

Ethiopia

Total population (July 2000 estimate): 64,117,000

Area: 1,127,127 km²

Annual population growth rate (2000): 2.76%

Life expectancy at birth (1998): 43.4 years

People not expected to survive to age 40 (1998): 42.1% of the total population

GDP per capita (1998): US \$574



Ethiopia, located in the Horn of Africa, is a largely mountainous country. The central highlands with altitudes between 1,500 and 4,000 m are dissected by numerous rivers, including the Blue Nile. The highlands are split by the Rift Valley, which runs from the Danakil depression close to the Red Sea to the southern part of the country in a south-southwesterly direction.

The economy of Ethiopia is primarily based on agricultural production. The agricultural sector contributes approximately half of the GDP and provides a livelihood to more than 80% of the population. The main food crops are 'teff' (*eragrostis teff*), which is a small grain cereal crop, wheat, barley, sorghum, millet, yams, potatoes, and beans. The major export crop is coffee.

The mineral potential of Ethiopia lies mainly with the development of gold, potash, thermal energies, and industrial minerals.

Almost 90% of the population of Ethiopia live in the Ethiopian highlands (above 1,500 m), which cover almost half of the country. Animal manure and crop residues, instead of being returned to the land, are largely used as fuel and livestock feed respectively. Due to intensive land use and high population pressure, the land is severely degraded and eroded. In addition, the nutrient status of most soils is decreasing. Between 70 and 75% of the agricultural soils of the highland plateau area of Ethiopia are phosphorus deficient (Duffera and Robarge 1999).

Mining plays a minor role in Ethiopia's economy. Nevertheless, more than 100,000 persons are involved in small-scale mining (mainly gold mining) in Ethiopia (International Labour Organisation 1999).

Geological outline

Geologically, Ethiopia lies at the northern end of the continental part of the Eastern Rift. Voluminous piles of mainly Tertiary volcanic rocks occupy large parts of the country along the Rift Valley. Proterozoic rocks occur in western Ethiopia, and Mesozoic and Tertiary rocks underlie most of the eastern part of the country. The floor of the Rift Valley is filled with relatively young lacustrine sediments and volcanics. Several alkaline plugs are known from Ethiopia, but no carbonatite has been delineated as yet.

AGROMINERALS

Phosphates

Considerable efforts have been made by the Ethiopian Institute of Geological Surveys (EIGS) over the last few decades to discover phosphates in Ethiopia. Assefa (1991) summarized the exploration efforts of the EIGS and showed the potential of finding phosphate accumulations in various geological settings of Ethiopia. Based on paleo-environmental and lithological considerations along with findings from borehole evidence, Assefa (1991) showed that the late Cretaceous (Coniacian-Campanian) Faf Series of eastern Ethiopia has great potential for phosphate accumulations. The Upper Cretaceous represents a phosphogenic period in which many phosphorites have been discovered worldwide. Unfortunately, the Upper Cretaceous sediments do not crop out at the surface. Largely obscured and covered by Paleogene successions, these sediments are only known from boreholes (Assefa 1991).

Sheldon (1984) evaluated the potential of finding phosphates in Ethiopia and concluded that the greatest chance of finding large quantities of sedimentary phosphates are in the eastern part of the country, in Tertiary sedimentary sequences associated with transgressions and regressions in the Somalia-Ogaden embayment. He pointed out that the Auradu sequence in particular has the potential of bearing phosphates as these sediments were deposited under conditions favourable for phosphate accumulation. These characteristics include a favourable paleogeographic setting, cyclic transgressive-regressive sequences, a

typical chert-limestone-marl association and deposition during a major phosphogenic time interval, the Eocene.

Sheldon (1984) concluded that other potential phosphorite accumulations could be expected in the black shale-chert-limestone associations of another major phosphogenic period, the Neoproterozoic. In Ethiopia these sequences occur in the Tulu Dimtu meta-sedimentary sequence of Wollega region, in the Adigrat area of Tigre region, and in various other geological formations (Sheldon 1984; Assefa 1991).

Sheldon (1984) and Assefa (1991) also point out that other potential areas for finding phosphates are the carbonatite-peralkaline ring structures of Cenozoic age.

The Bikilal phosphate resource

The only igneous phosphates discovered to date, are at Bikilal, 24 km north-northeast of Ghimbi in Wollega Administrative Province (Abera 1988; Assefa 1991; Abera 1994; Abera *et al.* 1994). The phosphate mineralization is relatively unusual, as it is associated with a Proterozoic layered gabbro-anorthosite intrusion. Low-grade phosphates (3-8% P₂O₅, mean 4.56% P₂O₅) have been encountered in the apatite-magnetite-ilmenite mineralization that is spatially and genetically associated with the intrusive complex (Abera 1988; Assefa 1991). The apatite-magnetite-ilmenite mineralization in hornblendites occurs in a zone about 15 km long and 0.7 to 1.2 km wide. Several apatite-bearing hornblendites have been delineated in steeply dipping bands (Abera 1988). The crystallographic unit-cell a-value of the Bikilal apatites is $a = 9.394 \text{ \AA}$ (Abera *et al.* 1994), indicative of a relatively unreactive fluor-apatite (Abera 1988).

Reported reserve estimates of apatite-bearing material in the Bikilal area, to a depth of 200 m, are 127 million tonnes at 3.5% P₂O₅, 23.8% Fe₂O₃, 7.3% TiO₂ (Yohannes 1994).

The near-surface, low-grade igneous phosphates from Bikilal have been evaluated on their suitability for upgrading through seizing and magnetic separation (Abera 1988; Abera *et al.* 1994). Apatite concentrates up to 36% P₂O₅ were produced using simple processing techniques. However, the recovery rate was low at only 40-58% (Abera *et al.* 1994).

Extraction of P from Unreactive Bikilal Phosphates

Initial agronomic testing of directly applied apatite concentrate from Bikilal using maize as a test crop showed that direct application of Bikilal apatite concentrate was not effective. However, studies by Bekele and Hoefner (1993) showed that Bikilal phosphate concentrate could be effective on Ethiopian soils when using rapeseed (*Brassica napus* L.) as a crop.

Other phosphates

Small amounts of mitridatite, a very rare Ca-Fe-Mn phosphate mineral with the formula $\text{Ca}_6(\text{H}_2\text{O})[(\text{Fe}^{3+}_{8.2}\text{Mn}^{3+}_{0.8})\text{O}_6(\text{PO}_4)_9] \cdot 3\text{H}_2\text{O}$ has been found in lacustrine sediments in the Shungura Formation near Kelem north of Lake Turkana, in southwestern Ethiopia (Rogers and Brown 1979). These minerals occur together with hydroxy-apatite, following partial dissolution of carbonate substituted apatite (fish scales and bones). The beds described by Rogers and Brown (1979) are, however, only a few centimetres thick. The lateral extent of these lacustrine phosphatic beds is not known. These phosphate finds are important as they indicate biogenic phosphate mineralization in a lacustrine rift-related environment, similar to that in which the Minjingu phosphate deposit in the Tanzanian rift valley has been found.

A sample of unknown location was provided by Assefa (pers. comm. 1992) for analysis. The red 'soil' sample contained 10% P₂O₅ and elevated Rare Earth Element (REE) concentrations, indicative of a residual soil overlying a phosphate containing carbonatite. So far, however, no carbonatite occurrence has been reported from Ethiopia.

Potash

There are large potash resources in Ethiopia in the extremely hot and arid Danakil depression near Dallol. The potash deposit is part of a Quaternary evaporite sequence that covers an area of about 1,150 km², of which only a small portion has been explored. Exploration work by the US-based Ralph M. Parsons Company included drilling of more than 300 boreholes, seismic work and shaft sinking to 100 m depths, as well as approximately 600 m underground openings (Holwerda and Hutchinson 1968). The company delineated two ore bodies in the Dallol area: the Crescent ore body and the Musley ore body. In this area the evaporite sequence is greater than 1,000 m thick and includes large potash reserves. Most of the potassium salt is in the form of sylvite (KCl), but carnallite and kainite are also reported. The main sylvite-bearing zone ranges from 15-40 m in thickness.

The tonnage of recoverable potash product in the Musley ore zone, based on 85 drill holes, is 30,021,000 short tons (Arkin 1969). Since the flooding of the exploration shaft in March 1967, all exploration and development work stopped. According to Arkin (1969), the whole depression contains at least 160,456,000 short tons of ore with 31-34% KCl. Reserve estimates by Abera (1994) exceed 60 million tonnes of recoverable KCl. A 1968 evaluation report by the consulting company MacKay and Schnellmann (quoted in Arkin 1969) confirmed that drill-indicated plus possible reserves of saleable potash product would be on the order of 86 million short tons. The grade of ore and recovery process indicates a 3:1 ratio in tons of ore to product.

For small-scale mining, only the sylvite and carnallite found at the surface near the Black Mountains, less than 1.5 km southwest of Dallol, could be mined. Some 3,578 short tons and 2,500 short tons were mined by small-scale extraction techniques in 1917 and 1927 respectively (Holwerda and Hutchinson 1968).

Limestone/dolomite

As illustrated in Figure 2.6, soil surveys of Ethiopia show that the soils of large areas of western and southwestern Ethiopia are acid, with pH levels below 5.5 (Schlede 1989). The largest volumes of limestone are located, however, in the eastern part of the country. Exceptions are the extensive and thick Mesozoic limestone and gypsum sequences in the Blue Nile River area in Central Ethiopia.

Proterozoic limestone/dolomite deposits in western and southwestern Ethiopia have considerable potential as they are located close to the acid soils. Dolomitic limestones and marbles have been reported from many places in western Ethiopia, including Daletti, near Mendi (Abera 1991). Scientists from the Institute of Agricultural Research carried out successful agronomic experiments with limestone on acid soils of the Nejo area close to Mendi, Wollega Province (Institute of Agricultural Research 1975).

Liming material can be found in Ethiopia within three major geological units:

- in Proterozoic rocks, mainly as marble,
- in Mesozoic sedimentary sequences, mainly as limestone, dolomite, and marl,
- in Cenozoic sediments, as limestones, dolomites, and marls.

Proterozoic liming materials

Proterozoic marbles occur in northern Ethiopia (Tigray), in the west (Gojam, Wollega, Illubabor, Kaffa), southern (Omo, Sidamo) and eastern (Hararghe) parts of Ethiopia. Accounts of these resources are provided by Schlede (1989). A general observation is that these resources occur in areas where strong to moderately acid soils ($\text{pH} < 5.5$) are dominant. Schlede (1989) states that the marble deposits are well distributed over the area of acid soils that require liming materials to improve soil productivity.

Mesozoic liming materials

Mesozoic limestone, dolomitic and marl deposits in western and northern Ethiopia occur in Tigray, in the Danakil Alps and in the Blue Nile (Abbay) valley. They also outcrop over large areas on the Somali plateau. Smaller outcrops of Mesozoic liming materials occur in the central plateau area near Ambo town, in the Didessa valley. Smaller deposits occur in the Kella area south of Addis Ababa.

The Jurassic Antalo Group with sequences of limestone, dolomites and marls occur in the Blue Nile (Abbay) valley and the Mekele area (Tigray). In the Mekele area the Antalo limestone is about 750 m thick (Kazmin 1972).

In general, the Mesozoic limestone, dolomite and marl resources are located further away from areas with strong to moderate acid soils ($\text{pH} < 5.5$).

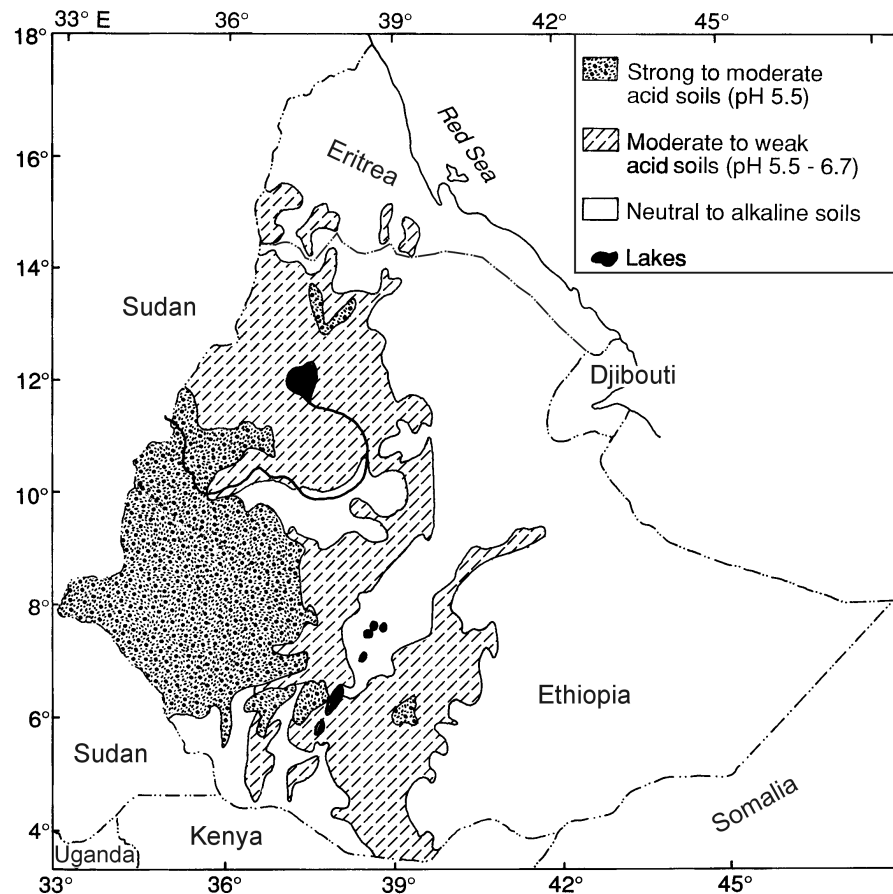


Figure 2.6: Distribution of acid soils in Ethiopia and Eritrea (after Schlede 1989).

Cenozoic liming materials

Cenozoic calcareous sediments occur in three areas of Ethiopia: in eastern Ogaden, in the Danakil Depression and in the lower Omo Valley. The limestone resources from the east of the country are too far from the acid soils of western and southwestern Ethiopia to be of economic interest.

Gypsum/anhydrite/sulphur

There are extensive and thick gypsum and anhydrite deposits in central Ethiopia (in the Blue Nile area), and some deposits of lesser thickness in the Mekele area of northern Ethiopia and in the southeast of the country (Abera 1991).

Native sulphur is reported in sediments of the Danakil depression and also in association with volcanic activities and solfataras in the Awash Valley and the Danakil area. Small-scale extraction was carried out in the Dofan area of the Awash Valley and, in the 1950s, in the Dallol area (Jelenc 1966).

Natural zeolites

Several million tonnes of high-grade zeolite deposits (mordenite and clinoptilolite) were discovered by geologists of the Ethiopia-Canada agrogeology project in rift valley sediments near Nazret and Boru, west of Nazret (unpublished). Zeolites have high cation exchange capacities and, specifically, high ammonium selectivities (Mumpton 1984). There are many applications of zeolites in agriculture and horticulture (van Straaten 1993; Allen and Ming 1995). Among them are applications of zeolites in chicken houses that can reduce the losses of ammonium-nitrogen by ion exchange and adsorption into the channels of zeolites. These ammonium-charged zeolites could be used as an effective slow-release N soil amendment.

No agronomic experiments with these minerals have been undertaken as yet.

Scoria/pumice

Large resources of volcanic scoria and pumice have accumulated within and along the margins of the rift valley. These resources can be used in soil moisture conservation techniques, called rock mulching. Experiences from other parts of the world, especially the Canary Islands, have shown that rock mulch can considerably reduce evaporation from soil surfaces (Fernandez Caldas and Tejedor Salguero 1987; Groenevelt *et al.* 1989).

Moisture Conservation Using Rock Mulch

Rock mulch field experiments using local scoria and pumice resources from near Nazret were carried out in the framework of the Ethiopia-Canada agrogeology project (Woldeab *et al.* 1994). The results of field experiments illustrated the effects of scoria and pumice mulches in the Rift Valley of Ethiopia. The application of 3 to 5 cm scoria or pumice mulch on top of the soil surface resulted in effective soil moisture conservation, as well as grain yield increase of maize by as much as 4 times (Woldeab *et al.* 1994). The main constraints to this system are availability of mulching materials in the close vicinity to soils with moisture stress, and economics.

Agromineral potential

Ethiopia is endowed with a great variety of agrominerals. The only known phosphate resources in Ethiopia, the Bikilal phosphates, are very low-grade igneous phosphates with low solubilities. The mining and upgrading of these low-grade, unreactive phosphates on a large scale would require considerable

investment if economic feasibility could be proven. Also small-scale extraction and upgrading of this resource is questionable.

The occurrence of small amounts of lacustrine phosphate in the Shungura Formation in southwestern Ethiopia is of interest. Detailed surveys should be carried out to determine the lateral extent of these phosphatic beds. There is the potential of finding 'Minjingu-type' biogenic phosphates in lacustrine, late Tertiary to Recent lake beds in southern Ethiopia and in rift related sediments.

Exploration efforts to delineate carbonatites should be intensified.

There is reasonable potential for the discovery of nitrates in the rift valley extension of the Lake Turkana rift. In raised beds of old lake sediments in the Kenyan Rift Valley immediately south of the Ethiopia/Kenya border, Owen and Renault (1989) discovered diatomaceous lacustrine silts with up to 7.5% interstitial nitrates (see section on Kenya).

The application of gypsum as a soil amendment for alkaline soils on S-deficient soils and for groundnut production should be agronomically tested. Gypsum deposits should also be tested on the acid soils of western Ethiopia, especially in acid soils with high Al-toxicities.

The extent of the natural zeolites in the Rift Valley should be surveyed, and the zeolites need to be characterized mineralogically and chemically. Practical applications for the natural or modified zeolites of Ethiopia in agriculture and horticulture have to be assessed.

The highest potential for increased crop production using agrominerals rests with dolomitic limestones of Proterozoic age, especially in western Ethiopia. Here the soils are acid and, in places, crop production is impeded by Al-toxicities. Local resources of agricultural limestones and dolomites, as well as gypsum, should be investigated for their potential to ameliorate acid and Al-toxic soils. As in many countries, these resources of 'aglime' and dolomite have largely been overlooked. Research should be carried out to determine cost-effective extraction and low-cost crushing and grinding technologies followed by demonstration of the agronomic effectiveness of liming materials and gypsum on acid soils. Further exploration and testing of their suitability and agronomic effectiveness are needed. In addition, it is important to demonstrate the benefits of using local limestone/dolomite and gypsum to farmers.

References:

- Abera S 1988. The evaluation of Bikilal Apatite-Magnetite-Ilmenite deposit with particular reference to apatite as a potential phosphate resource. M.Sc. thesis, University of Hull, UK, 132pp.
- Abera S 1994. Review of industrial minerals in Ethiopia. In: Mathers SJ and AJG Notholt (eds.) Industrial minerals in developing countries. AGID report series Geosciences in International Development 18:173-180.
- Abera S, Woldeab A, Assefa A, van Straaten P and W Chesworth 1994. Report on the results of the Ethiopia-Canada Agrogeology Project-Igneous phosphates. Report to IDRC, University of Guelph, Guelph, Canada, 49pp.
- Allen ER and DW Ming 1995. Recent progress in the use of natural zeolites in agronomy and horticulture. In: Ming DW and FA Mumpton (eds.) Natural zeolites '93: occurrence, properties, use. International Committee on Natural Zeolites, Brockport, New York, USA: 477-490.
- Arkin Y 1969. Potash in Ethiopia. Ministry of Mines, Geological Survey. Unpubl. Report, Addis Ababa, Ethiopia, 28pp.
- Assefa A 1991. Phosphate exploration in Ethiopia. Fert. Res. 30:155-163.

- Bekele T and W Hoefner 1993. Effects of different phosphate fertilizers on yield of barley and rape seed on reddish brown soils of the Ethiopian highlands. *Fert. Res.* 34:243-250.
- Duffera M and WP Robarge 1999. Soil characteristics and management effects on phosphorus sorption by highland plateau soils of Ethiopia. *Soil Sci. Soc. Am. J.* 63:1455-1462.
- Fernandez Caldas E and MK Tejedor Salguero 1987. Mulch farming in Canary Islands. In: Wachira JK and AJG Notholt (eds.) *Agrogeology in Africa*. Commonwealth Sci. Council, Technical Publ. Series 226:242-256.
- Groenevelt PH, van Straaten P, Rasiah V, and J Simpson 1989. Modifications in evaporation parameters by rock mulch. *Soil Techn.* 2:279-285.
- Holwerda JG and RW Hutchinson 1968. Potash-bearing evaporites in the Danakil area, Ethiopia. *Econ. Geol.* 63:124-150.
- Institute of Agricultural Research 1975. Unpublished progress report. Results of research in Nejo substation, 70pp.
- International Labour Organization 1999. Social and labour issues in small-scale mines. *TMSSM/1999*, 99pp.
- Jelenc DA 1966. Mineral occurrences of Ethiopia. Ministry of Mines, Addis Ababa, 720pp.
- Kazmin V 1972. The Precambrian of Ethiopia and some aspects of the geology of the Mozambique Belt. *Geol. Surv. Rep.* 23, Addis Ababa, Ethiopia.
- Mumpton F.A. 1984. Natural zeolites. In: Pond WG and FA Mumpton (eds.) *Zeo-agriculture: Use of natural zeolites in agriculture and aquaculture*. Westview Press Boulder, Colorado, 247-254.
- Owen RB and RW Renault 1989. Nitrate deposition in the Turkana basin of northern Kenya. *J. Afr. Earth Sci.* 10:701-706.
- Rogers RJ and FH Brown 1979. Authigenic mitridatite from the Shungura Formation, southwestern Ethiopia. *Am. Mineralogist* 64:169-171.
- Schlede H 1989. Distribution of acid soils and liming materials in Ethiopia. Ethiopian Institute of Geological Surveys. Unpub. Rep., Note 326.
- Sheldon RP 1984. Phosphate resource potential of Ethiopia based on available geologic data. Unpubl. Rep. UN/DTCDC/ETH/83-025, United Nations, New York, 45pp.
- van Straaten P 1993. Zeolites in agriculture and horticulture: reduction of nitrogen losses. Abstract, Symposium of Geol. Ass. Canada: Industrial minerals in environmental applications. Vancouver, Canada, Nov. 18/19th 1993.
- Woldeab A, Assefa A, Yematawork A, Abera S, van Straaten P, Groenevelt P and W Chesworth 1994. Report on the results of the Ethiopia-Canada Agrogeology Project - Rock Mulch. Report, University of Guelph, Guelph, Canada: 76pp.
- Yohannes WW 1994. Ethiopia. *Mining Annual Review*, Mining Journal Ltd. London, p.143.