is a very small amount compared with JC-1. High presence of sulfur in the coal during combustion as fuel can cause health problems. The amount analyzed in this work is an acceptable and tolerable amount for the use of coal as fuel.

The components of coal that are released at high temperatures in the absence of air are referred to as volatile matter. They contain a mixture of hydrocarbons and sulfur. High volatile content is indicative of low quality of coal [44, 45]. The amount of volatile content in JC-1 and WIC-1 was found to be 20.37 and 13.83%, respectively. The carbon presented in the material remaining after the expulsion of volatile materials is the fixed carbon content of coal. The range of fixed carbon content is from 50 to 98% excluding moisture and ash [8].

3.2.4. Chemical Characterization of Iron Ores. The quality of the ore and viability of commercial exploration are largely determined by the chemical composition of raw iron ore. Table 8 shows the results of the total chemical analysis of iron ore samples in weight percentages. Fe, gangue (SiO_2 and Al_2O_3), and contaminations such as P and S are the most important elements and components of iron ores that occur as hematite (Fe_2O_3) with low gangue content in raw forms. Samples from two weredas, Jamma and Mekane Selam (MI-1 and JI-1), exhibited hematite content, 50.0 and 53%, respectively, with correspondingly low levels of silica (19.9%) and alumina (31.2%), whereas two samples (MI-2 and SI-1) showed medium hematite content (38 and 28%), respectively, and higher silica (24%) and alumina (47%) contents. However, the sample taken from Kelala (KI-1) was determined as having very low hematite content and very high silica and alumina.

In addition, the ores contain other impurities such as CaO, MgO, Na_2O, K_2O, MnO, P_2O_3, TiO_2, and H_2O, which exist in considerably negligible amounts. Alumina, sulfur, and phosphorous represent contaminations in the steel-making process and are specific targets during iron ore beneficiation [7, 8]. Generalized contents for SiO_2 and Al_2O_3 requirements in commercial iron ores are 6 and 4%, respectively [9]. The LOI is a measure of the water content of the ore and an important step in iron ore analysis.

4. Conclusions

Ethiopia is a country under huge construction of roads, railways, industries, infrastructures, hotels, houses, and other constructions; however, construction materials such as cement, steel, and sand are highly demanded compared with those needed before. On the other hand, factories that manufacture those materials are limited in the country, and the annual production of construction materials from those factories is very low which cannot satisfy the demand of the country. Ethiopia is the only country with rich resources of limestone but low production and high cost of cement. The main objective of this study was to characterize the chemical nature of limestone, gypsum, sand, iron ore, coal, and clay samples obtained from weredas along with Nile basin. The data generated from the analytical tools for samples submitted for analysis revealed that Mekane Selam, particularly near Arsema Monastery, was found promising as well as the high potential of limestone and gypsum samples from Wegidi, along with Woleqa River, with high quality. High-quality coal and iron ore were found in Jamma. In conclusion, all responsible bodies of region and country must be aware of building cement factories near the location to access cement and absorb labor workers.

Data Availability

The data used to support the findings of this study are included in this paper. If additional data are needed, the authors can provide.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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