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REVIEW ARTICLE

THE MINERAL RESOURCES POTENTIAL OF ETHIOPIA

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Introduction

The exploitation and search for mineral deposits in Ethiopia has gone on for the past 2000 years or so [1], and its early cultures were based partially on the mineral wealth of the day. Such has been the case of gold production and utilization, which has become part of Ethiopia's history, oral tradition and folk-lore. The mining and working of iron for the manufacture of tools, utensils and weapons, the stone carvings, statues, the rock hewen churches, the earthen wares, and the use of salt and salt-bar all indicate to a fairly long mining tradition.

However, in the present century mineral production from Ethiopia has been negligible by world standards (Tables 1,2,3). The country's economy is dominated by a large agricultural sector. In 1984 for example, agriculture accounted for nearly 41% of the gross domestic product (GDP). The share of industry and services in the GDP was 19 and 40% respectively. In the same year mineral production had an estimated value of Birr 34.5 million. The 1984 GDP was Birr 8,939 million; thus the mining sector contributed only 0.39% of the GDP. The sector employs a labour force of around 9,000 of whom more than 55% are involved in the non-metallic minerals sub-sector.

This paper reviews the present state of exploitation of the mineral deposits and points the opportunities for industrial development based on these minerals. The review is based on earlier works [2-13]. The selected topics are grouped as follows:

1. *Utilized and well studied minerals and rocks* like gold, platinum, manganese, common salt, limestone, gypsum and anhydrite, clay, feldspars, sand quartz, structural and crushed stones, marble, pumice and mineral waters.
2. *Presumably available, as supported by geological evidences, but inadequately evaluated mineral resources*, such as iron, nickel, sulphur, mica, talc, gemstones, zinc, barite, graphite, radioactive minerals and asbestos.
3. *Discovered mineral deposits with major reserves that may attain important roles in mineral production in the near future*, such as potash salts, diatomite, soda ash, copper and niobium-tantalum.
4. *Mineral fuels and other energy resources*: petroleum, coal, oil shale and radioactive minerals.

2. The physical environment

2.1. Physiographic divisions. With an area of 1,235,000 km^2 Ethiopia is the tenth largest country in Africa, and has 10 major lakes and 16 rivers. It has a coastline of 1240 km along the Red Sea and total of over 300 off-shore islands. Its greatest length extends 1625 km from north to south, and 1645 km from west to east. Only 5% of its total area is covered by forest. Ethiopia is divisible into three major geographical units: *The Ethiopian Highlands*, *the Rift Zone* and *the Somali Plateau* (Fig. 1).

The Ethiopian Highlands occupy a major part of the country sloping downward towards the west and south, and therefore the major river valleys (Tekeze, Atbara, Abbay, Baro, Akobo, Omo, and Mereb) follow the same direction. The altitudes of the Highlands range from 3,000 - 4,000 m in the north east to 1,500 m in the south east, with average heights between 1,300 and 2,500 m.

Table 1. Selected economic indicators for Ethiopia and some LDCS and 2 DCS.

Country	Populat ion in millions (1990)	Density of population (per sq.Km)	GNP/ capita Dollars (1990)	Average amount growth rate (1965-90)
A. Low Income Economics				
Ethiopia	49.8	41	120	-6.6
Tanzania	25.2	27	156	0.9
Ghana	14.8	62	399	-2.1
Haiti	6.3	228	356	1.1
Madagascar	11.4	19	185	-1.2
Kenya	24.3	42	358	2.3
Afghanistan	14.8	23	258	0.5
Lestho	1.7	56	432	6.3
Liberia	2.6	23	425	0.3
Bolivia	6.6	6	625	0.6
Zambia	7.9	10	274	-1.3
Egypt	54.8	55	610	4.2
Zimbabwe	10.1	26	636	1.5
Morocco	25.6	57	707	2.9
Congo	2.2	7	830	3.5
B. Upper Middle Income Economics				
Mexico	86.4	44	1783	3.2
Algeria	25.0	10	2382	3.6
S. Africa	38.5	32	2071	1.6
C. Industrial Market Economics				
U.K.	57.0	233	10917	1.7
U.S.A.	248.2	26	19789	1.7

Table 2. Value of mineral production per capital and share of minerals in merchandise export.

Country	Value of Minerals (1973) (Million Dollars)	Mineral products per capita in Dollars	% share of minerals in export
A. Low income economics			
Ethiopia	16.9	0.7	0.2
Tanzania	12.9	0.6	5
Ghana	119.3	9.3	N.A.
Haiti	11.0	2.1	N.A.
Madagascar	17.6	1.9	12
Kenya	17.6	0.93	29
Afghanistan	116.9	6.2	N.A
Lesotho	2.2	1.5	N.A
Liberia	357.1	170.0	67
Bolivia	683.9	115.0	93
Zambia	732.9	124.3	97
Egypt	2374.6	52.5	70
Zimbabwe	402.6	50.9	24
Morocco	707.0	34.0	39
Congo	226.8	126.0	-
B. Upper middle income economics			
Mexico	7371.2	98.3	73
Algeria	6810.4	330.6	99
S. Africa	3107.7	257.4	14
C. Industrial market economics			
U.K.	12350.4	219.4	24
U.S.A.	73837.7	315.0	9

Source: 1. World Development Report, 1985, OUP. 2. F. Callort; World production and consumption of minerals in 1978, Mining Journal Books Ltd. 1981. 3. Ethiopian Central Statistical Office, Statistical Abstracts, 1986.

Table 3. Contribution of mining to GDP in selected countries.

Country	Year	Share of GDP mining (%)
Ethiopia	1984	0.39
Bolivia	1984	6.0
Mexico	1984	1.3
Brazil	1984	3.85
Peru	1984	9.6
Guyana	1983	16.0
India	1985	13.0
Botswana	1984	45.0
Namibia	1984	28.0
Swaziland	1982	5.0
Algeria	1982	28.0
Libya	1982	61.0
Zambia	1982	16.0
USSR	1982	23.0
U.S.A.	1982	6.0
China	1982	16.0

The Rift Zone crosses all of Ethiopia and forms the northern section of the East African Rift System. The *Rift Zone* is sub-divided into the Ethiopian Graben, and the Red Sea Rift Zone, of which the latter is divisible into the Afar Depression, the Danakil Graben and the Red Sea Coast. The altitude of the *Rift Zone* ranges from 116 m below sea level to 1,000 m.

The Somali Plateau occupies the entire south eastern Ethiopia and descends to the Indian ocean in the form of wide, low terraces. The major rivers in the area, Wabi Shebelle and Ghenale, flow in the same general direction. The larger part of the plateau is occupied by the Ogaden Basin, nearly all of which lies below 1,000 m and has a monotonous landscape characterized by vast, occasionally hilly plains.

2.2. *The geological outline.* The geology of Ethiopia can be traced from the Precambrian to the recent. The main rock types which record the geology of Ethiopia are: the Precambrian rocks with associated intrusives which form the basement complex which cover 23% of the total surface area of the country, Paleozoic and Mesozoic sediments covering 25% of the total surface area, Early Tertiary volcanics covering 32%, Late Tertiary volcanics covering 12% and Tertiary

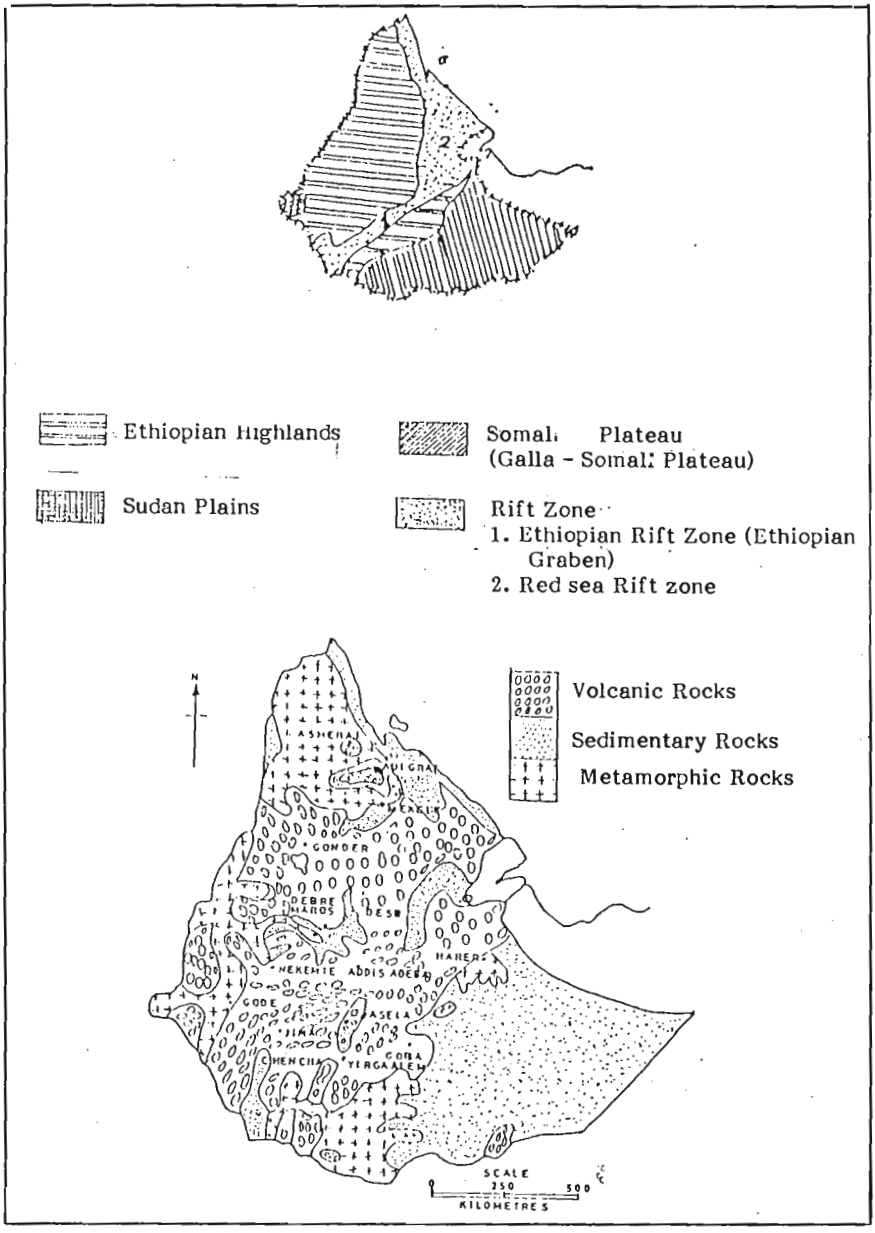

Fig. 1. Map showing the generalized geology and principal relief systems of Ethiopia

and younger sediments covering 3% of the total surface area. A simplified sketch map of the geology of Ethiopia is shown in Fig.1. Exploited and economically interesting minerals in Ethiopia occur in most of the above-mentioned rock units. But rocks with proven, or theoretical minerals potential can be grouped as follows:

a. The Precambrian rock units and associated intrusives. Principal mineral occurrences within these are gold, platinum, iron, chromium, asbestos, talc, niobium-tantalum, wolframite, molybdenite, nickel, cooper, tin, lead, vanadium, cobalt, manganese, mica, radioactive minerals, beryl and other metals. Marble and granite are also common.

b. Paleozoic sediments. These may have potential for oil and gas.

c. Mesozoic sediments. Principal industrial mineral and rock occurrences within these are limestone, sandstone, gypsum and clays. These may also have potential for oil and gas.

d. Early Tertiary volcanics. These are barren of any substantial deposits of metallic minerals. Thin beds of lignite and lateritic iron are found locally interbeded in these rocks. Perlite and pumice are common. Bentonite and other industrial clay may be present. In general, these volcanic rocks will provide mainly road metal and building stones.

e. Tertiary sediments. These may have potential for oil and gas.

f. Late Tertiary volcanics. Principal industrial mineral and rock occurrences within these are: perlite and pumice, road metal and building stones.

g. Quaternary sediments and sedimentary rocks. Principal mineral and industrial rock occurrences are potash, sulphur, lignite, limestone, gypsum, diatomite, salt and clay.

Figs 2 and 3 show the distribution of the main deposits of the principal minerals and industrial rocks occurring in Ethiopia. The number of major mineral occurrences are given in Table 4.

3.Present status of the mining sectors

Ethiopia has untapped deposits of gold, platinum, copper, iron and manganese ores, potash, sulphur, as well as oil, and is firmly set on the path that will make her one of Africa's major sources of raw materials by the year 2000. The government has made the exploitation of natural resources, particularly the previously neglected mining sector, one of the cornerstones of its economic strategy. Yet in the years between 1955 and 1986, the mineral sector produced less than 1% of Ethiopia's GDP. It also contributed less than 1% of its exports. However, mineral commodities share of total import averages approximately 12%. The products responsible for nearly 100% of the total value of Ethiopia's mineral production are shown in the Tables 5 and 6. It can be easily seen from these Tables that only eight products account for over 90% of the whole mineral production value - namely cement, salt, limestone, marble, gold, platinum, manganese and copper ores. Of these only gold, platinum and salt may be considered as really abundant. Manganese and copper ores production and reserves are relatively deficient (Tables 5 and 7). The large reserves of limestone and marble will never become internationally important because of the low prices of these products. Comprehensive data on labour force employed in the mining industry are not available, but partial data on those employed in the non-metallics sector show an average number of 3600 for the past 32 years. With respect to its entrepreneurial structure, the non-metallics sector is operated through mineral industries that number, on the average, approximately 35 for the same number of years. These industries include major units operated by the state, medium scale industries established by the private sector, and units operated jointly by the state and foreign companies.

Table 4. Number of major mineral occurrences in Ethiopia

	Mineral group	Specific Minerals	Occurrences
1	metallic minerals	Aluminum	1
		Beryllium	1
		Cobalt	2
		Copper	14
		Chromium	3
		Gold	90
		Iron	25
		Lead	5
		Magnesite	3
		Manganese	4
		Molybdenum	2
		Nickel & Chromium	4
		Nickel	11
		Titanium	2
		Tungesten	3
		Zirconium	2
		Total	172
2	Fuel minerals	Coal	14
		Oil shale	1
		Petroleum and natural gas	16
		Total	31
3	Industrial Minerals and rocks	Asbestos	13
		Barite	5
		Clay	11
		Common salt	25
		Feldspar	6
		Granite	1
		Gypsum	2
		Graphite	4
		Limestone	6
		Marble	2
		Mica	11
		Potash	1
		Sulphur	2
		Silica	12
		Talc	4
		Amphibolite	3
		Total	108

4. Utilized and well studied minerals and rocks

4.1. Gold. From Biblical times gold has been foremost of the minerals associated with Ethiopia. The distribution of gold occurrences is shown in Fig. 2. The Eritrean region produced the bulk

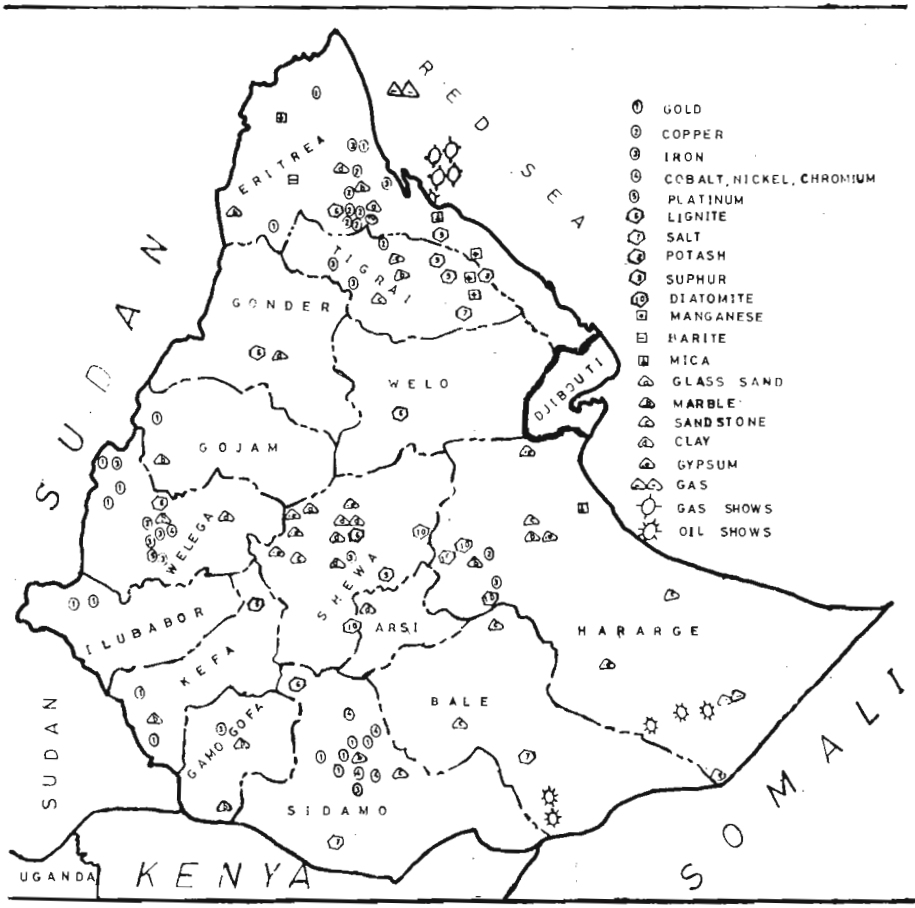

Fig. 2. Important mineral occurrences of Ethiopia.

of its gold from primary sources, Wollega to a much lesser degree. Primitive exploitation of alluvial, and to some extent elluvial, gold has been, and still is, associated with several fields in the western and eastern regions, of which the Adola field of Sidamo has been the significant producer in most recent times. Operating mines produce gold from primary sources in such localities as Dermi Dama, Sakaro and Lega Dembi. Mechanized alluvial working is confined to the state-operated gold field of Adola. Mining of primary gold on any significant scale was accomplished at the following localities:

a. Eritrea: Ugaro, Damishoba, Suzena, Adi Nefas, Doop, Adi Ferhe, Adi Rassi, Hara Hot, Shiumagelle and Medrizien. *b. Wollega*: Primary gold deposits have been prospected and explored by local inhabitants and by various companies in the past within such localities as Tulu Kami, Metti, Laga Baguda, Chokorsa, Tulu Kapi and Ankori, Kata, Oda Godare, Bomu Menghi, Bascia, Ciomos and Gambela. No deposits of significance are worked today and at no stage can

Table 5. Estimated production of major economic minerals and mineral products in Ethiopia for selected years

Commodity–unit	955/56	1961/62	1965/66	1966/67	1971/72	1972/73	1973/74	1974/75	1978/79	1982/83	1985/86	1987/88
Gold - kg	714.9	497.8	726.0	669.4	683.2	791.3	525.2	621.1	247.9	463.0	923.0	728.3
Platinum - kg	7.6	–	8.5	8.8	7.7	8.9	7.2	5.5	3.4	1.7	2.4	1.5
Iron ore - ton	–	–	400	400	–	–	–	–	–	-	-	–
Manganese ore - ton	–	–	2,000	2,000	–	–	–	–	–	-	-	–
Quarry salt - ton	–	–	10,000	10,000	–	–	–	–	–	-	-	–
Quartz sand -ton	–	–	2,000	2,000	–	120	5,556	–	–	-	-	–
Clay - ton	–	–	500	600	–	–	–	–	–	-	-	–
Talc - ton	–	–	100	100	–	–	3.0	–	–	-	-	–
Anhydrite - ton	–	–	6,000	8,300	–	–	–	4,479	–	-	-	–
Cement[1] - ton	21,769	29,905	88,930	137,649	–	–	128,620	148,503	120,126	-	-	–
Clay/bricks - pcs	7,140	7,520	23,825	25,272	16,140	1,807	757	30,523	25,111	-	-	–
Mosaics - m^2	–	–	–	34,500	–	–	–	–	–	-	-	–
hydrated lime[2] - ton	640	4,520	10,732	11,051	–	–	–	36,137	–	-	-	–
Glass & glass products - 10^3 pcs	5,346	–	18,000	25,300	–	–	–	4,932	24,363	-	-	–
Salt (sea) - ton	181,181	135,225	220,150	202,035	162,765	107,077	121,932	–	–	-	-	–
Mineral water - 10^3btl	5,288	5,005	101,030	85,261	8	3,358	3,475	–	–	-	-	–

Table 5. Cont'd

Commodity - unit	1955/56	1961/62	1965/66	1966/67	1971/72	1972/73	1973/74	1974/75	1978/79	1982/83	1985/86	1987/88
Lignite - ton	--	--	--	--	--	--	308	--	--	--	--	--
Copper - ton	--	--	--	--	--	--	1,900	--	--	--	--	--
Sand - m^3	--	--	--	--	14,132	22,033	5,764	--	--	--	--	--
Limestone - ton	--	--	--	--	36,552	8,531	7,871	--	--	--	--	--
Marble - m^3	--	--	--	--	44,450	307	1,004	--	--	--	--	--
Granite - m^3	--	--	--	--	--	--	712	--	--	--	--	--
Sulphur - ton	--	--	--	--	240	--	--	--	--	--	--	--
Stone (trachyte-basalt, scoria..) - m^3	--	--	--	--	25,393	23,213	8,458	--	--	--	--	--

Sources: Ethiopian Central Statistical Office, Statistical Abstracts 1965-1986; Annual Reports of the Geological Survey of Ethiopia, 1972-1974; U.S. Bureau of Mines, Mineral Year Books, 1967, 1968, 1974, 1975, 1978 and 1979.

[1] Cement from limestones, gypsum and clay;
[2] Hydrated lime from limestone
[3] Glass from quartz sand

Table 6. Estimated value (in 1000 Ethiopian Birr) of major economic minerals and mineral products of selected years.

Commodity	1965/66	1966/67	1971/72	1972/73	1973/74	1978/79	1982/83	1985/86	1987/88
Gold	1,829.0	1,686.0	2,474.6	2,856.2	5,126.4	3,757.6	3,140.0	20,951.7	21,243.2
Platinum	46.7	48.4	66.3	68.6	86.0	78.2	43.2	49.7	54.9
Iron ores	10.0	10.0	–	–	–	–	–		–
Manganese ores	170.0	170.0	–	–	–	–	–		–
Quarry salt	130.0	130.0	–	–	–	–	–		–
Quarry sand	40.0	40.0	–	–	–	–	–		–
Clay	10.0	10.0	–	–	–	–	–		–
Talc	2.0	2.0	–	–	–	–	–		–
Anhydrite	129.0	120.0	–	–	–	–	–		–
Lignite	–	–	–	–	41.3	–	–		–
Copper	–	–	–	–	970.0	–	–		–
Sand	–	–	16.0	33.2	6.6	–	–		–
Limestome	–	–	1,799.8	294.2	59.0	–	–		–
Marble	–	–	44.5	11.0	97.9	–	–		–
Granite	–	–	–	–	1.4	–	–		–
Sulphur	–	–	7.7	–	–	–	–		–
Stone	–	–	59.1	53.0	19.9	–	–		–
Salt	–	–	8,668.4	8,428.9	9,253.1	–	–		–
Bricks of clay	–	–	548.7	54.2	22.7	10.6	–		–
Cement	–	–	–	–	11,130.0	28,627.0	–		–

Sources: Ethiopian Central Statistical Office, Statistical Abstracts 1965-1986, Annual Reports of the Geological Survey of Ethiopia 1972-1974; U.S. Bureau of mines. Mineral Year books, 1967, 1968, 1974, 1975, 1978 and 1979.

mining activity have equated the endeavors within Eritrea. *c. Sidamo*: Shakiso area, Dermi Dama, Sakaro and Lega Dembi.

Secondary gold deposits are common in the following localities:

a. Eritera: Asus, Gosha, Ugaro, and 100 km south of Barentu. *b. Sidamo*: Adola, Mormora Basin, Shakiso, Awata Basin, Aflata Basin, Dawa Basin, Ganale Basin, Ujima Basin, Makanissa Basin, Kojowa Basin and Agere Mariam. *c. Other regions*: gold has been exploited in Gojam (Guba and Wombera), Keffa and Illubabor (the Akobo River), in Sidamo (the many placers contained by the Wondo-Negele-Yavelo area), and in Wollega (the Sirkole-Yabus-Gona system, the Mengi-Tumat-Shangul area to the Sudanese Border, and the drainages of the Didessa and Birbir).

The primary gold deposits in almost all the above-mentioned localities occur in veins associated with quartz, sericite, chlorite, amphibolite, cordierite and other schists, many of them intercalated with diorites and diorite and diabases. The ore bodies average 1.2-100 g gold per metric ton. The secondary gold deposits, on the other hand, are mainly composed of erosion products originated from the Precambrian rocks. The gravels in these products are generally composed of sterile quartz, quartz mineralized with gold, quartzites, amphibolites, and granites which are usually decomposed to clay and sand. The amount of gold is entirely proportionate to the amount of amphibolite in the gravel [6]. The ore bodies average 0.009-8.3 g gold per cubic meter.

Records of gold production in Ethiopia for selected years between 1955 and 1988 is shown in Table 5.The range in annual production is between 247.9 and 923.0 kg. However, annual production of earlier years has fluctuated between 248.4 and 1242.2 kg. From 1898 to 1934, for example, 15,250 kg gold was produced mainly from Bani Shangul and Eritrea [7]. Official production data are certainly under-estimated because the main producers, the local inhabitants, lack official control.

The gold reserves in Ethiopia can be considered as very large. However no accurate estimates are available.

4.2. Platinum. The Yubdo area, Wollega, is the only active Ethiopian Platinum mine. The platinum, according to Molly [14], Augustithis [15] and UNDP [16], is associated with ultramafic complexes, and more especially with the alteration products of these ultramafic rocks.

The average composition if platinum concentrates from the Yubdo Mine, where grades of 0.005-1.31 gm m^{-3} have been reported [6,7], is platinum 79.48%, rhodium 0.75%, iridium 0.8%, Osmiridium 1.4% and gold 0.49%. The remaining percentage is iron.

The output of platinum may be noted in Table 8. The total platinum reserves in the Yubdo area are estimated at 2000-4000 kg by Usoni [3], 2356 kg by Barnard [5], 1320-1770 kg by Dahlstrom [17], 1120 kg by Dowson [18], 3876 kg by Jelenc [6], 12,060 kg by Nippon Mining Co. [19] and 29,830 kg by Igzaw Solomon [20]. The most acceptable estimate seems to approximate 200 kg with proven reserves of 72 million cubic meters at an average grade of 0.031 gm m^{-3}. A recent study shows that the platinum in Yubdo is associated with estimated reserves of 9.9 tons of gold and 123,000 tons of chromite.

Platinum occurrences have been reported from Dalatti and Tulu Dimtu in Wollega, and the valley of Demi Denissa and Bone Rivers as well as Tulla mountain area in Sidamo. However, platinum deposits are not exploited in many of these localities. It does seems quite likely that platinum mineralization will be found in these and other localities with ultramafic rocks, and thus the possibility of economic deposits must be borne in mind.

4.3. Manganese. The Enkafala area in Tigrai is responsible for the Ethiopian manganese ore production. Other areas in Tigrai where manganese mineral occurrences are known are Beliga, Handeda, Adi Berbere-Adi, Chigono and Mussley. The manganese deposits in these localities are interlayered with Tertiary-Quaternary sediments.

At Ghedem, Eritrea, iron and manganese oxides and carbonates occur in calc-schists and gneisses. The deposit is hydrothermal in Precambrian meta-sediments.

Table 8. Output of platinum in Ethiopia.

Period	Output (kg)
1926-1935	1309.6
1936-1945	489.9
1946-1955	51.9
1956-1965	63.3
1966-1975	73.3
1976-1985	22.3

Exports of manganese ore, mainly from the Enkafala mine fluctuate but reach up to about 346.6 kg per annum. Reserves of the Enkafala area are believed not to exceed 75,000 metric tons [21]. On the other hand reserves of the Ghedem area are estimated at 15,000 metric tons of Mn ore (about 40% Mn) [7].

4.4. Common Salt. The salt production comes mainly from the solar evaporation of the Red Sea waters at Assab and Massawa. Facilities at each of these localities allow the production of about 100 metric tons per annum.

Rock salt is produced from the Dankail Depression, which covers a surface of many thousands of square km with reserves estimated at 3,000,000 metric tons of salt. The annual production averages 10,000-20,000 metric tons.

Many salt water sources are exploited for salt in salines which are located in Bale (Kalamies, Garado, Creen, Dol, Hicdu, Eldere and Emei), Gojjam (50 km south east of Debre Markos) and Sidamo (near Mega).

4.5. Limestone. The limestone deposits of Ethiopia fall into the following groups: *a. Mesozoic rock units* crop out in Tigrai, Shoa, Gojjam, Wollega, Sidamo, Harerege and Bale. *b. Cenozoic calcareous rock units* of the Red Sea Coast, eastern Ogaden, Danakil Depression, the Omo River Valley; and lacustrine deposits of both the Ethiopian Rift System and the Highlands.

The limestone deposits vary from pure limestone through magnesium limestone to dolomites. The cement industry is the largest consumer of limestone in Ethiopia. Cement and lime are the main manufactured products. Limestone has also been extensively used in northern Ethiopia and Hararge for building and ornamentation. Enormous unestimated quantities of limestone are available in Ethiopia.

4.6. Gypsum and Anhydrite. A limited amount of gypsum is produced for domestic consumption in Ethiopia, mainly for the cement industry, but very large deposits are known to occur in the sedimentary formations of the Red Sea coastal area, Danakil Depression, Ogaden, Shoa, Gojjam, Tigrai and Hararge. Total reserves are probably enormous because the thickness of the gypsum deposits is many hundreds of m and the formations are known to extend laterally for hundreds of km.

4.7. Clay. Ethiopia is well provided with industrial clay materials. Refractory bond clays and clays suitable for cement manufacturing occur in Eritrea, Gondar (Chelga) and Shoa (Koka). Alluvial clay deposits for the bricks tile, pottery and pipe industry occur in Shoa (Addis Ababa area, between Debre Sina and Debre Berhan, Mullo, Karrio and Zega Wodem), Eritrea (Adi Caich), Kaffa (Decano), Sidamo (Kebre Mengist area), Hararge (Dire Dawa area), Abbay River Valley and the Rift Valley Lake region. Clay materials for the manufacture of pigment occur in Gondar and

Table 7. Computation of mineral deposits, in 1000 tons or Kg or m^3, believed to exist in suffficient quantity to warrant consideration for development

Ore - quantity						
Mineral	Proven	Probable	Possible	Location	Other localities	Remarks
Potash	66,223	32,331	61,897	Dalol	More expected in the same area	33% KCl
Copper	800	800	–	Tigrai	Adi Rassi, Shikketi, Kadado, Obd, Cafina Montesacar, Terashi, Embadero	10.5% Cu 36.55 g/t Au, 2.05 g/t Au proved 5.1% Cu, 21.31 g/t Ag 0.74 g/t Au, probable
Copper	–	1,000	–	Debarwa south	Woki, Lamzasegarti Tsehaf Emba,	2.4% Cu 51.94 g/t Ag
Zinc	1,010	420	–	Adi Nefas	Ketta (Wollega)	11.5% Zn, 1.1% Cu, 164,69 g/t Ag, 4.37 g/t Au Proved 4.2% Zn, 0.6% Cu, 44,33 g/t Ag, 0.73 g/t Au probable
Gold (Kg)						
Adolla Placer	–	32	–	Sidamo	Keffa, Gojjam	
Adolla Primary	–	28	–	Sidamo	Illubabor, Eritrea, Wollega	
Sirkole	–	.711	–	Wollega		27 km of valley
Degerro	–	.10	–	Wollega		4 km of valley
Soda ash	–	–	740,000	L. Shala, L.Chitu		Brine
Diatomite	–	4000	-	Zwai, Abiata	Wollenchiti	
Marble (m^3)	–	4000	–	Daleti-Wollega	Harrarge, Eritrea, Sidamo, Tigrai	
Kaolin	475	215	730	Eritrea	Several areas in Sidamo	Seven localities
Kaolin	28	–	–	Sidamo		
Feldspar	–	7000	–			
Quartz	–	1300	–	Sidamo	Other areas in Sidamo	
Barite		650		Haneb	Other areas in Eritrea	
Barite		200		Debarwa, Eritrea	Other areas in Eritrea	
Bentonite		550000		Harar, Gewane, Warenso	Wollo	Exploration
Nickel	17,000			Adolla	Tulu Dimtu - Wollega	
Iron			800	Wollega		(Kori Workalu, Yubdo and Chage)
Iron			2325	Ghedem Agamita, Eritrea	Woki, Zahger Belew, Defere - Eritrea; Genji, Bikilal - Wollega	

Kaffa. Ceramic clays are common in Ambo, Shoa. Oil shale deposits occur near Dessie, Wollo and in the Rift Valley.

The public and private sector, including the cottage industry, consumes an average of 4456.7 metric tons of clay per annum. Bricks averaging 16,140,571 pieces are produced per annum.

4.8. Feldspars. Feldspars occur in a number of localities in Ethiopia, the most important of which are in Hararge (Babile-Bombas, Harar-Jijjiga, Harar-Dire Dawa, and Lange), Eritrea (Zula) and Sidamo (Neghele). Generally all of these localities show outcrop of basement rocks with pegmatites. The feldspars are associated with the pegmatites. Feldspar mineral is microcline in all administrative regions except in Eritrea and partly Hararge where orthoclase seems to be dominant. Both of these feldspar types are usually found in compounds with quartz and must be separated mechanically from it.

Another possible source of feldspar is represented by some leuco granite facies of the Basement complex. Their composition includes quartz and feldspar, with very rare elements of micas and other accessory minerals.

Eventhough feldspar is an indispensable mineral in the manufacturing of ceramic, glass, etc., its annual production is extremely low in Ethiopia and the total reserves have not been estimated. Between 1964 and 1968, for example, approximately 22,430 metric tons of feldspars were produced [22].

4.9. Sand and Quartz Sand. A potential source of quartz is obviously represented by the same materials as are exploitable for feldspar, but until now, quartz produced in Ethiopia has been derived from different sources such as: a. large veins related to gneisses of the Basement Complex, consisting of almost pure quartz, b. quartzites and related stratiform silica deposits in the Basement Complex, c. sands and gravels that are the residual products of Basement rocks and d. sands and gravels of the Paleozoic-Mesozoic sedimentary rocks.

Ethiopia's sand and quartz sand production as shown in Table 5 is greatly insufficient in relation to the availability of raw materials.

4.10. Structural and crushed stones. Supplies of rocks suitable for building and road construction purposes are plentiful in Ethiopia. The most important of these are: granite-gneiss, rhyolite, limestone, travertine, sandstone, basalt and scoria. Basalt and scoria are used mainly for road construction, whereas the rest are utilized by the building industry. Grinding and pounding items are produced for domestic use. No accurate estimate is available as to the total amount consumed. It is, however, believed that well over a million cubic meters of various stones are used annually.

4.11. Marble. Crystalline limestones are widespread in the Basement rocks of Ethiopia, in particular the calcareous schitst, and some of these have been exploited by the cement industry and for building stone.

Marble has been quarried in such localities as: Enda-eis, Ghinda and Mt. Kurka in Eritera; west of Makale and south of Adowa in Tigrai; Galetti, Soka, Ramis, Rochelle, Kuni and other valleys of Chercher Mountain area in Hararge; areas built of Precambrian schists in Gonder; and the Dabus River and other neighbouring river basins in Gojjam, as well as in Gamu.

4.12. Pumice. Pumice occurs in several localities of the Rift Valley as recent shore sediment of lakes, as older lacustrine sediments and also as pyriclastic fall deposit. Pumice reserves are located near Adama (Nazareth) railway station and in the Mojo area. Other deposits occur as shore sediments at Bishoftu, Langano, Awassa and other Rift Valley lakes. The use of Pumice has been limited to its ground form as an abrasive, which is sold on the local market.

4.13. Mineral Waters. More than 130 thermal springs are known in Ethiopia of which about 30 are situated on the plateau, mostly in the Lake Tana basin or close to the Rift System. Undoubtedly many more hot springs remain to be discovered. As far as it is known these springs have not been studied in detail and information about temperature and salinity is available only for the hot springs at Ambo, Babile, Dongollo, Ailet and Tsosa.

Mineral water production for selected years between 1955 and 1974 is shown in Table 5

5. Presumably available as supported by geological evidence, but inadequately evaluated mineral deposits

5.1. Iron. For many centuries iron has been mined and worked in Ethiopia for the manufacture of tools, utensils and weapons. In recent years a number of iron ore deposits have been discovered in various localities in Eritrea, Tigrai, Wollega, Kaffa, Hararge, Sidamo and Showa (Fig. 2). These deposits have been reviewed by Jelenc [6] and Hamrla [23]. There are about 13 deposits of iron ore that have been investigated and which have economic potential. These are shown in Table 9.

Table 9. Important iron ore deposits

Location	Probable Tonnage	Average Iron
Eritrea		
Agametta-Sabub	300,000	58
Gumhod	10,000	58
Falcat	250,000	55
Ghedem	325,000	48
Worki-treashi	1,370,000	49
Hamasien	5,000,000	30
Tigrai		
Adwa-Axum-Entioho	5,000,000	30
Wollega		
Koree	250,000	67
Yubdo	50,000	65
Gordana Katcho	50,000	63
Chago	80,000	64
Nejo	50,000	65
Kaffa		
Mai Gudo	75,000	40

5.2. *Nickel.* Ethiopia has no known large reserves of nickel ore, although 17,000 tons of ore with approximately 1.0% nickel content is identified within the general area of the Adola gold field. No accurate estimates are available for other potentially rich localities such as Monissa, Cabssa, Lolotu, Fulanto and Anno in Sidamo; the area near shameghe river confluence of Asiai and Tardal rivers, along Allamarb river, and between Uetau and Tamia rivers in Eritrea.

The nickel mineralization is connected with a. pyroxenites and dunites in precambrian rocks, and b. only serpentines in precambrian rocks.

5.3. Sulphur. In view of the common occurrence of volcanoes in the Ethiopian Rift System, sulphur deposits are more numerous than has been indicated by past exploration. Jelenc [6] listed six occurrences in Eritrea, Tigrai and Shoa. These are Zariga, Kibret Ale, Dallol, Gombo, Deneb and Dofan. They present a large potential for sulphur deposits but up to now only that at Dallol has been properly evaluated. Here the sulphur ore is estimated at 300,000 tons and contains 18.21% sulphur.

5.4. Mica. Again reference should be made to the great geological potential for mica deposits related to pegmatites. Some mica occurrences are already known [6]. The most important of these are: Shil Licki, Poggro Ebe, Keru, Amien and Shiankis in Erltrea; Shebelli, Cheha, Carara and Tulu Hora in Hararge; Chembi, Meleka and Agere Mariam in Sidamo; and Marechi in Wollega.

To date, the production of mica from Shil Licki, Shebelli and Carara deposits is small, and knowledge of the geological controls should enable them to be successfully exploited on a small scale. Expansion prospects are linked with the possibility of exploiting some new deposits within the pegmatite-bearing rock units of the Precambrian terrain of Ethiopia.

5.5. Talc. Talc mineralization is widespread in Sidamo (Neghele, Agere Mariam, Ula Ulo and Yula), at Farar, South of Dara in the Danakil Alps and in many parts of Wollega. But it seems likely that considerably more occurrences will be found as geological mapping and prospecting continues. The talc deposits are generally of two types: those occurring in schists and those associated with serpentinite bodies.

A very small production has been maintained for the last seven years and is expected to continue at the level of approximately 100 tons a year, as shown by the partial data for the past 20 years.

5.6. Gemstones. Minerals of gemstone quality such as quartz (agate, amethyst, jasper, etc); opal; corundum (ruby and sapphire); beryl (aquamarine, golden beryl, etc); garnet (almandine, pyrope, andradite, etc); feldspar (moonstone, sunstone and amazonstone); olivine (chrysolite); malachite; obsidian; rutile; topaz; tourmaline; and zircon are said to occur in several localities of Ethiopia particularly within pegmatite dikes and stream placers. However, no details are known. The problems of the domestic gemstone industry are lack of adequate knowledge of potential deposits of high-quality gemstones, and lack of technical skills and facilities for cutting and polishing gemstones.

5.7. Zinc. Zinc is reported from Adi Nefas in Eritera where the estimated reserve is about 1,100,000 tons. Another important occurrence in Eritrea is at Embadereho. Promising zinc indication are also known from Tsehafi Emba in Tigrai.

5.8. Barite. A total of four occurrences are recorded of which two are found in Eritrea (Haneb and Debarus) one in Tigrai (Adi Desta), and the other in Wollega (Ada Godere). The reserves estimated for Haneb and Debarua are 400,000 and 1,000,000 tons respectively.

5.9. Asbestos. The principal deposits are in Eritrea (Arwad, Shamge, and the areas near the Gulf of Aula), Tigrai (Fayalina and Merewa), Hararge (Gara Jebi), as well as several localities in Sidamo and Wollega.

5.10. Graphite. Graphite is reported from Soka and Kuni localities in Hararge, the Adola area in Sidamo and a few localities in Wollega.

5.11. Other Minerals. Other minerals such as chromium, mercury, fluorite, borates, phosphates, wolframite, abrasives especially garnets, molybdenum, vanadium, tin lead and tungsten occur in interesting concentration throughout Ethiopia. Investigations have been made on several of these commodities but little published information is available and quantity, quality and economic considerations have not been studied in any detail.

6. Discovered mineral deposits with major reserves that may attain an important role in the near future

6.1. Potash. It is believed [24] that Ethiopia may have sufficient resources to become a major potash producer. Potash reserves are located mainly in the Danakil depression where 140 million tons (20-25% K2O) are estimated. Intensive mining, at the above locality, was carried out with annual production of 25,000 tons, between 1925 and 1926 but work ceased in 1932.

6.2. Diatomite. Diatomite occurrences are wide-spread through the country, but deposits of commercial value are mainly restricted to the Rift Valley and the Afar depression. The main sources are the areas of Lake Abiata, Chefe Jila, Adami Tulu and Welenchiti with an estimated tonnages of 2,902,000, 50,000, 950,000 and 510,000 respectively.

Diatomite also occurs in a number of localities in Hararge, particularly in Kora, Meisso, Afdem and Anenu. To date, the total amount of estimated and proved reserves of diatomite are in the order of 75 million tons.

6.3. Copper Ore. Past prospecting and exploration has indicated possible copper ore bodies at a number of localities, of which the most important are indicated in Fig 2. In almost all of these localities the mineral occurrences are associated with intermediate calc-alkaline type metaplutonics and/or metavolcanics and related metaclastics.

The occurrence of copper, frequently associated with gold, has been known for considerable time, but has never been successfully mined for any extended period of time. None of the copper deposits at Debarwa in Eritrea reached large-scale production. Debarwa's reserves of copper are estimated at one million tons of ore averaging 2% copper.

6.4. Soda Ash. The Rift Valley Lakes, particularly Lake Shala and Chitu, contain hundreds of millions of brines of soda ash and salt. Total reserves were estimated as 740,000,000 tons from Shala and 1,200,000 tons from Chitu.

6.5. Niobium - tantalum. The recently discovered columbo-tantalite mineral deposit in Kenticha, 50 km. Southeast of Shakisso in Sidamo holds the largest Ethiopian tantalum reserves. This rare earth metal occurs associated with niobium (also called Columbite) in extensive pegmatite bodies. The estimated reserves amount to 3,000 tons at current world price of US$ 90/kg. Similar pegmatites with Columbo-tantalite mineralizations are expected to occur in other parts of Sidamo as well as other areas of Ethiopia with similar geologic settings.

7. Mineral fuels and other energy resources

The main energy sources in Ethiopia, both currently used and potential, are: mineral fuels such as petroleum, coal, oil shale and radioactive minerals; hydropower; geothermal; biomass fuels; and nonconventional energy sources. This section points out briefly the major energy problems of Ethiopia, and give a general view of the location, extent and quality of the individual sources of energy.

7.1. Petroleum. Petroleum is undoubtedly the most wide spread and flexible source of energy utilized anywhere in the world today, in its various forms and products. Petroleum represents a substantial part in the total energy consumption of Ethiopia too. 6.6% of the total non-muscular energy is drawn from commercial energy resources such as petroleum, coal and hydropower.

Petroleum covers 94% of these commercial resources. The yearly import of about 899,000 tons of crude oil and petroleum products is absorbing more than one third of Ethiopia's annual export earnings.

It is estimated that nearly 33% of the total surface area of the country is covered by sedimentary basins that merit consideration for the exploration of oil and natural gas. These basins are Mekele Basin, Abbay River Basin; the Red Sea Coast, the Ogaden Basin, South Eastern Sidamo (Genale and Dawa River Basins), Afar depression, the main Ethiopian Rift, the lower Omo River Valley, and the Southern and Western Borders of Ethiopia.

These basins are classified into three groups based on the order of their importance as potential petroleum provinces:

a. The most promising areas: Those areas where indications of hydrocarbons have been found, and sedimentary conditions are favorable for the existence of oil and natural gas.

b. The promising areas: Those areas where sedimentary conditions are favorable for the existence of oil and natural gas but with no indications of oil and natural gas.

c. Less promising areas: Areas where thickness of sediments is small, or with thick basalt cover, or with extensive igneous intrusives.

Included in the first category are the Ogaden Basin and the Red Sea Coast. The second category includes south eastern Sidamo, the lower Omo River Valley, and the southern and western borders of Ethiopia. The rest of the sedimentary basins fall in the third category.

The Ogaden Basin covers an area of over 350,000 km^2 and contains over 5,000 m thick sediments. Initial exploration in the Ogaden started in 1920 and since then 12 major and 12 minor wells have been drilled by 8 well known international oil companies such as Sinclair, AGIP, Tenneco, etc. Inspite of these activities no oil has yet been found. Only one of the

drilled wells, Calub, (Fig. 3), yielded 4.5 million m^3 of gas with 75% recoverability. The overall results of these activities are encouraging enough to warrant continued exploration, since very thick marine sediments, suitable source, reservoir and cap rocks, and some natural gas pockets are known to exist, which, are positive indications of possible oil and gas fields [25].

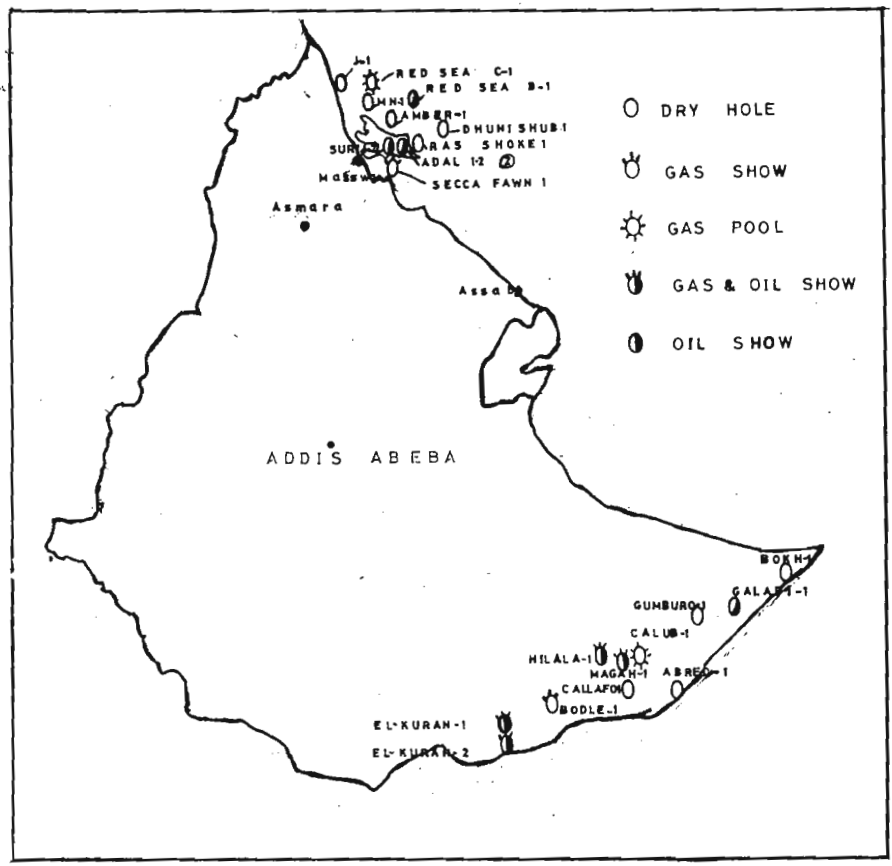

Fig. 3. Map of oil and gas "shows".

Exploration work has also been conducted intermittently since 1935 in the Red Sea coastal area. To date only 3 out of the 18 wells drilled by international oil companies encountered gas and oil bearing horizons. However, the well data indicate that petroleum prospects are also clearly promising for a large part of the Red Sea Coast because of the following geologic conditions: the presence of very thick sediments, the availability of potential source and reservoir rocks such as the Habab formation, and the presence of possible cap rocks such as the Amber salt within these thick sediments, as well as the possible abundance of structural and stratigraphic oil and natural gas traps.

Owing to the existence of very thick and laterally continuous clastic continental sediments in the areas mentioned under group (b), and the fact that oil has been discovered within similar sediments in basins of interior Sudan, oil may be expected to be found in these areas. This

Table 10. Occurrences of lignite in Ethiopia [11]

Locality	Location associated rock units	Comments
Bressa Valley - Shoa	2 Km NW of Debre Berhan; Inter-Trappean	10-100 cm bed of lignite associated with sands and shales
Ankober - Shoa	40 Km from Debre Berhan; Inter-Trappean	100 m long, 1.6m x 2.3m x4m.
Mush Valley - Shoa	9° N & 39 40'7° E; Inter-Trappean	30-50cm band of lignite associated with shale and sands
Sululta - Shoa	Near Addis; Inter-Trappean	Several outcrops
Mugher Valley -Shoa	Near Mulo farm; Inter-Trappean	Several outcrops
Rift Valley (near Mojo - Shoa)	Inter-Trappean	Several localities
Kariaso and Selmi Valleys - Shoa	Debre Libanos; Between Cenozoic area volcanics & Mesozoic Sediments Sediments in sand stone	1 m thick of coal (over lying jurassic limestones.) Also reported from the Fega Madelo-Valley
Zega Wodem gorge (near Fitche) - Shoa	Fiche area; Between Cenozoic volcanics Mesozoic sediments (in marly sandstone)	Several outcrops
Aletu Valley - Wollega	Near Nejo In Cenozoic Volcanics resting on basement rocks	20 outcrops of lignite; 50-100 cm band of lignite interbedded with 10-20 m thick sand and conglomerate
Dilla Valley - Wollega	Near Nejo In Cenozoic Volcanics resting on basement rocks	100-140cm band interbedded with blue-green shales
Didessa Valley - Wollega	SW of Lekemti; In cenozoic volcanics resting on basement rocks	50 cm band in sands, shales and marl
Kindo & Challe Valley - Sidamo	60 Km from Sodo near the Omo-Demie confluence; Inter-Trappean	3-5 bands with individual thicknesses ranging from 50-200 cm
Kibre Mengist - Sidamo	25 Km west of Kibre Mengist in the drainage basin of Awata river; Inter-Trappean	Small and with high percentage of ash
Wuchalle - Wollo	50 Km north of Dessie; Intertrappean	3 thin (20-40 cm) bands interbeded with shales & sand
Desaie area - Wollo	N. of Desaie near Borkena River; Inter-Trappean	Very poor grade, associated with clays
Chilga area - Gondar	35 Km on the Gonder - Metema road; Inter-Trappean	15 Km^2 with 5 thin (50-90 cm) bands interbeded with clays, sand and conglomerates, low sulphur content.
Adi Ugri - Eritrea	Area bound by Adi Ugri, Adi Bihe & Adi Nefar; Between mesozoic stone & cenozoic volcanics	80 cm band of pyritiferous lignite in shale
Areghit-Azerna - Eritrea	53 Km SSW of Asmara; Inter-Trappean	50-80 cm in shale; est. 6000-10000 tons

Table 11. Analyses on the main Ethiopian coal occurences [11]

Locality	Moisture %	Ash %		Sulphur - (Sulphide) %		Volatile %		Fixed carbon %		Calorific value Cal/kg		Notes/Source
		Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry	
Chilga (Gonder)	13.36 13.1	5.9 27.4	5.9 31.5	0.55 0.4	0.64 0.5	 32.2	 37.0	 27.3	 31.5	4500 1710	 1960	Rich sample, [26] Mean sample [6,27]
Mush Valley (Shoa)	19.30 - 21.34 10-29 21.3 14.6	52.1 - 54.2 2-6 29.0 13.4	 22.22	1.25 - 1.40 1-15		23.1 - 25.5 14-4 29.2 31.0	 39.25	1.34-3.09 5-58 20.5 41.0	 38.5	3820-4020 3000 (BTU) 3900 (BTU)	 4552	Old Italian investigation [28] Pitting [6]. Several samples; extreme values [29] Upper part [29] Lower part [29]
Kindo Valley (Sidamo)	2.8 - 4.5	45.3 - 62.2				15.6 - 20.3		19.4 - 33.6		3950 - 6300 (BTU)		3 compositae samples; exterme values [29
Wuchalle (Wollo)	6.13 5.48-10.50 7.93-11.33 9.21-12.32	13.86 6.45-17.19 24.00-44.00 12.36-22.64		4.70 3.15-3.84 1.23-2.62 0.87-2.50		32.03 24.07-56.23 14.71-21.37 18.36-29.71		47.98 30.00-46.70 46.68-48.72		4500 4510-6400 3936-4516 4770-5761		Old analysis [26] Old analysis [30] Upper bed, 2 analyses [28] Lower bed, 2 analyses [28]
Dessie (Wollo)	50-55	30								1900		Peat, old data [3]
Aleltu river (Wollega)	14.4-21.4	2.4-32.2				30.5-42.9		17.0-40.3		2700-5400		Several outcrops; extreme values [3]
Didessa river - Wollega	1.1-15.9	14.9-53.6				17.9-46.1		20.8-25.4		3370-5145		Several outcrops; extreme values [3]

expectation is further supported by the possible abundance of source, reservoir and cap rocks in such continental clastic sediments.

Oil and natural gas might occur in some horizons of the sediments, underlying extremely thick volcanic rocks of the basins of Mekele and the Abbay river. However, present technology does not permit exploration and exploitation below this thick volcanic cover. Much cannot be expected from areas such as the Afar Depression and the main Ethiopia Rift, whose pertoliferous character has been partly disturbed by volcanism either during the deposition of the sediments or there after.

7.2. Coal. Coal is not mined on a commercial scale as yet in Ethiopia, and the quantities required must be imported from abroad. Imports of coal, coke and coal products into the country fluctuated widely between 9,738 tons in 1961 and 10.0 tons in 1983.

No true coal-bearing sedimentary basins are known at present, and current knowledge of the geology and geological setting of Ethiopia does not provide much hope of finding any. However, lignite, one of the lowest ranked coal, is known to occur in many localities and promises to be a good prospect to meet some of the local industrial and domestic needs. So far known lignite deposits are located in Shoa, Wollaga, Sidamo, Wollo, Gonder and Eritrea. Fig. 4 shows important lignite occurrences of Ethiopia, and Table 10 lists the major lignite seams and associated rock types. About 18 deposits have so far been reported but only a few of them have been explored in some detail for their economic potential and subsequent mining (Table 11).

Data regarding others are just preliminary observations not based on systematic studies and mapping, and with no information about their thickness, extension in depth, lateral extension and exploitable reserves. The exploitable reserves of some of the better-known coal deposits are shown in Table 12.

Table 12. Exploitable coal reserves of Ethiopia.

Locality	Exploitable reserves
1. Mush River Valley	200,000
2. Aletu River Valley	3,000,000
3. Kindo River Valley	200,000
4. Wuchalle	3,300,000
5. Chilga	11,000,000

In the absence of any known coal deposits in Ethiopia and keeping in view the necessity for important substitution and self reliance and exploitation of the country's indigenous resources, the presently known occurrence of lignites in Ethiopia assume great significance. Very few areas of the country remain geologically unknown and unexplored. Therefore, there is little prospect of finding new coal deposits, although extension in depth of the existing deposits is possible and should be checked in selected areas through test drilling. The known deposits could extend in depth, but their economic mining will be possible only if the quality and reserves are both good. Most of the presently known deposits, with a few exceptions, are such that open pit mining will be the only economic method of exploitation. It is possible to make an approximate estimation of their economic potential now that enough preliminary data is available. This estimation is based on the limiting factors, e.g.

a. the calorific values, b. volatile matter, c. ash content, d. depth of burial, etc

Most significant is the depth of burial of the seams. In general with the increase in the depth of burial an increase in the quality could be expected, but this is not always true.

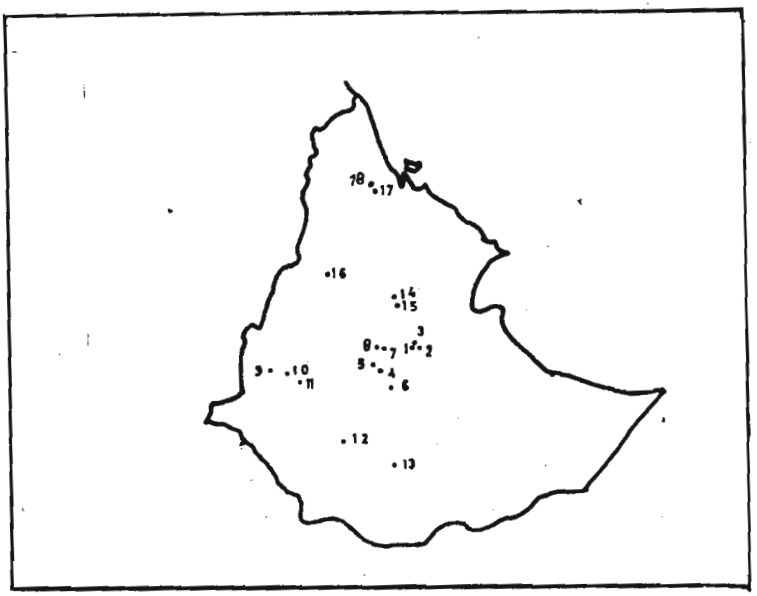

Fig. 4. Important lignite occurrences of Ethiopia (numbers refer to localities mentioned in Table 10). 1. Beressa Valley, 2. Ankober, 3. Mush Valley, 4. Sululta, 5. Mugher Valley, 6. Rift Valley (especially near Mojo), 7. Karisso & Selmi Valleys, 8. Zega Wodem Gorge (near Fiche), 9. Aleltu Valley, 10. Dilla Valley, 11. Didessa Valley, 12. Kindo & Challe Valleys, 13. Kibre Mengist, 14. Wuchalle, 15. Dessie area, 16. Chilga area, 17. Adi Ugri, 19. Areghit - Azerna.

Further, it calls for underground mining which will prove economical only if the deposit is large enough and not in the case of so far known deposits which are rather small. Moreover, remoteness and the difficulty of access to many of these deposits is another constraint in their economic exploitation. Even one of the best deposits known so far (the Chilga deposit) does not promise more than a few tens of million tons of recoverable reserves. But this area is easily accessible and near the important town of Gonder, and the lignite, therefore, could be economically exploited for local use. Other deposits with high calorific value and with possibility of cheap open-pit mining occur in the Wollega region. The total reserves here, distributed over three main deposits could be over ten million tons. Since these are also easily accessible and not very far from towns, these could be economically exploited for local use. It is therefore evident that, though there are in all, but a few tens of million tons of lignite reserves, some of them are of fairly good quality, but their uneven distribution, highly variable properties and difficult accessibility will prevent any majorexploitation in the near future but as already mentioned, they could certainly be of much local significance in the areas nearer to their occurrences and could meet some of the small industrial and domestic energy requirements.

7.3. Oil shale is soil and occur near the village of Keyou, which is located on the right bank of the Barki stream near Dessie, and between Lake Zewai and Lake Abiata in the Valleys of the Bulbula river and its tributaries [7]. The deposits occur intercalated with in Cenozoic volcanics. The reserves estimated for the Keyou deposits amount to 2,000 tons. No details are known for the Bulbul river deposits.

7.4. Radioactive Minerals. Extensive radioactive mineral deposits have so far not been discovered in Ethiopia. Uranium and thorium minerals have been observed to occur in pegmatite veins belonging to gneisses of Hararge. Precambrian granite as well as Cretaceous and Jurassic sediments in the same region, particularly in the Dire Dawa-Harar area, are also considered to be favorable host rocks for radioactive minerals. There are also reports of occurrences of radioactive minerals in Sidamo, (Wadera, Zenbaba and Genale localities), Eritrea, Kafa, Illubabor and Wellega administrative regions.

8. Summary and conclusions

The mining activity in Ethiopia consisted essentially of small-scale exploitation of gold, platinum, industrial rocks and minerals (mainly limestone, gypsum, clay, sand, salt, feldspar, common salt, marble, structural and crushed stones). In addition, very small quantities of manganese ores, iron ores, copper ore, talc, lignite, sulphur, and anhydrite have been produced in some years. Except for most of the industrial rocks and minerals, the bulk of the minerals are raised only for purposes of export entirely in the crude condition without any processing or fabrication; e.g. the whole outputs of manganese ore. These exports bring out a small return to the country either in the shape of adequate prices or exchange commodities. The present state of the activity is characterized by a mixture of traditional methods and modern mining, with an increasing proportion of the latter. The annual production value of these minerals and mineral commodities for all these years accounted for less than 1% of Ethiopia's GDP. Data on employment by the extractive industries are not available; however the total labor forces including those engaged in quarrying, presumably amounted to several thousand. These workers comprised only a very small part of the 43.4 million population [31] (1984 estimate) over 90% of whom were dependent upon farming or livestock raising.

Important potential reserves, as yet unexploited or only worked on a very small scale, are copper, soda ash, columbo-tantalite, potash and diatomite deposits.

Geographical distribution of other mineral occurrences is widespread and the range of the mineral types is also extensive, including, ferrous, base metals and industrial minerals. However, very limited work has been done on quantity, quality, and economics of these mineral deposits.

Oil has yet to be found but the results are encouraging enough to warrant continued exploration, since appropriate sediments, suitable structures and some natural gas pockets are known to exist, which are positive indications of possible petroleum or gas fields.

Much of the country has been examined by geologists, but it would be premature to say that there are no further deposits of useful minerals awaiting discovery. Only a comparatively small part of the country has been geologically mapped on a systematic basis. Geologic maps at scales of 1:100,000 to 1:25,000 should be prepared for areas where mineral deposits are to be prospected for and where known deposits are to be developed or exploited. At present the best available map is the one at 1:250,000. This and other programs of mineral exploration basically call for:

a) Equipment and funds from bilateral, multilateral and local sources.

b) A wide range of expertise for the selection of appropriate exploration method, the evaluation of deposits, the assessment of their suitability to various purposes and the investigation of markets.

c) A long-term national program for mineral exploration. Without exploration from "grass-roots" prospecting, geological mapping, and geochemical and geophysical surveying to the final phases of a feasibility study, a mineral sector can not grow or survive over a long period.

d) Heavy investment in infrastructure. Many of the deposits are in remote areas and their exploration requires investment in infrastructure and long lead times - more than 10 years from the identification of the deposit to the start-up of the production is not unusual.

e) International and regional cooperation in mineral resources research, particularly in the exploration and utilization aspects.

9. References

1. J. Walsh, Introductory remarks on Ethiopian mineral deposits. In Senbeto Chewaka and Maartein J. de Wit, Plate tectonics and metallogenesis: some guidelines to Ethiopian mineral deposits, Bull.Ethiopian Min. of Mines - Inst. Geol. Surveys, **2**, 128 (1981).
2. A. Prasso, Documenti alle suo scoperto minerarie nell' Ovest Ethiopico, Industrie Grafiche Abete, Rome (1939).
3. L. Usoni, Resorse Minerarie dell' Africa Orientale, ministero dell' Africa Italiana, Inspecttorato general Rome (1952).
4. W.S. Atkins, and Partners (Consulting Engineers), Preliminary investigation of certain mineral resources, and hydroelectric power potential in Ethiopia. Unpublished report (1963).
5. G. Barnard, Report on the Minerals and Mining Industry of Eritrea, Ethiopia. Unpublished report (1941).
6. D.A. Jelenc, Mineral Occurrences of Ethiopia, Ministry of Mines, Addis Ababa (1966).
7. Mohr, P.A. The Geology of Ethiopia, University College of Addis Ababa, Addis Ababa University Press, Addis Ababa (1962).
8. T.G. Murdock, Petroleum Possibilities of Ethiopia, U.S. Foreign Econ. Admin. Internal Report (1974).
9. T.G. Murdock, The Geology and Mineral Resources of Ethiopia, U.S. Dept. of the Interior, Bureau of Reclamation, Ethiopian U.S. cooperative programme for water resources, Geology working paper No. 10 (1960).
10. Senbeto Chewaka and Maartein, J. de Wit Plate Tectonics and Metallogenesis: some guidelines to Ethiopian mineral deposits. Bull. Ethiopian Min. of Mines - Inst. Geol. Surveys, **2**, 128 (1981).
11. Getaneh Assefa and G.N. Saxena, Energy, Exploration and Exploitation, **3** (1) 35 (1984).
12. Getaneh Assefa, S. Pretti, and R. Valera, An Outline of the Metallogenic History of Ethiopia, International meeting on "the geology of Somalia and the surrounding regions", Mogadishu, Somali Democratic Republic (1987).
13. H.A. Quinn, Geology, Rocks, Minerals and Mines of Ethiopia. World Mining, February and March, (1964) pp.34-41.
14. E.W. Molley, Econ.Geol., **54**, 467 (1959).
15. S.S. Augustithis, Chemie Erde, **24**, 159 (1965).
16. UNDP Report on the Mineral Survey in two Selected Areas of Ethiopia, Report No. 149 (1971).
17. E. Dahlstrom, Report on the Yubdo Platinum Mines, Wollega, Ethiopia. Unpublished report (1947).
18. E.H. Dawson, Reconnaissance of the Mineral Resources of Italian East Africa. Unpublished report (1939).
19. Nippon Mining Co., Report of Geological Survey of Wollega Area, Ethiopia, Unpublished report (1976).
20. Igzaw Solomon, Basis for Rehabilitation of Yubdo Mining Project Wollega, Ethiopia, Ministry of Mines, Addis Ababa (1976).
21. U.S. Bureau of Mines Mineral Year Book (1962), Washington D.C. (1963).
22. U.S. Bureau of Mines (1968), Mineral Year Book (1967) Washington D.C.
23. M.I. Hamrla, Geologija, **9**, 439 (1966).

24. J.G. Holwerda and R.W. Hutchinson, Potash bearing evaporites in the Danakil area, Ethiopia. Econ. Geol. **63**, 124 (1966).
25. Getaneh Assefa, Journal of Petroleum Geology, **11** (4) 46 (1988).
26. F. Liberti, La Lignite di Celga nel Governo dell' Amhara. In Materie Prime D' Italia e dell Impero, III (1938).
27. U.S. Bureau of Mines, (1960), Mineral Year Book Washington D.C. (1959).
28. A. Maffei, Realazione sul problema Generale dei Carburanti di Sosituzione coloniale. Rep. O Generale dell A.O.I. (Unpubl). (1939).
29. S.K. Babu and Getaneh Asefa, Geophytology **11**, 204 (1981).
30. Y. Fontana, Sulle Ligniti Di Uccialli (Dessie), Rep. to Ufficio Minerario d'el Governo Dell' Asmara (Unpubl) (1938).
31. Ethiopian Central Statistical Office, Statistical Abstracts, Central Statistical Authority, Addis Ababa (1965-1988).