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An overview of Ethiopia's coal potential as a source of energy and future mining opportunities

Jisan Kebede[1], N. Rao Cheepurupalli [2*]

[1]Department of Geology, Bule Hora University, Ethiopia
[*2]Department of Mining Engineering, Bule Hora University, Ethiopia
Corresponding Author: N.Rao Cheepurupalli, Email: nraomining@gmail.com

Abstract
Ethiopia's major coal reserves are in two distinct geological settings (Pre-Trap volcanic and Inter Trappean), and are physiographically spread over the central plateau, NW plateau, SW plateau, and rift escarpment. The country's many locales, including Arjo, Nejo, Getema, Moye, Delbi, Yayo region, Mush valley, Chilga, four from Chida Waka, and two from Hababo Guduru wollega, were used to gather the sample. The ultimate and proximate techniques of geochemical research were used to assess the quality of Ethiopian coal. Its fixed carbon, ash, sulphur content, calorific values, volatile matter, and moisture content have all been identified. Ethiopian coals were ranked from lignite to bituminous mostly on the basis of their fixed carbon content and calorific value. 21.22–82.4% of the coal's carbon is fixed; its calorific values range from 2392.8 to 1173Kcal/Kg; its moisture content is between 15% and 18.74%; its volatile matter content is between 28% and 39.37%; its ash content is between 20 and 36%; its sulphur content is between 0.43% and 2.06%; and its reserve and rank range from lignite to sub-bituminous coal with a thickness of 2.2m to 300.7x106 tonnes. The energy content of coal is shown by its quality. This article aims to elucidate Ethiopia's secured gap on coal potential. Many regions use open-pit mining techniques, and the majority of these are used by local communities and sold to the cement industry.

Key words: Coal, Coal quality, energy sources, mining industry

1. INTRODUCTION

Coal is classified as a fossil fuel that originates from ecosystems in which plant remnants were conserved via the processes of wood and mud preservation, resulting from oxidation and biodegradation. Coal is combusted in order to generate energy and is used in the production of steel. It serves as a viable option for generating heat in several industrial processes, including lime production, aluminium scrap processing, coke production, cement manufacturing, copper smelting, and metallurgical operations. Furthermore, it finds use in several chemical sectors and plays a crucial role in the manufacturing of nitrogenous fertilisers, including urea (Tibebu et al., 2003). When selecting coals for a certain application, it is important to take into account various chemical and physical features such as heating value, fixed carbon content, ash melting temperature, sulphur content, presence of other impurities, as well as mechanical strength.

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Table 1: General Coal ranks with their application

Coal Rank	**Carbon content (%)**	**Heat value (BTUs-per pound)**	**Application**
Anthracite	86-98	15,000	home heating
Bituminous	45-86	10,500 to 15,500	generate electricity and make coke for the steel industry, supplying heat for industrial processes
Sub-bituminous	35-45	8,300 to 13,000	cleaner burning
Lignite	<35	<8,300	Coking

Because of the current global energy crisis, poor quality fuel (coal, oilshale, tars, and so on) are becoming alternative energy supplies in many nations throughout the globe. Many nations focused on developing coal policies. Most African nations are also exploring procedures for expanding diverse coal deposits. To address Ethiopia's ever-increasing energy demand, several research are being conducted in different disciplines to develop hydroelectric power plants, geothermal energy plants, natural hydrocarbon plants, solar energy plants, and so on. In Ethiopia, wood, hydrocarbons, and hydroelectric power are the primary sources of energy for the residential, industrial, and transportation sectors. In the nation, wood was utilised as a residential fuel by the whole rural and a substantial portion of the urban population. Delbi Moye coal, for example, is better suited for thermal combustion rather than coking. It is well recognised that Ethiopia is endowed with commercially mineable natural resources, such as the coal deposits shown in Figure 1. Except for the present mining operation of Delbi Moye, no coal mining operations have begun due to a lack of research and exploratory efforts.

The grade of Ethiopian coal is likewise unknown. Geological, mining techniques, coal quality, nature of uses, marketability, ecology, thickness of coal seam, over burden thickness, mode of occurrence, structural disturbance, lateral variation of seams, spacing of seams, nature of roof and floor, water and gas problems (Wolela A., 1991). Ethiopian coal is being investigated at various scales by various specialists at various times. Coal deposits and occurrences have been recorded in several sections of the nation (Getaneh and Saxena, 1984, Wolela, 1991, 1992, and Tigist, 2007). Ethiopia is rich in commercially mineable natural resources, such as coal deposits and petroleum. Even if Ethiopia has coal potential, there is little detailed scientific investigation other than noting and reporting the resources. Except for the present mining operation of Delbi Moye, no coal mining operations have begun due to a lack of research and exploratory efforts.

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As a result, the practical implementation of the paper has a significant contribution to the country's economic development; relieving the pressure on using wood as fuel for small scale industries, substituting imported coal and saving significant foreign currency, substituting fire wood as domestic fuel for rural and urban populations, and so on. This study covers Ethiopia's coal potential in terms of distribution, geological setting, quality, and mining options. In terms of quality, the rank of coal reflects the gradual reaction of specific coal resources to increasing heat and pressure.

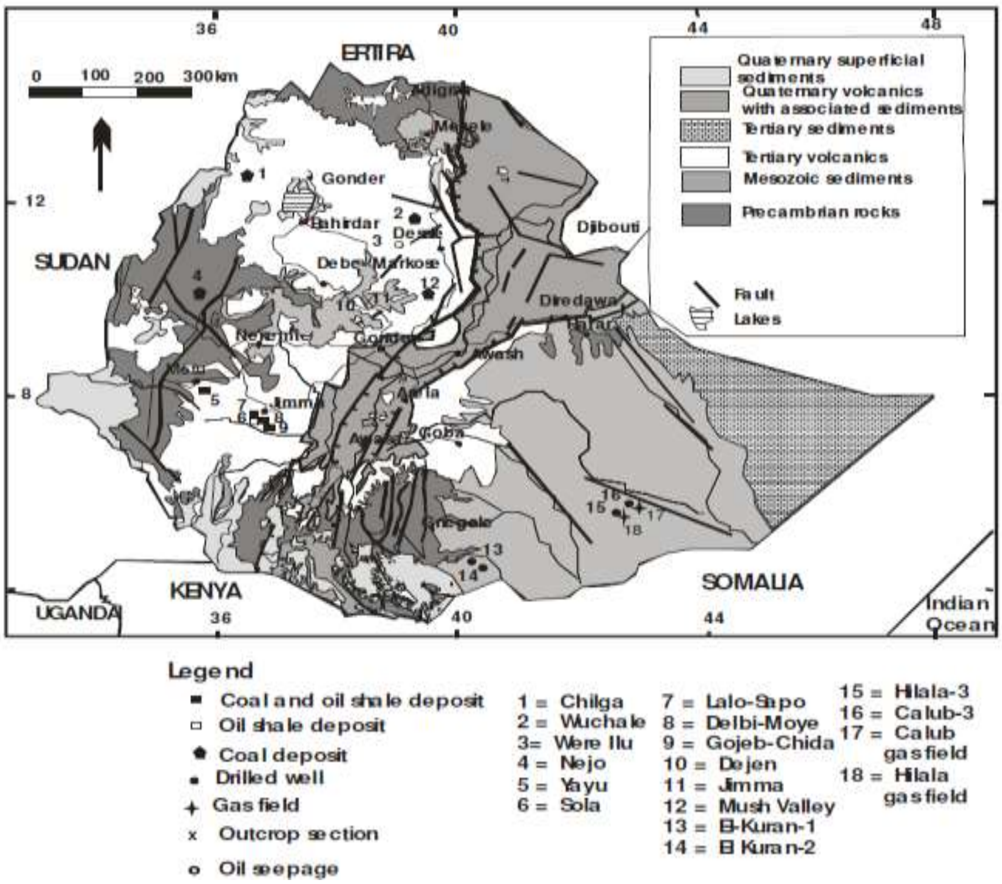

Fig. 1: Distribution of fossil fuel in Ethiopia (Wolela A., 2007)

2. GEOLOGICAL SETTINGS

Sedimentary rocks comprise about 33% of Ethiopia's land surface area and are exposed in five basins: the Ogaden, Blue Nile, Gambella, Mekele, and Southern Rift Basins (N-S striking) (Wolela A., 2008). Ethiopian territory is covered by the Blue Nile basin (55,000-120,000 sq km) (Wolela A, 2007 and Dawit E, 2010), the Mekele outlier (Tadesse et al, 2018), the Ogaden basin (350,000 sq km), and the Gambella basin (15,365 sq km) (Ethiopian South West Energy bureau, 2012). Figure 2 is a diagram. The Ogaden, Abay, and Mekele basins are thought to be intracontinental rift basins produced by extensional forces caused by Gondwanaland's breakup in

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the Upper Paleozoic. The hydrocarbon potential of Ethiopia's five basins includes coal and petroleum. According to Getaneh and Saxena (1984), the majority of Ethiopian coals are lignites, which are related with various geologic contexts. The majority of them are mixed up with the Cenozoic volcanic rocks of Ethiopia's northwestern and southwestern plateaus. Some are sandwiched between Mesozoic continental clastics and Cenozoic volcanic rocks, while others are sandwiched between Precambrian basement rocks and Cenozoic volcanic rocks. Ethiopian coal deposits may be classified into three types based on their geological settings: Inter-Trapean, between volcanic and Mesozoic Sedimentary successions, and between volcanic and Basement rocks (Nejo-Type Lignites) (Asefa and Saxena, 1984). In comparison to the others, Ethiopian coal reserves in the form of Inter-Trapean coal are substantially more common. Ethiopia's south western and central plateaus are known for their coal occurrences intermingled with trap volcanic with a total amount of 297x106 tones and their distribution in significant amount is well recognised and identified from Delbi-Moye, Lalo-Sapo, Yayu, Sola, Chida, Chilga, Mush valley, Wuchale, and Nejo basins (Wolela, 2008). Tables 2 and 3 indicate, respectively, the geographical distributions of Ethiopian coal and oil shale (source: Wolela A., 1991) and the classification of geological settings of coal containing formations by different specialists (Wolela, 1992).

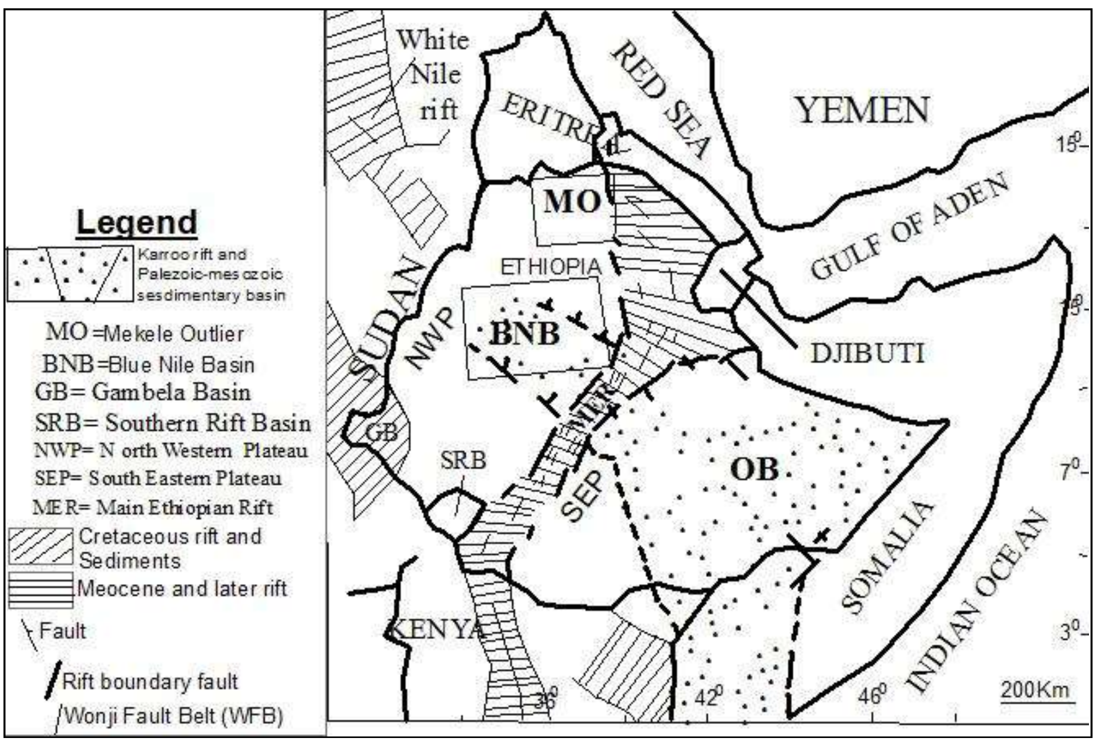

Fig. 2: Regional geological and structural setting of Ethiopia showing major sedimentary terrains and structural setting of northeast Africa (after Asrat, 2015)

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Table 2: Geographical distributions of Ethiopian Coal and oil shale (source: Wolela A., 1991)

No	Area	Map sheet no.	Administ rative region	Geological Setting	Physograp hy and tectonic setting	General classific ation	Paleo-environmen t
1	Ancober	NC 37-11	Shoa	Inter-Terrapean	Rift escarpmen t	Humic	Lacustrine(?)
2	Arjo-Getema	NC37-9	Wollega	Inter-Terrapean	SW Plateu		Lacustrine (?)
3	Chida	NB37-1	Keffa	Inter-Terrapean	Sw Platau		Fluvio lacustrine
4	Chilga	Nd37-13	Gonder	Inter-Terrapean	Sw Platau Within Tena rift	Mixed coal	Fluvio lacustrine
5	Debre Birhan	NC37-11	Amhara	Inter-Terrapean	Rift escarpmen t	Humic	Lacustrine
6	Debre libanos	NC37-10	Amhara	Inter-Terrapean	Central Plateau	Humic	Lacustrine
7	Delbi	NC37-1		Inter-Terrapean	SW plateau	Humic, sapprope lic and Kerogen I	Lacustrine
8	Dessie	NC37-13	Wollo	Inter-Terrapean	Rift escarpmen t	Humic coal	Lacustrine
9	Dirre Dawa	NC37-12	Harar	Inter-Terrapean	SE Plateau	Humic coal	Fluvitaile
10	Fiche	NC37-10	Shoa	Inter-Terrapean	Central Plateau	Humic coal	Lacustrine
11	Hunda Bilisumm a	NC37-18	Harar	Inter-Terrapean	Rift Escarpme nt	Humic coal	Lacustrine
12	Jiren	NC37-1	Keffa	Inter-Terrapean	SW Plateau	Humic coal	Lacustrine
13	Shakiso	NC37-10	East Guji	Inter-Terrapean	SE Plateau	Humic	
14	Kindo Halale	NC37-6		Inter-Terrapean	Rift Escarpme	Humic	Fluvitile

					nt		
15	Lalo	NC37-1	Wollega	Inter-Terrapean	SW Plateau	Humic, mixed coal and oilshale	Fluvio lacustrine
16	Mandi	NC37-12	Wollega	Pre-volcanic	SW Plateau	Humic	Fluvitile
17	Mersa	NC37-3	Wollo	Inter-Terrapean	Rift Escarpment	oilshale	Lacustrine
	Mojo	NC37-15	Shoa	Inter-Terrapean	Rift system	Humic coal	Fluvitile(?)
18	Morka		Sidama	Inter-Terrapean	Rift escarpment	Humic coal	Lacustrine
19	Moye	NB37-1	Illubabor	Inter-Terrapean	SW Plateau	Humic coal	Fluvio-lacustrine
20	Mugher	NC 37-10	Shoa	Pre volcanic	Central Plateau	Humic coal	
21	Mush valley		Shoa	Inter-Trappean	Rift escarpment	Humic coal	Lacustrine
22	Nejo	NC37-12	Wollega	Pre volcanic	SW Plateau	Humic coal	Lacustrine
23	Sola	NB37-1	Keffa	Inter-Terrapean	SW Plateau	Humic coal, oilshale	Fluvio-lacustrine
24	Soyoma	NB37-8	Keffa	Inter-Terrapean	SW Plateau	Humic coal, oilshale	Fluvio-lacustrine
25	Waka	NB37-1	Keffa	Inter-Terrapean	SW Plateau	Mixed coal	Fluvio-lacustrine
26	Wuchale	NC37-13	Wollo	Inter-Terrapean	Rift escarpment	Humic coal	Lacustrine
27	Hababo Guduru		Horro Guduru, Wollega	Inter-Terrapean and Pre Volcanic	NW plateau	Humic	

Table 3: Classification of Geological setting of Coal bearing formation by various

experts (Wolela, 1992)

Geological Setting	Locality	Source	work done by
A. Coal bearing horizons in Mesozoic Sediments	Debre libanos, Nejo	The lignite deposits of Ethiopia	Brown Barnum, (1945)
B. Intercalation of coal bearing Horizon in Trap Volcanic	Chilga, Wuchale, Dessie, Debre-Berhan, Mushvalley, Jiren Etc		
A. Intervocalic coal bearing sediments	Chilga, Mush-valley, Debre- Berhan, Sodo, Wuchale, Dessie etc	Mineral occurrences of Ethiopia	Danilo A. Jelenc (1966)
B .Coal deposits on Precambrian basement Rocks	Debrelibanos, Nejo, Arjo, Didessa river, etc		
A. Lignite beds on Precambrian basement or Jurassic Limestone and overlain by the plateau basalt	Debrelibanos, Nejo	Evaluation of Lignite Occurrences of Ethiopia	P.Reinhardt and Sisay Disassa (1981)
B. Lignite beds between volcanic covers	Mush-valley, Kindo-Halale, Wuchale, Dessie		
C. Lignite beds in late Tertiary graben Sediments	Chilga		
A. Inter- Trappean lignite (Lignite within volcanics)	Berssa, Mush-valley, Ankober Sululta, Kindo and challe-Valleys, Kibre-Mengist, Wuchalle Dessie,chilga, Dilla, Areghit and Azerna, Ficha valley (Hababo Guduru)	A review of Ethiopian lignite occurrences Prospections and possibility	Getaneh Assefa and G.N. Saxena, (1984), Jisan K. (2019)
B.Intra-Trappean (lignite on Mesozoic Sediments)	Adiugri		
C. Nejo type lignite (lignite on Precambrian basement)	Nejo		

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A. Coal beds intercalated in Cretaceous sediment	Muger, Debrelibanos, Nejo, Arjo	Coal Occurrences of Ethiopia	Heeman W. (1985)
	Fincha valley of Horro Guduru Wollega	Provenance analysis of Sandstone	Jisan Kebede (2019)
A. Pre-Trap Volcanic Coal-bearing sediments	Nejo, Arjo, Mendi, Diddesa, Hunda Blesuma etc.	Coal and oil-shale occurrences and their geological setting in Ethiopia	Wolela Ahmed,(1991
B. Inter- Trappian coal and Oil-shale bearing sediments	Chilga, Jiren, Dilbi-Moye, Meteso, lalo, Soyoma, Mojo-Ancharo, Chida- Waka, Mushvalley, Wuchale etc		
Oilshale trapped within Mesozoic sediments	Gindo-beret		Current field work

Table 4. Summary of Coal Reserves in Ethiopia (Wolela, 1992)

	Estimated Reserve					
Locality	A-Category (Measured resource in thousand tons)	B-Category (Indicated resource in thousand tons)	C_1 Category (in thousabnd tons)	C_2 Category (in thousand tons)	Sum (A+B+C) (in thousand tons)	Calorific Value (Kcal/Kg)
Delbi			6,455.020	7,561.710	14,016.73	2392.8-7543.8 (mmmf)
Moye			7,274.058	20,271.24	27,545.298	4820.5-8333.3
Yayu Witette	12,270.000	37,525.000	128,781.000		178,576.000	4465.35-4981.97 (dmmf)
Yyu Achibo Sombo			64,453.113	57,003.92	121,457.030	3713.95-6739.44 (mmmf)
Chilga				19,000.00	19,000	4129.6- 5691.17 (mmmf)
Gojeb-Chida				9,380.000	9,380	5835 (mmmf)
Arjo						4545.0
Supe-Sodo						3716.4

Jiren						
Nejo				2,900.000	2,900	4545.0
Total	**12,270.000**	**37,525.000**	**206,963.191**	**116,116.870**	**372,875.058**	

Note: Among the above coal deposits only Delbi Moye coal deposit is under concession. Delbi is under mining and Moye is under exploration.

Data demonstrate that large coal deposits are physiographically scattered across the south western plateau, north western plateau, central plateau, and rift escarpment in two geological settings (Inter Trappean and Pre Trap volcanis). D. Jelenc, 1996 stated pre-trap volcanic coal seams were commercially interesting. Table 4: Ethiopian Coal Reserve Summary (Wolela, 1992).

3. UNREPORTED ETHIOPIAN COAL OCCURRENCE

3.1. Sola Area Coal

According to the available data, major coal deposits are physiographically scattered on the south western plateau, northwestern plateau, central plateau, and rift escarpment, with two distinct geological settings (Inter Trappean and Pre Trappean volcanis). According to D. Jelenc, 1996, pre-trap volcanic coal seams are commercially attractive. Table 4 shows the Summary of Coal Reserves in Ethiopia (Wolela, 1992).

3.2. Seka area Coal Occurrence

Oil shale in the area seems prospective, but needs further study.

3.3. Soyoma - Yeba Area Coal Occurrence

Meteso-Dilbi and Soyoma-Yeba areas might belong to the same basin separated by volcanic activities or could be separate basins laying adjacent to each other. In Soyoma and Yeba areas, the sedimentary exposure covers 6km2 and 5.5 km2 respectively**.**

3.4. Debre Libanos Area Coal Occurrence

Only one occurrence at Agat river, 300 meters north of Tekle-Haimanot church encountered. Based on the information from local people, lacustrine sediments could exist in the area.

3.5. Jiren Coal Occurrence

Aerial extension of the coal seams is very small. Quality of the coal very low (high ash content) due to abundant interbedded clay layers and small seam thickness. The rank is Lignite.

3.6. Mendi Area Coal Occurrence

Although a good part of it covered by enormous pile of Tertiary lava, there is a possibility to find quite extensive sedimentary basin. Carbonaceous sediments and coal seams were found between the basement and Tertiary lavas. Search in adjacent areas may come up with lignite of a better quality and thickness.

3.7. Morka Coal and Carbonaceous Shale Occurrence

There are two 1.50-meter-thick coal and carbonaceous shale strata in the region (a remark from REMRDA, SNNPRS). To ascertain the quality and resource of coal and carbonaceous shale occurrence, more thorough research is necessary.

Source: - A REMRDA SNNPR note. Rural Energy and Mineral Resource Development Authority is known as REMRDA.

3.8. Gohastion Coal

The resource is in Gohastion woreda, Northern Showa, Oromia regional state. It sandwiched between two volcanic (Ashange basalt) both at the top and bottom. The seam has 3m vertical thickness and 30m horizontally extended. The color is gray and thin fibrous plant body remains are observable, which makes it Lignite in rank shown in figure 3.

Fig 3. Coal from Gohastion area

3.9. Hababo Guduru Coal

The unit is exposed in Hababo Guduru woreda at two places. One is around Ilamu Malole kebele, 5km from NE of Dedu town and the other is around the kubsa kidame kebele toward the

Fincha suger Factory. The one which is in Ilamu Malole are sandwiched (interbedded) within Tertiary volcanic rock and are exposed where the upper basalt is eroded and presumably being an erosion remnant. So relatively the age of this coal is Tertiary. The seams have around 1.5m thickness beared by claystone. The other which is in Kubsa Kidame Keble toward Finca'a suger Factory are sandwiched between Mesozoic sandstone, means that both at the top and bottom there is Adigrat sandstones. Since there is still observable remains of plant fragments and the unit is not as much shine at hand spacemen for both kebeles, the quality of that coal is lignite. Shown in figure 4 below.

Fig 4. Field photograph showing Lignite coal from Hababo Guduru

3.10. Tolay Coal

The coal is located in south western part of Ethiopia, Jimma Zone, Tolay Woreda district. The coal is characterized by black grey to shine physically and sub bituminous rank chemically. The seam is bounded by sand and mudstone at the top and mud at the bottom shown in figure 5. The coal bearing lithology is sandwiched between volcanic both at the top and bottom. So it is the kind of Inter-trappean coal. The seam has around 7m vertical thickness and horizontally extended.

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Fig 5. Coal at Tolay

3.11. Kamashi Coal

This coal resources are located in Benishangul Gumuz regional state, in kamashi area, west of Nejo. It has brown-black color with shine surface. The rank of the coal ranges from Lignite to Bituminous with calorific value greater than 3000kcal/kg. The coal in the area exhibits almost tabular formation which is horizontally layered and some coal deposits in this area s reveal distributed with fold and minor faults geologic structures.

4. OPPORTUNITIES FOR COAL MINING

The coal mining industry in Ethiopia is regarded as one of the significant areas that have covered a big amount of the nation's economy but have yet to be practised in our country. The relevance of the coal mining industry stems from the availability of supplies to various coal energy consuming sectors. Because several businesses, particularly the cement industry, rely heavily on coal as an energy source, coal mining opportunities should be expanded. In various parts of Ethiopia, locals mine coal using traditional techniques such as group digging. As a result, it is prudent to use a scientific approach to developing mining processes, including coal seam modelling, mine design and planning, and coal resource evaluation. Open cast mining is suited for coal that is spread with fold and minor fault geologic structures (for example, Kamashi coal) to enhance the design in complicated geology settings and coal seam development. The forms of coal extraction are defined mostly by the depth of seams that are relatively near to the surface, the quality of the seams, the thickness of the coal seams, the geologic condition, economic and environmental variables. Based on these considerations, the majority of Ethiopian coal from various places is mined using the open cast technique, which is both traditional and scientifically validated. For example, in Western Wollega (Nejo, Kamashi, and Tolay), locals gather and mine coal by excavating as open cast mining techniques and selling it to the cement industry. The open cast mining of Tolay coal, in particular, is failing due to overburdening. Figure 6 follows. The pattern of open cast coal mining in the Tolay region is shown. This is due to a lack of

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scientific testing during mine design or the mine was never developed. This compels the owners to halt mining since it has a negative impact on the environment (land degradation and damage to life). As a result, they need scientific assistance. Scientifically, the Delbi coal has a favourable mining appeal.

Fig 6. Shown the pattern of Open cast coal mining at Tolay area

The findings of the proximate and calorific value studies demonstrate that Ethiopian coals have a lignite to sub-bituminous rank, a high ash content, a low fixed carbon content, and around average moisture and volatile matter. In general, Ethiopian coal has a fixed carbon content of 21.22-82.4%, a calorific value of 2392.8cal/kg - 1173Kcal/kg, a moisture content of 15%-18.74%, a volatile matter content of 28%-39.37%, an ash content of 20-36%, a sulphur content of 0.43%-2.06%, and reserves ranging from 4x 106 tonnes to 300.7x106 tonnes.

Delbi- Moye coal deposit is regarded as a viable possibility because to the apparent commercial thickness of coal and lignite seam development, significant area, and potential for open-pit mining. Exploration in the Achibo-Sombo region shows that there is a strong chance of developing the coal resource in the area. The apparent lateral extent and thickness of the coal seams in the Chilga region constitute a viable prospect for the development of an open-pit mine. Based on the quality analysis and distribution of the exposed coal seam, there is a considerable prospect for coal development in the Supe region.

4. CONCLUSION

Coal strata are classified genetically as sapropelic, humic, or mixed coal. The humic coal is the most prevalent among these. From a megascopical perspective, the Humic coal exhibits vitrain, clarian, and sporadic lithotypes. In contrast, the Sapropelic coal is characterised by the following lithotypes: boghead, cannel, cannel boghead, and boghead cannel. However, the majority of contemporary researchers concur that inter-Trappean coal deposits are economically more intriguing. According to existing research and secondary data, the Delbi and Moye coal deposits are the most cost-effective in the country. Furthermore, surface extraction of the Tolay coal was highly attractive even in the absence of scientific investigation. Therefore, after conducting a comprehensive analysis of the lignite resources in certain areas such as the Getema region, Hababo Guduru, Gohastion, and Mugher, it can be inferred that the lignite potential is not economically substantial and does not warrant additional research.

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