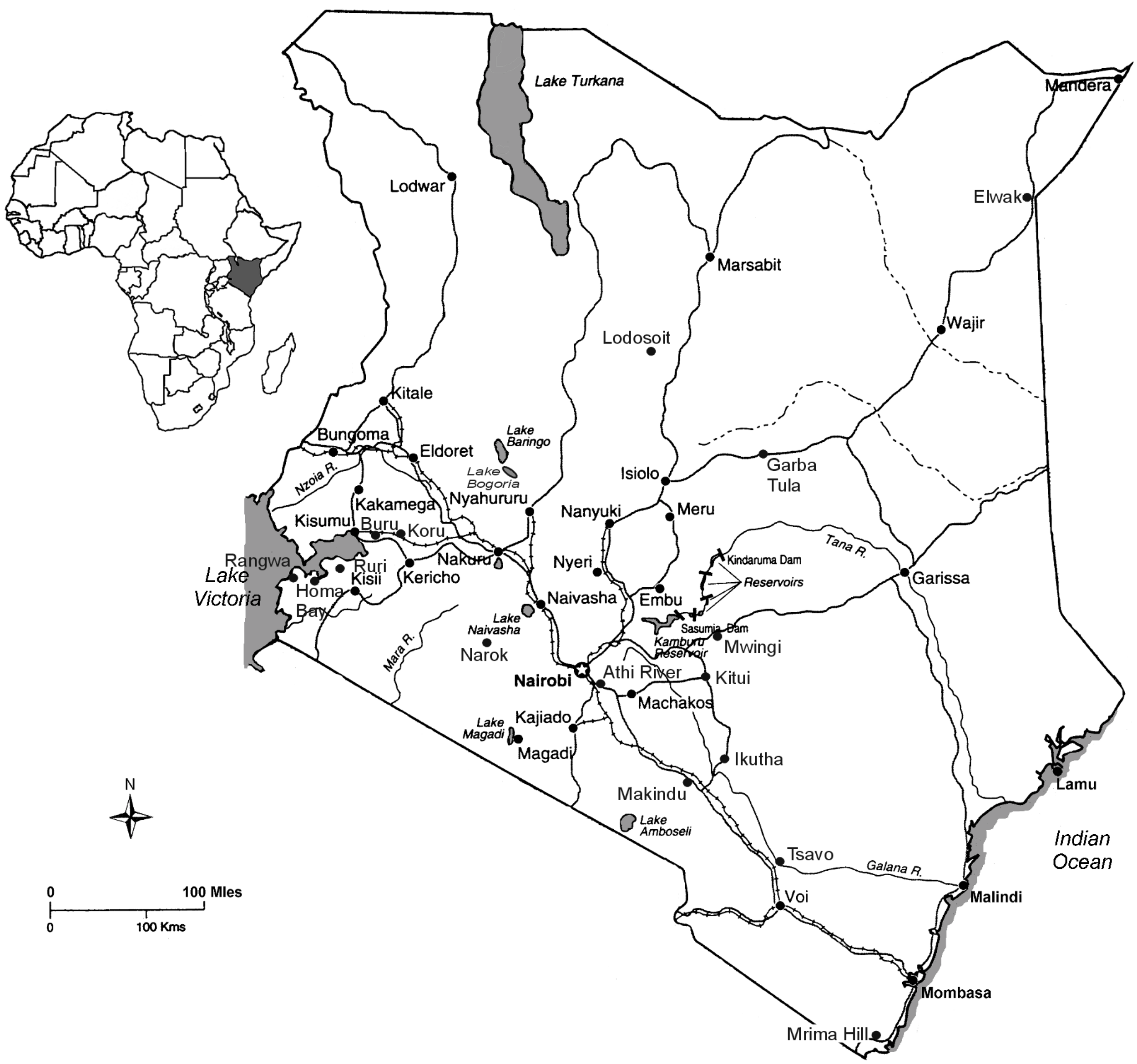
Kenya

Total population (July 2000 estimate): 30,340,000
Area: 582,650 km^2
Annual population growth rate (2000): 1.53%
Life expectancy at birth (1998): 51.3 years
People not expected to survive to age 40 (1998): 30.6% of the total population
GDP per capita (1998): US $980



Kenya lies along the equator in East Africa. Most of the country consists of high plateau areas and mountain ranges that rise up to 3,000 m and more. The plateau area is dissected by the Eastern Rift Valley, which is 40-50 km wide and up to 1,000 m lower than the flanking plateaux. The narrow coastal strip along the Indian Ocean is backed by a zone of thornbush-land. Some areas in central Kenya, at the flanks of the Rift Valley, and in western Kenya, close to Lake Victoria, are very densely populated.

The backbones of Kenya's economy are agriculture and tourism. In 1999, the agricultural sector accounted for 23% of the GDP. Large parts of the population make their living from subsistence agriculture. The predominant food crops are maize, rice, wheat, bananas and cassava. The main export crops are coffee and tea.

The mineral industry is small, accounting for only about 1.3% of the GDP in 1993 (Izon 1993). The main minerals of economic significance are soda ash (from Lake Magadi), limestone for the cement industry, and other industrial minerals. Small gold deposits are exploited by small-scale miners in the western part of the country. The International Labour Organization (1999) estimates the number of persons involved in small-scale mining in Kenya to be 30,000 to 40,000.

Increased population density has resulted in increased intensity of crop production and depletion of soil fertility. Per capita food production is decreasing. One of the main biophysical causes of lower food production is decreasing soil fertility, specifically low availability of soil phosphorus and nitrogen (Buresh *et al.* 1997; Sanchez *et al.* 1997; Smithson *et al.* 2001).

Geological outline

The geology of Kenya is characterized by Archean granite/greenstone terrain in western Kenya along Lake Victoria, the Neoproterozoic 'Pan-African' Mozambique Belt, which underlies the central part of the country and Mesozoic to Recent sediments underlying the eastern coastal areas. The Eastern Rift Valley crosses Kenya from north to south and the volcanics associated with rift formation largely obliterate the generally north-south striking Neoproterozoic Mozambique Belt (Schlueter 1997). Rift Valley volcanogenic sediments and lacustrine and alluvial sediments cover large parts of the Eastern Rift.

AGROMINERALS

Phosphates

The phosphate resources of Kenya are limited. They are confined to small guano deposits and small igneous phosphate resources associated with carbonatites (Gaciri 1991). No detailed surveys have been conducted to assess the potential for locating sedimentary phosphates in the Phanerozoic marine sediments and lacustrine sediments in the Rift Valley of Kenya as yet.

Igneous phosphates

The principal igneous phosphate occurrences are related to carbonatites and iron-rich dike systems. The main carbonatite related phosphate occurrences are found at Mrima Hill in the southeast of the country, and on the carbonatite south and east of Homa Bay in western Kenya. The only phosphate occurrence of uncertain origin is the intrusive vein-type iron deposit at Ikutha in central-southeast Kenya.

1. The Mrima Hill carbonatite.

Mrima Hill is located in the Coast Province of Kenya, some 78 km south of Mombasa at 4^{o} 29'10" S; 39^{o} 15' 10" E. The hill rises approximately 250 m out of the seaward-sloping plain. Geologically, Mrima Hill is an elliptical carbonatite plug approximately 2 km across. A thick blanket of unconsolidated, deeply weathered material covers the hill. This residual soil, in places more than 100 m deep, was explored mainly for niobium (Nb) and Rare Earth Elements (REE) (Coetzee and Edwards 1959; Hussein 1995).

Coetzee and Edwards (1959) and Hussein (1995) also carried out detailed geological investigations of the weathering processes that affected this carbonatite, and economic studies. Anglo-American reported 41.8 million short tons of 0.67% Nb_2O_5 in weathered rocks from the surface to a depth of 30 feet. Phosphates at Mrima Hill occur mainly in the form of monazite (a Cerium-Lanthanum phosphate mineral) and the complex barium phosphate mineral gorceixite. Only very minor amounts of apatite have been reported from Mrima Hill and no occurrences of secondary calcium-phosphates, such as francolite, are reported. Based on the investigations of Hussein (1995) and other geoscientists it can be concluded that no economic residual accumulations of apatites for agricultural use are associated with this carbonatite.

2. The Rangwa carbonatite complex.

The Rangwa carbonatite complex on the eastern shores of Lake Victoria has been the subject of many investigations, including studies on its phosphate potential. Le Bas (1977) reports of two types of carbonatite rocks in the Rangwa carbonatitic complex: 1) the Ekiojanga carbonatite and breccia, and 2) the Kinyamungu carbonatite and breccia with up to 20% apatite (approximately 8% P_2O_5) in some breccias. Le Bas (1977) also describes a ‘dyke of carbonated collophane rock’ (probably francolite) in the southwestern part of the complex. No details regarding the exact location or thickness of this phosphate-rich dyke is given.

Idman (1985) and Idman and Mulaha (1991) concentrated their efforts on finding phosphate mineralization in the inner ring carbonatite rock suite of the Kinyamungu carbonatite. They found boulders made up of ‘pure apatite rock,’ some of which was ‘crypto-crystalline,’ possibly francolite. Subsequent mapping and drilling in the primary carbonatite, intersected carbonatites with only slightly elevated phosphate contents (39 m with 3.87% P_2O_5 in DH 1, and 27 m with 5.37% P_2O_5 in DH 7). No sizeable accumulations of phosphates have been discovered in this environment as yet. Idman and Mulaha (1991) carried out a systematic soil survey with 50 m intervals and, at selected sites, pitting. The results of only one pit (out of 44) encountered highly weathered, yellowish earthy residual soils with 24.46% P_2O_5 over an interval of 1 m. All other samples proved to contain very low P_2O_5 concentrations.

Based on their intensive exploration work Idman and Mulaha (1991) concluded that the chances of finding extensive phosphate mineralization in the fine-grained Kinyamungu carbonatite are very low. The accumulation of phosphates in the fine-grained Kinyamungu carbonatite is limited to a narrow zone (100 x 300 m) with low grades of primary phosphates (3-4% P_2O_5). Also the phosphate concentrations in the eluvial and alluvial deposits of the Nyakirangacha Valley were clearly too low for economic extraction.

A prospector sent one phosphate rock sample to the International Fertilizer Development Center (IFDC) for analysis (IFDC, 1986). The total P_2O_5 content of the sample was found to be high (25.3%). The mineralogical investigation by IFDC (1986) showed that the phosphate is a francolite with a unit-cell a-value of 9.329 Å. The neutral ammonium citrate solubility (AOAC method) of the francolite is very high with 3.6% (IFDC, 1986; Van Kauwenbergh 1991). The exact location of this specific sample is unknown, but it is believed to originate from the Rangwa carbonatite complex.

Prins (1973) analyzed another sample of apatite, probably from primary calcium-carbonatite (soevite) of the Rangwa carbonatite. The refractive index of the Rangwa apatite was $\omega = 1.630$ and the unit-cell a-value measured 9.380 Å, indicative of fluor-apatite.

3. The Homa Bay, Ruri and Buru Hill carbonatites.

Pulfrey (1950) described small and insignificant phosphate occurrences at the Homa Bay carbonatite complex and at the Ruri carbonatite complexes south of the Kavirondo Gulf in western Kenya. At the Buru Hill carbonatite, east of Kisumu, Japanese exploration companies were looking for Rare Earth Elements (REE) and niobium. They found only small amounts of these elements and very low-grade phosphates in the primary and weathered rocks. Follow-up work by Finnish and Kenyan geologists indicated low and sporadic concentrations of apatite in parts of these carbonatite complexes. In addition, grade and volume are too low to be of any economic interest, even from a small-scale mining point of view (van Straaten 1997).

4. The Koru carbonatite.

The Koru carbonatite, 55 km east of Kisumu, is estimated to contain 65 million tonnes of cement grade limestone (Kortman *et al.* 1991). It was considered in the past as a possible source for cement production, but is used at present for the production of lime for road construction, agriculture, the sugar processing industry, and, in some instances, for the gold mining industry (for cyanide treatment of ores). Homa Lime Co. Ltd. currently mines the Koru carbonatite for lime production at a rate of approximately 25,000 tonnes per annum. The mined carbonatite material contains a small amount of phosphate (1.5-1.9% P_2O_5).

5. The Ikutha vein-type iron ore/phosphate occurrence.

The phosphate mineralization at Ikutha (2^o 8'20" S; 38^o 11'40" E) is associated with the intrusive vein-type Ikutha iron ore deposit. The volume of the minor mineral apatite proved to be very small. Detailed geological and geophysical investigations and drilling by a Finnish project (Kuivasaari 1991) show ore reserves of about 80,000 tonnes containing magnetite concentrate (66% Fe_2O_3) and 31,000 tonnes of 35% P_2O_5 apatite concentrate. The Ikutha iron ore deposit does not constitute an economic phosphate resource.

Other agrominerals

Limestone/dolomite/travertine/calcrete

Bosse (1996) compiled data of limestone, dolomite, travertine and calcrete occurrences and deposits from existing geological maps of Kenya. More than 27 major ‘crystalline limestone’ occurrences are reported from meta-sedimentary gneiss sequence of the Mozambique Belt in Kenya. Marble and dolomite marble horizons occur in the southeast of the country near Voi, at sites close to the main Nairobi-Mombasa road, near Kitui, at Kajiado south of Nairobi, and near Mwingi, Isiolo and Garba Tula. Some of these extensive marbles occur in remote areas far from farming areas and are thus of little practical use. A major Precambrian marble to be exploited for lime production occurs near Kajiado in central Kenya.

Mesozoic to Quaternary limestones and coral reef limestones occur in the coastal basin. Porous coral limestones are mined and calcined south of Mombasa for the production of lime by Homa Lime Co. A thick limestone bed is quarried at Bamburi near Mombasa and provides limestone feed for the Bamburi cement industry.

Other carbonate resources include carbonatites (Homa, Koru-Legetet, Rangwa), calcrete and travertine. As mentioned before, some 25,000 tonnes of lime are produced annually from the Koru carbonatite in western Kenya.

Calcrete resources in the Athi River Quarry, SE of Nairobi are exploited as a raw material for the Athi River Cement Plant. Five additional small travertine occurrences are reported, some of which are used for small-scale lime production (Bosse 1996). The combined rate of Kenya's cement production exceeds 1.3 million tonnes per year, a large portion of which is exported to neighbouring countries.

Gypsum

Several gypsum occurrences are reported from the eastern part of the country and two occurrences from central Kenya. Impure gypsum is reported from Garissa consisting of pinkish gypsum in clays. Indications of large volumes of gypsum in soft earthy gypsum/clay aggregates (approximately 2,000 million short tons) are located near El Wak at the Somali border (Walsh 1970). Good quality gypsum occurs in the Kajiado area in central Kenya and has been used for the Athi cement industry. Some of the gypsum used for the Bamburi cement industry near Mombasa is mined at Roka, 37 km southwest of Malindi (Theuri 1994).

Nitrates

Owen and Renault (1989) describe an occurrence of natural sodium nitrate (nitratine) accumulation in the remote semi-arid area of Lake Turkana in northern Kenya. Here, nitrates are widely distributed in the Galana Boi Formation, which covers an area of approximately 1.2 x 0.5 km. In this area the thickness of the Galana Boi Formation ranges between 10 and 32 m. These sediments represent part of a series of stranded raised Holocene sediments that surround modern Lake Turkana. Nitrates occur as interstitial nitratine ($NaNO_3$) in diatomaceous lacustrine silts. The sodium nitrate content ranges from 1.1-7.5% by weight. (In comparison, most of the sodium nitrates exploited in Chile from 'caliche' deposits have grades of 7-10% nitrate.) Owen and Renault (1989) point out prospective areas for further investigations and suggest that the Suguta Valley south of Lake Turkana and much of the southern part of the Ethiopian Rift should be investigated for potential nitrate deposits.

Guano

Small bat guano deposits are reported from several caves in Kenya. Randel and Johnston (1991) describe guano accumulations in the lava tunnels of the Suswa Volcano in the central part of the Rift Valley. The guano occurs as a loose, fine, brown powder on the tunnel floors. The nitrogen content of four samples from these accumulations varies from 7-12.5% and the P_2O_5 content varies from 7.0-13.3%. Other cave deposits are known from the Chyului Hills near Makindu, and from the Amala area, north of Narok. Analytical results from guano samples from Amala gave P_2O_5 values of 7.07 and 3.28% for the powder and chunky, massive samples respectively. The total nitrogen contents of the samples were 3.82 and 4.5% respectively. The volume of the Amala guano is not known (van Straaten 1997).

Vermiculite

Four small vermiculite deposits have been worked in Kenya. One of the vermiculite deposits is located at Kinyiki, half way between Nairobi and Mombasa. This vermiculite mineralization, associated with an ultramafic dunite body, was exploited in the past. However, the volume was small and mining ceased. A vermiculite deposit that has been mined intermittently is the Wasin Mine near Lodosoit, approximately 30 km west of the main Nanyuki-Isiolo-Marsabit road in northern Kenya. The vermiculite mineralization is associated with an altered sheared mafic rock (Walsh 1970; Mason and Theuri 1980). Between 1972 and 1998 some 72,000 tonnes of vermiculite were produced from the Wasin mine. Peak production was reached in 1987 when 9,220 tonnes were produced at Wasin. Most of the vermiculite products are used in the local building industry. Only minor use of vermiculite is made in the horticultural industry of Kenya.

Natural zeolites

Analcime and natrolite concentrations up to 40% have been described from siltstones in the Lake Bogoria basin in the Kenyan Rift Valley (Renault 1993). Ego (2000) describes clinoptilolite and analcime in the Miocene Ngorora Formation in the Kenya Rift Valley. The zeolites are interpreted as reaction products of volcanic glass with saline, alkaline waters in closed basins.

No massive zeolite beds have been reported from Kenya as yet. Based on experiences from other parts of the world it seems likely, however, that large high-grade zeolite deposits could have formed in this relatively young volcanic area with predominantly alkaline pore waters.

Pumice

Large deposits of pumice have been found in the Rift Valley in the Naivasha area, southeast of Longonot and as valley fillings in the Njorowa Gorge, all in the Rift Valley (Walsh 1970). Other deposits are found in the Sultan Hamud area. The pumice occurs as terrestrial bands and as lacustrine deposits. The pumice deposits are commonly composed only of pumice without foreign rocks. Local firms have been extracting pumice as source of building materials. No use has been made as yet for horticultural purposes.

Agromineral potential

The nitrate deposit at Lake Turkana warrants detailed geological investigations including studies of the size and volume of the deposit. Additional exploration should be carried out in the Suguta Valley south of Lake Turkana.

There is potential for the discovery of sedimentary phosphates in coastal sediments. Late Cretaceous to early Tertiary sedimentary sequences, especially those associated with transgressive phases and located at local embayments should be investigated (see chapter on Ethiopia).

Phosphate exploration should also be conducted in the Eastern Rift Valley of Kenya. There are considerable chances of finding lacustrine and biogenic phosphate accumulations in Rift Valley sediments, similar to the ones at Minjingu in Tanzania. Residual igneous phosphates can be expected in an area that covers the Ekiojanga carbonatite and breccia in the Rangwe complex of western Kenya. Efforts should be made to delineate and assess the grade and extent of the 'dyke of carbonated collophane rock' in the southwestern part of the Rangwa carbonatite complex.

The carbonate resources of Kenya are significant and additional agricultural trials should be carried out to evaluate the agronomic effectiveness and economics of the liming materials on acid soils. The efficacy of liming materials from the Koru deposit, mined and processed by Homa Lime Co. Ltd., should be tested on acid soils in western Kenya.

The potential for finding substantial volumes of zeolites in the Rift Valley is high. The potential use of these materials for agriculture is described in Pond and Mumpton (1984).

References:

Bosse H-R 1996. Kenya. In: Bosse H-R, Gwosdz W, Lorenz W, Markwich, Roth W and F Wolff (eds.) Limestone and dolomite resources of Africa. Geol. Jb., D, 102:180-199.

Buresh RJ, Smithson PC and DT Hellums 1997. Building soil phosphorus capital in Africa. In: Buresh RJ, Sanchez PA and F Calhoun (eds.) Replenishing soil fertility in Africa. Soil Sci. Soc. Amer. Special Publ. 51:111-149.

Coetzee GL and CB Edwards 1959. The Mrima Hill carbonatite, Coast Province of Kenya. Transact. Geol. Soc. South Afr. 62:373-395.

Ego JK 2000. Zeolite mineralisation in the Neogene paleolakes of the Ngorora Formation, Kenya Rift Valley. Special Abstract Issue. 18th Coll. African Geology, Graz, Austria. J. Afr. Earth Sci. 30:25-26.

Gaciri SJ 1991. Agromineral resources of Kenya. Fert. Res. 30:165-166.

Hussein SS 1995. The Mrima Hill carbonatite, Kenya: Mineralogy, geochemistry and supergene alteration. Unpubl. M.Sc. Thesis, ITC, Delft, Netherlands, 109pp.

Idman H 1985. The phosphate-investigations in Western Kenya. Annual Report for 1984, Mines and Geological Department, Nairobi, 71pp.

Idman H and T Mulaha 1991. Assessment of phosphate and niobium in carbonatitic and alkaline silicate complexes of South Nyanza, Kenya. Mines and Geol. Dep., Geol. Memoir 8, 30pp.

International Fertilizer Development Centre 1986. Cursory characterization of a phosphate ore sample from Northern Kenya. IFDC Unpubl. Rep., 12pp.

International Labour Organization 1999. Social and labour issues in small-scale mines. TMSSM/1999, 99pp.

Izon D 1993. The mineral industry of Kenya. In: Mineral Industries of Africa. United States Department of the Interior, Bureau of Mines - 1993 International Review:77-79.

Kortman C, Githinji I, Alviola R., Mulaha T. and K Nzau 1991. Assessment of Western Kenya limestone deposits for cement manufacture. Koru and Songhor deposits. Mines and Geol. Dept., Geol. Memoir 5, 30pp.

Kuivasaari T 1991. Assessment of phosphate in the Ikutha iron ore deposit, Kenya. Mines and Geol. Dep., Geol. Memoir 7, 29pp.

Le Bas 1977. Carbonatite-nephelinite volcanism. An African case history. John Wiley & Sons Ltd., UK, 347pp.

Mason JE and FG Theuri 1980. Industrial mineral development in Kenya. 4th Industrial Minerals Intern. Congress, Atlanta, USA 1980, 18pp.

Owen RB and RW Renault 1989. Nitrate deposition in the Turkana basin of northern Kenya. J. Afr. Earth Sci. 10:701-706.

Pond WG and FA Mumpton (editors) 1984. Zeo-Agriculture: Use of natural zeolites in agriculture and aquaculture. Westview Press, Boulder, Colorado, USA, 296pp.

Prins P 1973. Apatite from African carbonatites. Lithos 6:133-144.

Pulfrey W 1950. Ijolitic rocks near Homa Bay, Western Kenya. Quart. J. Geol. Soc. CV:373-402.

Randel RP and RW Johnston 1991. Geology of the Suswa area. Ministry of Environm. and Natural Res., Mines and Geol. Dept. Report 97:41pp.

Renault RW 1993. Zeolitic diagenesis of late Quaternary fluviolacustrine sediments and associated calcrete formation in the Lake Bogoria Basin, Kenya Rift Valley. Sedimentology 40:271-301.

Sanchez PA, Shepherd KD, Soule MJ, Place FM, Buresh R J, Izac AMN, Mokwunye AU, Kwesiga FR, Ndiritu CG and PL Woomer 1997. Soil fertility replenishment in Africa: An investment in natural resource capital. In: Buresh RJ, Sanchez PA and F Calhoun (eds.) Replenishing soil fertility in Africa. Soil Sci. Soc. Amer. Special Publ. 51:1-46.

Schlueter T 1997. Geology of East Africa. Gebrueder Borntraeger, Berlin-Stuttgart, Germany, 484pp.

Smithson P, Jama B, Delve R, van Straaten P and R Buresh 2001. East African phosphate resources and their agronomic performance. Presentation July 2001, Kuala Lumpur, Malaysia.

Theuri FG 1994. The Kenyan industrial minerals sector. In: Mathers SJ and AJG Notholt (eds.) Industrial Minerals in Developing Countries. AGID Geosciences in International Development 18:167-172.

Van Kauwenbergh SJ 1991. Overview of phosphate deposits in East and Southeast Africa. Fert. Res. 30:127-150.

van Straaten P 1997. Geological phosphate resources in Central East Africa, Trip report June 23-July 21 1997, Report, University of Guelph, Canada, 49pp.

Walsh J 1970. Minerals of Kenya. Geol. Surv. Kenya, Bull. 11, 82pp.