INDUSTRIAL MINERALS IN TANZANIA

An Investor's Guide

Ministry of Energy and Minerals
United Republic of Tanzania

GEOLOGICAL SURVEY OF TANZANIA GST

BGR Bundesanstalt für Geowissenschaften und Rohstoffe

SMC STAMICO State Mining Corporation

INDUSTRIAL MINERALS IN TANZANIA
An Investor's Guide

Prepared by the
Government of the United Republic of Tanzania

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FOREWORD

In your hands you have the first edition of the publication “Industrial Minerals in Tanzania. An Investor’s Guide” which is a supplement to the long-established and well-known guide book “Opportunities for Mineral Resource Development” in Tanzania. This supplement is published at a time when prices for many minerals have reached record highs, and exploration is booming.

Although mining investments in Tanzania have so far concentrated on precious metals and gemstones, the industrial mineral wealth of the country is also substantial. Available industrial minerals and rocks include phosphate, limestone, gypsum, soda ash, kaolin, graphite, silica sand, feldspar, a variety of rocks for dimension stones, magnesite, mica, and many others. The mining history of some of these industrial minerals is even older than commercial mining for gold in Tanzania as it dates back to the beginning of the last century. Although it is possible that some of the minerals that were of considerable interest one hundred years ago are no longer looked for anymore, new applications for others have emerged with ready markets in Tanzania, East Africa and the industrialized world.

Lately, entrepreneurs have become aware of the long dormant opportunities and have embarked in Tanzania on the mining of phosphate, limestone, gypsum, pumice, aggregates, and dimension stones. However, investment is still at a low level despite the opportunities: which is why this potential is now being promoted, so that such minerals can be economically exploited. The time has now come to focus on the industrial minerals which our rapidly developing country need in large quantities. Industrial minerals and rocks are used for the construction of buildings, the production of fertilizers, and the manufacture of many basic goods like glass, paper, and paint. Most of these mineral commodities can be found in Tanzania, but only a few are being mined, and even less are being exported.

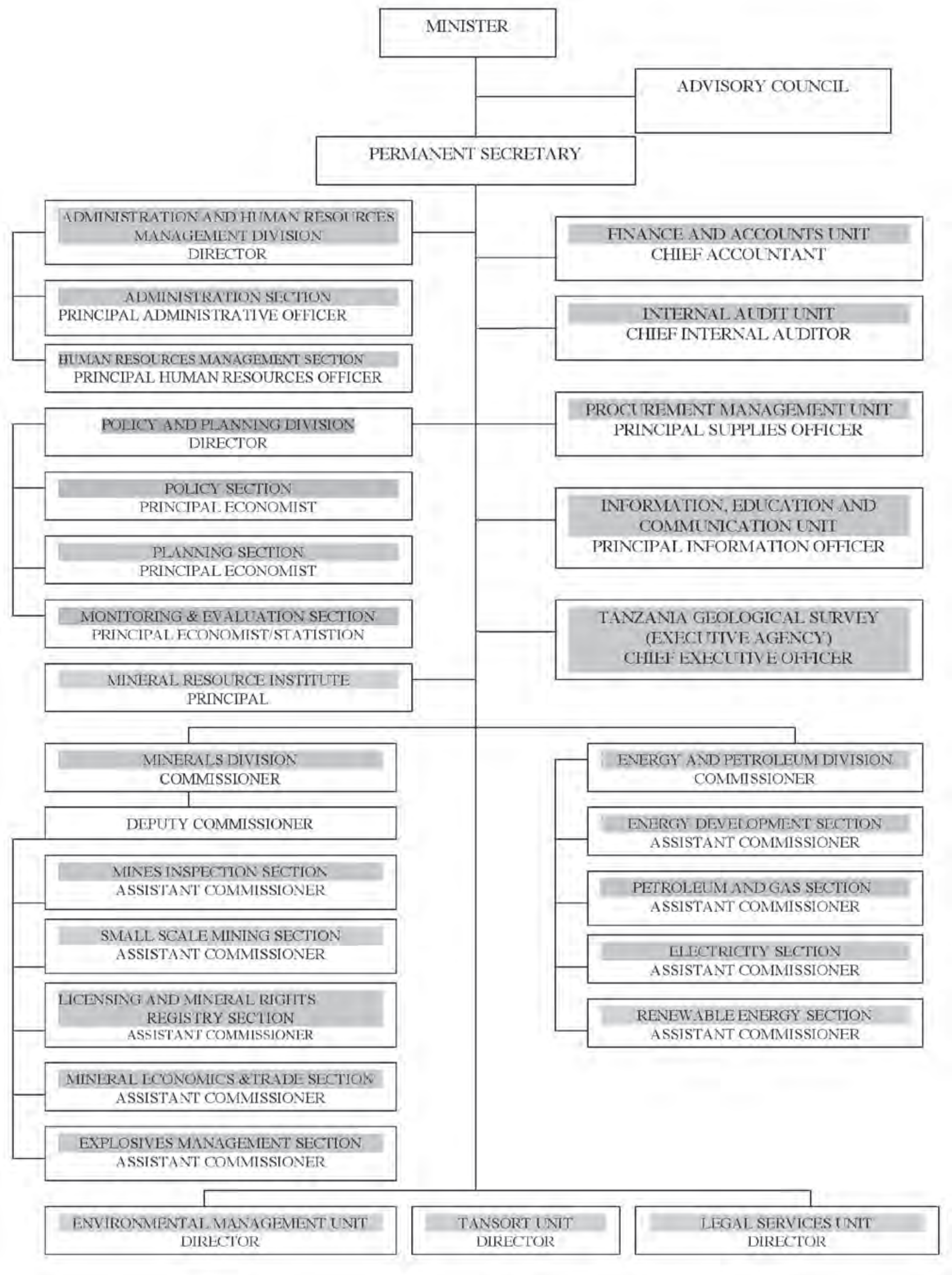
This brochure is devoted to providing important information on the occurrences of industrial minerals available in Tanzania, and points out the many opportunities for investment. We hope you will find this investment guide not only informative and attractive but also a clear indicator of where to invest best. We look forward to a growing revival in the exploration and exploitation of this additional important mineral wealth in our country for mutual benefit. With respect to investment climate for mining in Tanzania, the Government is committed to ensuring that the country remains a prime investment destination in Africa.

Let me conclude by inviting you to visit our beautiful country, and form your own opinion regarding the manifold investment opportunities for the exploration and mining of industrial minerals.

You are Welcome.
Karibuni Sana

Dr. Dalaly Peter Kafumu
Commissioner for Minerals

ORGANISATION STRUCTURE OF THE MINISTRY OF ENERGY AND MINERALS



TANZANIA OFFERS INVESTORS

1) Over 800,000 km^2 of varied geological terrains with potential mineral resources.
   - An Archaean shield environment with a number of classical Canadian-type and Australian-type greenstone gold lode deposits, many capped by tropically weathered enrichment zones.
   - An extensive Proterozoic terrain containing lode and near-surface gold deposit types, now attracting exploration attention in South America, West Africa and elsewhere.
   - Potential for epithermal gold deposits in the faulted younger rocks on the coastal plain.
   - A world-class diamondiferous kimberlite at Mwadui and more than 200 other kimberlites, many of which are yet to be thoroughly evaluated.
   - Scores of occurrences of high-value coloured gemstones, such as ruby, tsavorite, sapphire, tanzanite and alexandrite.
   - A wealth of other opportunities in minerals, particularly base and other metals, coal, and industrial minerals including graphite, gypsum, salt, kaolin, limestone, phosphate and dimension stones.
   - More than a dozen carbonatites, only a few of which have been thoroughly explored.

2) A history of precious and base metals mining, with opportunities for revival in a new economic era.

3) Ample inventory of still unexplored mineral ground.

4) A comprehensive, systematically archived database on geoscientific information and mineral resources.

5) Minimal competition at present from large multinational mining firms.

6) An atmosphere of political stability and economic revival.
   - Changed role of the Government to become facilitator, regulator, promoter and service provider.
   - Globally competitive tax and regulatory regime for mining investors.
   - Accelerated and simplified handling of investment proposals.
   - Guaranteed access to foreign exchange for repatriation of profits.

7) Technical staff trained in various disciplines associated with mining.

8) An abundant supply of labour.

9) A peaceful working environment free of ideological confrontations, ethnic strife and labour disputes.

10) Well-established supporting services to the mining industry.

CONTENTS

GENERAL INFORMATION

Tanzania continues to be one of Africa's biggest mining success stories, endowed with geology which is highly prospective for precious metals, gemstones and industrial minerals, and offering a stable political environment with sound legal and fiscal policies.

Within a period of 15 years since the early 1990s, Tanzania has risen from an insignificant gold producer to become Africa's third largest gold producing country. More than 52 tons of gold were produced in Tanzania in 2005. The value of the country's mineral exports rose from US-$ 312 million in 2001 to more than US-$ 728 million in 2005. Minerals exported are not only gold, but in rank of value also coloured gemstones, diamonds, copper, silver, salt, ornamental stones, gypsum, and phosphate.

So far most of the mineral development activities are focussing on precious metals, base metals, and gemstones. On the other hand industrial minerals which are a pillar for industrial development just like base metals have been given minimum attention. Industrial minerals and rocks are not only useful and can easily be extracted by local communities for the improvement of livelihoods and direct poverty reduction, they can also generate a good profit when mined sustainably and used and marketed professionally.

The purpose of this brochure is to promote the utilization of industrial minerals in Tanzania and to raise the awareness of the international mining community of the spectrum of investment opportunities available in the development of this important group of minerals in Tanzania. However, because bulk minerals used for building purposes only, i.e. common clays and crushed rocks, are ubiquitous in Tanzania they do not need any promotion and are therefore not included in this brochure.

The introductory part of this publication is intended to present the investor with a broad view of the country in terms of its mineral sector policy, as well as its physical environment and infrastructure. This part is followed by a technical discussion of the geological and mineral deposit setting and a description of the available database.

The bulk of the publication, however, is devoted to a presentation of the industrial minerals of Tanzania. Each commodity is described with its most important applications, followed by a comprehensive description and complete list of relevant occurrences in Tanzania. All of the available analytical and resource data are given in each case. General maps and satellite images are included to show the locations of commodities mentioned in the text. Internationally accepted assessment criteria regarding quality and quantity of minerals described are cited, followed by tips for potential investors on where and how to start first. Information on the relevant literature concludes each mineral section, with a list of basic literature concluding the brochure.

It is hoped that the organization of this document will facilitate its use by interested potential investors and of course, finally, promote the mining and utilization of more industrial minerals in Tanzania.

The Ministry of Energy and Minerals acknowledges the preparation of substantial parts of this brochure by experts from the Federal Institute for Geosciences and Natural Resources (BGR) in Germany with contributions from The Geological Survey of Tanzania (GST) in Dodoma and State Mining Corporation (STAMICO) in Dar es Salaam. Also various industrial mining companies in Tanzania have given permission to cite from their exploration reports and to take and analyse samples from their operations or prospects. Publication of this brochure was funded by the Federal Ministry of Economic Cooperation and Development of the Federal Republic of Germany through the Federal Institute for Geosciences and Natural Resources (BGR).

INVESTMENT ENVIRONMENT

Concerted efforts by the Government of The United Republic of Tanzania implemented since the late 1980s, have made the country a prime destination for private sector investment. Besides political stability unparalleled in Africa, Tanzania provides investment guarantees, business-friendly macro-economic stability, unconditional transferability of capital and profits, simplified bureaucracy and a package of incentives to investors.

The country has received international recognition for its endeavours: in 2005, its investment promotion agency, Tanzania Investment Centre (TIC) won the *Best Investment Agency Award* of Africa, South of Sahara. In 2006, the Financial Times, a business magazine, conducted a survey of investment climate in African countries: Tanzania won *Country of the Future Award* for East and Central African Region. In 2007, TIC scooped *The Best Practice and After Care Facilitation Award* from the World Investment Promotion Agency (WIPA). Furthermore, the World Bank, through its report of Doing Business of 2006/07, rated Tanzania amongst the best 10 top reformers in the world.

INVESTMENT GUARANTEES

Investments in Tanzania are guaranteed against political risks, nationalization and expropriation through the Tanzania Investment Act, 1997. Tanzania is a member of the Multilateral Investment Guarantee Agency (MIGA) and is in the list of countries that get approved treatment by international insurance agencies. In the event of a dispute between a foreign investor and the Government, all efforts shall be made to settle the dispute amicably through negotiation. Should that fail, the Tanzania Investment Act, 1997, provides the following methods for settling the dispute as may be mutually agreed by the parties:

(a) in accordance with arbitration laws of Tanzania for investors;

(b) in accordance with the rules of procedure for arbitration of the International Centre for the Settlement of Investment Disputes;

(c) within the framework of any bilateral or multilateral agreement on investment protection agreed to by the Government of the United Republic and the Government of the country from which the investor originates.

THE MINERAL POLICY

POLICY OBJECTIVES

The Mineral Policy of Tanzania of 1997 has the following major objectives:

(i) To raise the contribution of the mineral sector to Gross Domestic Product (GDP) from 1.7 % in 1997 to above 10 % in the next 25 to 30 years;
(ii) To increase the country's foreign exchange earnings;
(iii) To increase government revenues;
(iv) To create gainful and secure employment in the mineral sector and provide alternative sources of income particularly for the rural population;
(v) To integrate mining in the national economy through forward and backward linkages;
(vi) To minimize any adverse social and environmental impacts from mining.

THE ROLE OF THE GOVERNMENT

In order to attain the above objectives, the role of the Government focuses on:

(i) Providing clear policy guidelines to attract and enable the private sector to take a lead in mineral exploration, mining, beneficiation and marketing;
(ii) Developing an enabling legal, regulatory, fiscal and institutional environment for private sector investment in mining;
(iii) Strengthening the ability of the State to effectively carry out its administrative, regulatory, promotional and investment facilitation functions;
(iv) Establishing environmental, health and occupational safety guidelines and ensuring compliance;
(v) Supporting the small-scale mining subsector by facilitating the transformation and upgrading of the present artisanal mining activities into organized and modernized small-scale mining;
(vi) Carrying out basic geological mapping of the country, and maintaining, updating and disseminating information on mineral resource potential.

Government participation in mining ventures is not mandatory although, in rare cases, it may have limited participation for strategic or promotional purposes.

LEGISLATIVE FRAMEWORK

ADMINISTRATION OF THE MINING ACT, 1998

The Mineral Sector is administered by the Minerals Division. The Mining Act, 1998 sets out the legal framework governing mineral exploration, exploitation and marketing. Various mining regulations have been established under the Mining Act, 1998 to regulate mining activities. The Mining Regulations and Rules are:

- The Mining (Mineral Rights) Regulations, 1999;
- The Mining (Mineral Trading) Regulations, 1999;
- The Mining (Occupational Safety and Occupational Health) Regulations, 1999;
- The Mining (Environmental Management and Protection) Regulations, 1999;
- The Mining (Salt and Iodation) Regulations, 1999;
- The Mining (Provisional Licences) Regulations, 1999;
- The Mining (Merelani Controlled Area) Regulations, 2001;
- The Mining (Diamond Trading) Regulations, 2002;
- The Mining (Gemstone Board) Regulations, 2004; and
- The Mining (Dispute Settlement Resolution) Rules, 1999.

LICENSING PROCEDURE

The Mining Act, 1998, establishes state ownership of minerals and provides rights and conditions whereby the rights to explore, develop and produce such minerals are granted. Licensing procedures ensure transparency and fairness by conferring ownership of mineral rights on "first come, first served" basis.

Under the Act, minerals are categorized as follows:

- All minerals other than building materials or gemstones;
- Building materials;
- Gemstones.

Licences for these mineral groups are issued under different categories as follows:

PROSPECTING LICENCE

A Prospecting Licence is granted for an initial prospecting period not exceeding three years, except in the case of an application for a Prospecting Licence for gemstones where the period may not exceed two yeas and is not subject to renewal. A Prospecting Licence covering a preliminary reconnaissance for all minerals other than building materials and gemstones may be granted for a period not exceeding two years.

An applicant who has been granted a preliminary reconnaissance period shall, on renewal, relinquish an area or areas sufficient to ensure that the area retained does not exceed the maximum area which may be held during the initial prospecting period. On first renewal, the holder shall relinquish 50 % of the initial prospecting area, and in the case of a second ren shall relinquish 50 % of the balance area, by giving sufficient shall relinquish description of the relinquished area.

The size of each Prospecting Licence shall be as follows:

- For a Prospecting Licence with a preliminary reconnaissance period, the maximum area shall be 5,000 km^2;
- For a Prospecting Licence for all minerals other than building materials or gemstones the maximum area during the initial prospecting period shall be 200 km^2.
- For a Prospecting Licence for gemstones the maximum area shall be 10 km^2; and
- For a Prospecting Licence for building materials the maximum area shall be 10 km^2.

A Prospecting Licence confers on the holder the exclusive right to carry out prospecting operations in the prospecting area for minerals to which the licence applies.

RETENTION LICENCE

The holder of a Prospecting Licence, other than a Prospecting Licence for building materials or gemstones, may apply for grant of Retention Licence on the grounds that:

(a) he has identified a mineral deposit within the prospecting area which is potentially of commercial significance; and

(b) the mineral deposit cannot be developed immediately by reason of technical constraints, adverse market conditions or other economic factors which are, or may be, of temporary character.

Retention Licence may be granted for a period not exceeding five years. It may be renewed for a period of five years but, before renewing such a licence, the holder may be required to provide updated studies and assessments of the prospects of the development and commercial exploitation of the mineral deposit.

SPECIAL MINING LICENCE

A Special Mining Licence is granted in respect of the development and production stages of a large mining operation. The licence may be granted for a period not exceeding 25 years or the estimated life of the ore body, which the applicant proposes to mine, whichever is shorter. On application duly made, it may be renewed for a period not exceeding twentyfive years.

Application for a Special Mining Licence must be accompanied by a proposal of mining operations, Environmental Management Plan (EMP), a proposal on employment of citizens of Tanzania and an Environmental Impact Assessment (EIA). A Special Mining Licence confers on the holder the exclusive right to carry out mining operations in the mining area and to dispose of any mineral product recovered.

MINING LICENCE

A Mining Licence is granted in respect of the development and production stages. The licence may be granted for a period not exceeding ten years, or the estimated life of the ore body which the applicant proposes to mine, whichever is shorter. On application duly made, it may be renewed for a period not exceeding ten years.

Each application under the Mining Licence must include a feasibility study, which shall set out the proposed programme of mining operations and must be accompanied by an EMP and an EIA.

The size of each Mining Licence shall be as follows:

- For a Mining Licence for all minerals other than building materials or gemstones the maximum area shall be 10 km^2;
- For a Mining Licence for building materials the maximum area shall be 0.5 km^2.

GEMSTONE MINING LICENCE

A Gemstone Mining Licence confers on the holder the exclusive right to carry out mining operations for gemstones in the mining area. The licence may be granted for a period not exceeding ten years, and may be renewed for the period for which application has been made, but not exceeding ten years. No Gemstone Mining Licence shall be granted to a non-citizen of Tanzania, unless the Gemstone Mining Licence is held by that person in undivided participating shares with a citizen of Tanzania whose undivided participating share or shares amount to not less than twenty five percent. For a Gemstone Mining Licence, the maximum area shall be 1.0 km^2.

All applications for a Gemstone Mining Licence shall be accompanied, among others, by the proposed programme for mining operations, which the applicant proposes to undertake during the first two years from the date on which the licence is granted. An EIA and EMP shall also accompany the application. The Minister shall not issue this licence without referring the matter to the Mining Advisory Committee for advice.

PRIMARY PROSPECTING LICENCE

A Primary Prospecting Licence authorizes the holder to prospect for minerals for any area located in the Zone for which the Zonal Mines Officer has responsibility. The licence shall be granted for a period of one year, and may be renewed for a similar period or periods.

PRIMARY MINING LICENCE

A Primary Mining Licence confers on the holder the exclusive right to carry out mining operations in the mining area. The licence is granted for a period of five years and may be renewed for a similar period. The holder of one or more Primary Mining Licence may apply to convert the licence or licences to a Mining Licence or a

Gemstone Mining Licence.

The size of each Primary Mining Licence shall be as follows:

- For a Primary Mining Licence for all minerals other than building materials the maximum size shall be 10 hectares; and
- For Primary Mining Licence for building materials the maximum size shall be 2 hectares.

The above maximum sizes shall not apply to Primary Mining Licences amalgamated for the purpose of conversion to Mining Licence or Gemstone Mining Licence.

No Primary Prospecting Licence and no Primary Mining Licence may be granted to an individual, partnership or body corporate unless:

(a) in the case of an individual, the individual is a citizen of Tanzania;
(b) in the case of a partnership, it is composed exclusively of citizens of Tanzania;
(c) in the case of a body corporate, it is a Company; and
  (i) its membership is composed exclusively of citizens of Tanzania;
  (ii) its directors are all citizens of Tanzania;
  (iii) control over the Company, both direct and indirect, is exercised from within Tanzania by persons all of whom are citizens of Tanzania.

FISCAL TERMS FOR MINING SECTOR

The fiscal regime for the mining sector in Tanzania is set out in the Road and Fuel Tolls Act, 1985; the Value Added Tax Act, 1997; the Mining Act, 1998; the Income Tax Act, 2004; and the East African Customs Management Act, 2004.

Royalty

The rates of royalty for minerals are provided for under Section 86 of the Mining Act, 1998. The rates are set at 5 % for diamonds and uncut gemstones; 0 % for cut diamonds and gemstones; and 3 % for all other minerals. They are calculated on the basis of net back value defined as the market value of minerals FOB at the point of export from Tanzania or, in the case of consumption within Tanzania, at the point of delivery within Tanzania, less:

(a) the cost of transport, including insurance and handling charges; and
(b) the cost of smelting and refining or other processing costs unless such other processing costs relate to processing normally carried out in Tanzania in the mining area.

DIRECT TAXES (INCOME TAXATION REGIME)

The mining sector has a special fiscal regime which was legislated in 1997. Section 145 of the Income Tax Act, 2004 conserves this regime in respect to direct taxes.

Corporation Tax

Applicable rate is 30 % which is the standard corporate tax rate for all sectors in Tanzania.

Deduction of Expenditure (Depreciation Allowance)

Mining companies are allowed 100 % immediate expensing of capital expenditure in any year of income.

Deductions allowed for Environmental Damage Rectification

Under the Income Tax Act, 2004, mines are allowed to deduct expenses incurred to rectify environmental damage in the same tax year when calculating taxable income. They are also allowed to deduct an amount of money budgeted for provisioning for future environmental expenditure in the same year that they are set aside but subject to approval by the Commissioner General of the Tanzania Revenue Authority.

Under Regulation 31 of the Mining (Environmental Management and Protection) Regulations, 1999, a holder of a special mining licence, mining licence or gemstone mining licence may be required to provide a rehabilitation bond which shall be either of the following forms: escrow account; capital bond; insurance or bank guarantee bond; pledging and assets; or any other form which may be agreed between the Government and the licensee.
The bond and financial guarantee will form a separate agreement between the Government and the licensee.

Withholding Taxes
Applicable withholding taxes to the mining sector are as follows:

- 3 % on technical services both for resident and non-resident providers;
- 3 % on management fees where such fees do not exceed 2 % of the operating costs claimed as deduction and 20 % for any such fee in excess of 2 % of the operating costs;
- Zero withholding tax on interest paid on loans in foreign currencies from third parties, otherwise 10 % withholding tax on interest on loans from affiliates; and
- 10 % withholding tax on dividend.

INDIRECT TAXES

Value Added Tax
Most of the goods and services purchased or imported by the mining companies are subject to VAT at the standard rate of 20 %. However, Section 11 and Third Schedule of the Value Added Tax Act, 1997 provides for special relief to mining companies on certain goods and services. Hence, mining companies are required to pay VAT on goods on which they do not have relief and claim a VAT refund as long as they registered for VAT with the Tanzania Revenue Authority.

Import Duty
Section 252 of the East African Community Customs Management Act, 2004 saves the fiscal regime in respect of import duty for the mining sector in Tanzania which was contained in the Customs Tariff Act, 1976 as amended by the Financial Laws (Miscellaneous Amendment) Act, 1997. Under the regime, both mining companies and their sub-contractors, are eligible for total exemption of import duty for exploration, mine development, mining equipment, machinery and supplies up to the first anniversary of commencement of commercial production. Thereafter, a cap limited of 5 % import duty was to apply. However, since financial year 2000/2001, all capital goods imported into East African countries are zero-rated under the East African Community Common External Tariff (EAC-CET).
The EAC-CET contain three tariff bands, namely, zero rate for capital goods and raw materials, 10 % for semi-processed products, and 25 % for finished products as per a Harmonised System Classification. Under this Classification, explosives, dump truck tyres and spare parts attract 10 % import duty while chemicals such as sodium cyanide are zero-rated.

Excise Duty
On the basis of a remission provided under Government Notice No. 480 of 25th October, 2002, mining companies are exempt from paying excise duty on fuel they import for mining of minerals intended for export.

Fuel Levy
A road and fuel tolls payment is capped at US-$ 200,000 per annum for mining companies.

Local Government Taxes
The Local Government Finances Act, 1982, provides for of revenue of District Councils. Relevant sections are 7(1) (aa) and 13 which empower Local Governments to make by-laws and charge a levy not exceeding 0.3 % of the turnover of Corporate entities net of value added tax and excise duty.

FISCAL STABILITY AGREEMENTS

Section 10 of the Mining Act, 1998, empowers the Minister responsible for mining affairs to enter into a Mining Development Agreement with an applicant or a holder of a mineral right which guarantees the fiscal stability of a long term mining project by reference to the law in force at the effective date of the agreement, with respect to the range and applicable rates of royalties, taxes, duties, fees and other fiscal imposts and the manner in which liability in respect thereof is calculated, and for that purpose, but not otherwise, may contain special provisions relating to the payment of any such fiscal impost to take effect in the event of a change in the applicable law.

COUNTRY PROFILE

Geography: The United Republic of Tanzania borders the Indian Ocean to the east, and has land borders with eight countries: anticlockwise from north, Kenya, Uganda, Rwanda, Burundi, the Democratic Republic of Congo (across Lake Tanganyika), Zambia, Malawi and Mozambique. The country includes Zanzibar - consisting of the main island, Unguja, plus Pemba and other smaller islands.

Landscape: The major portion of Tanzania is an ancient erosion surface of low relief, rising by a series of steps from the coast towards the interior to about 1,500 m, and then falling back to below 1,000 m in the Western Rift. There are a number of impressive mountain ranges, typically rising 500 to 1,000 m above their surroundings. Mts. Kilimanjaro and Meru in the northeast are Neogene volcanoes rising to 5,895 m and 4,562 m, respectively. Spectacular Mt. Kilimanjaro is the only permanent ice capped mountain in Africa. Mention should be made of the magnificent beaches on the Indian Ocean coast and the inland lakes with their spectacular wildlife. Outside the eastern Rift volcanic areas, the highest peaks approach 3,000 m in elevation.
Within the eastern branch of the East African Rift, which extends north-south across the centre of the country, lies a spectacular region of land-locked Lakes Natron, Manyara, Eyasi, and some smaller ones bounded by long fault scarps. These isolated valleys contain some of Tanzania's most interesting geology, fauna, scenery and minerals.

Area: 945,090 km^2. The territory includes 61,000 km^2 of water on bordering Lakes Victoria, Tanganyika and Nyasa. The country lies between Latitude 1° S to 11°45' S and Longitudes 29°36' E to 40°29' E.

People: Tanzania's population of about 37 million in 2006 represents a diversity of ethnic groups. About 125 African dialects are spoken as first languages. Kiswahili is the national language. English as second language is used in high institutions and businesses.

Major towns: In 2002, the year of the last census, Dar es Salaam, the commercial capital, had a population of 2,497,940. Dodoma, which is the administrative capital had a population of around 324,347. Urban Mbeya had a population of 266,422, City of Mwanza had 265,911 and Zanzibar Town had a population of 206,292. The total population of Tanzania in 2002 was counted to be 34,569,232.

History: According to evidence at Olduvai Gorge and in the Manonga Valley Tanzania may be humanity's place of origin. Around 500 AD Bantu people, the ancestors of the majority of the modern population entered the area. Arab coastal settlement and the introduction of Islam took place in 800 – 900 AD. Around 1200 AD people from Oman settled in Zanzibar. The slave trade began there. In 1885, Germany took over the Arab rule. In 1919, the League of Nations elected Britain to administer part of German East Africa while Belgium was given the mandate to administer Rwanda and Burundi. In 1946 Tanganyika became a UN trust territory. Tanganyika gained independence in 1961 and the United Republic which formed in 1964 between Tanganyika and Zanzibar has continued to the present day.

Climate: Varies with geographical zones: tropical on the coast where it is hot and humid (rainy season March – May); semi temperate in the mountains (with short rains in November and December and long rains February – May); and drier in the plateau region with considerable seasonal variations in temperature.

Environment: The most significant environmental issues are drought, soil degradation, deforestation, desertification and destruction of coral reefs.

Vegetation: Lush tropical at the coast, and bush. Forest and woodland cover 44 % of the land area, having declined at 0.2 % p.a. (1999-2000). Arable land comprises 4.5 % and permanent cropland 1.1 % of the total land area.

Wildlife: National parks and game reserves cover 16 % of the country and include the Selous Game Reserve and Serengeti National Park which is famous for its vast migratory herds of plain animals, notably wildebeest, zebra, eland and kude. Small bands of chimpanzee are found in the Gombe National Park along Lake Tanganyika. The steep mountain walls of Ngorongoro crater have provided protection and natural enclosure for animals in an environment of natural beauty.

LOGISTICS INFRASTRUCTURE

Tanzania is well served by land, sea and air transportation routes. A road network connects Tanzania with neighbouring countries Kenya, Malawi, Zambia, Uganda, Burundi and Rwanda. Any part of the country can be reached by the existing comprehensive road network of almost 54,000 km of which over 3,200 is asphalt. Many roads are currently being upgraded as a part of a major rehabilitation project.
Tanzania Railway Limited runs a 2,600 km network linking Dar es Salaam with the central and northern regions. The Tanzania – Zambia Railway Authority (TAZARA) operates 1,860 km of track, 976 km in Tanzania, which links Dar es Salaam with Kapiri Mposhi in Zambia. It is mainly used to transport Zambian copper to Dar es Salaam and Zambian imports in the opposite direction.
The principal coastal ports are Dar es Salaam, Tanga, Lindi, Mtwara and Zanzibar. International airlines operate in and out of Tanzania through Dar es Salaam and Kilimanjaro international airports. There is a third international airport on Zanzibar. Several regional airports and numerous landing strips for use by charter planes are also available. Air Tanzania, Precision Air, and Communitiy Airlines operates regular services to most regional towns, and has scheduled flights to neighbouring countries and to the Middle East.

Telecommunication facilities are available in most parts of the country. Fax, expedited mail service (EMS), private courier and cellular phones are also available. Coverage is very good. Tanzania has two earth satellite stations in Dar es Salaam, with a total capacity of 420 channels.

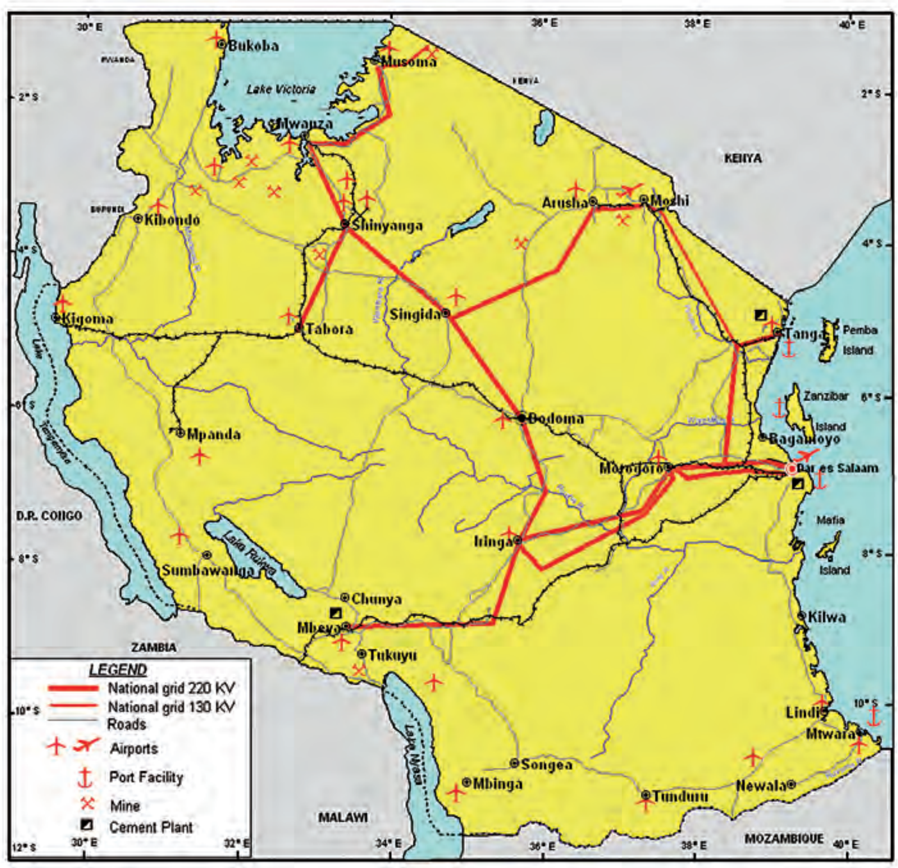


Figure 1: Infrastructure Map of Tanzania.

GEOLOGICAL ENVIRONMENT

Tanzania is blessed with a geological environment conducive for hosting diverse types of mineral deposits.The country hosts a mining investment area close to one million km^2 with lithotypes, representing virtually all the known chrono-stratigraphical units of the world ranging from Archaean, Proterozoic, Phanerozoic to Quarternary ages. These geological formations host a variety of minerals such as gold, base metals, diverse types of gemstones (including tanzanite, diamond, emerald, sapphire, ruby, beryl, tourmaline, garnet), various industrial minerals, building materials, water and hydrocarbons.

Much of the central and northern part of the country is underlain by the Tanzania Archaean Craton. The central part of the country is composed of the high grade metamorphic terrain (The Dodoman Supergroup is dominated by rafts of amphibolite to granulite facies metamorphic rocks in migmatitic granite terrain) whereas the northern part is covered by the Greenstone Belt (the Nyanzian – Kavirondian Supergroup comprising sequences of mafic to felsic volcanics, chert/banded iron formation and clastic sediments). The Tanzania Archaean Craton is well known as a host for world-class gold deposits similar to other Archaean Cratons around the world. The Craton is also intruded by a number of diamondiferous kimberlite pipes which include the Mwadui kimberlite pipe which is the second largest kimberlite pipe in the world.

The Tanzania Archaean Craton is surrounded to the southeast and southwest by Palaeoproterozoic Usagaran and Ubendian mobile belts respectively, with high grade crystalline metamorphic rocks with a number of postorogenic gabbroic and granitic intrusives hosting base metals, shear zone hosted gold, various types of gemstones and industrial minerals. The eastern part of the Usagaran Belt is mobilized by the Neoproterozoc Pan African Orogeny forming the Mozambique Belt with lithological, structural and metallogenic characteristics similar to that of the Usagaran - Ubendian Belt.

The Palaeoproterozoic Ubendian mobile belt is bound to the west by the mildly metamorphosed Mesoproterozoic Fold Belt (the Kibaran-Bukoban-Karagwe-Ankolean Supergroup*).* The supercrustal rocks of this Belt (mainly meta-argillites, phyllites, low-grade sericite schists and quartzites) are intruded by post orogenic granites which have alteration haloes containing veins with tin and tungsten mineralization. The Belt is also characterized by post-orogenic basic intrusives hosting PGM.

The Uha-Malagarasi Neoproterozoic to early Palaeozoic rocks form an intracratonic formation consisting of sedimentary-volcanic depositional sequences of sandstones, quartzites, shales, red beds, dolomitic limestones, cherts and amygdaloidal lavas with indications of strata-bound copper deposits and various industrial minerals.

Phanerozoic formations in Tanzania include the following:

(i) The *Karoo Supergroup* of Late Carboniferous to Jurassic age made up of continental sedimentary rocks famous for hosting good-quality coal resources occurring in several isolated coalfields in SW Tanzania.

(ii) Marine Formations that are dominated by shelf-facies clay-bound sands, marls and some isolated coral reefs good for production of portland cement, lime and construction aggregates. The marls and sands are good source and reservoir rocks respectively for hydrocarbons. At Mandawa there are salt domes made up of gypsum and other evaporates that can be used for various industrial purposes.

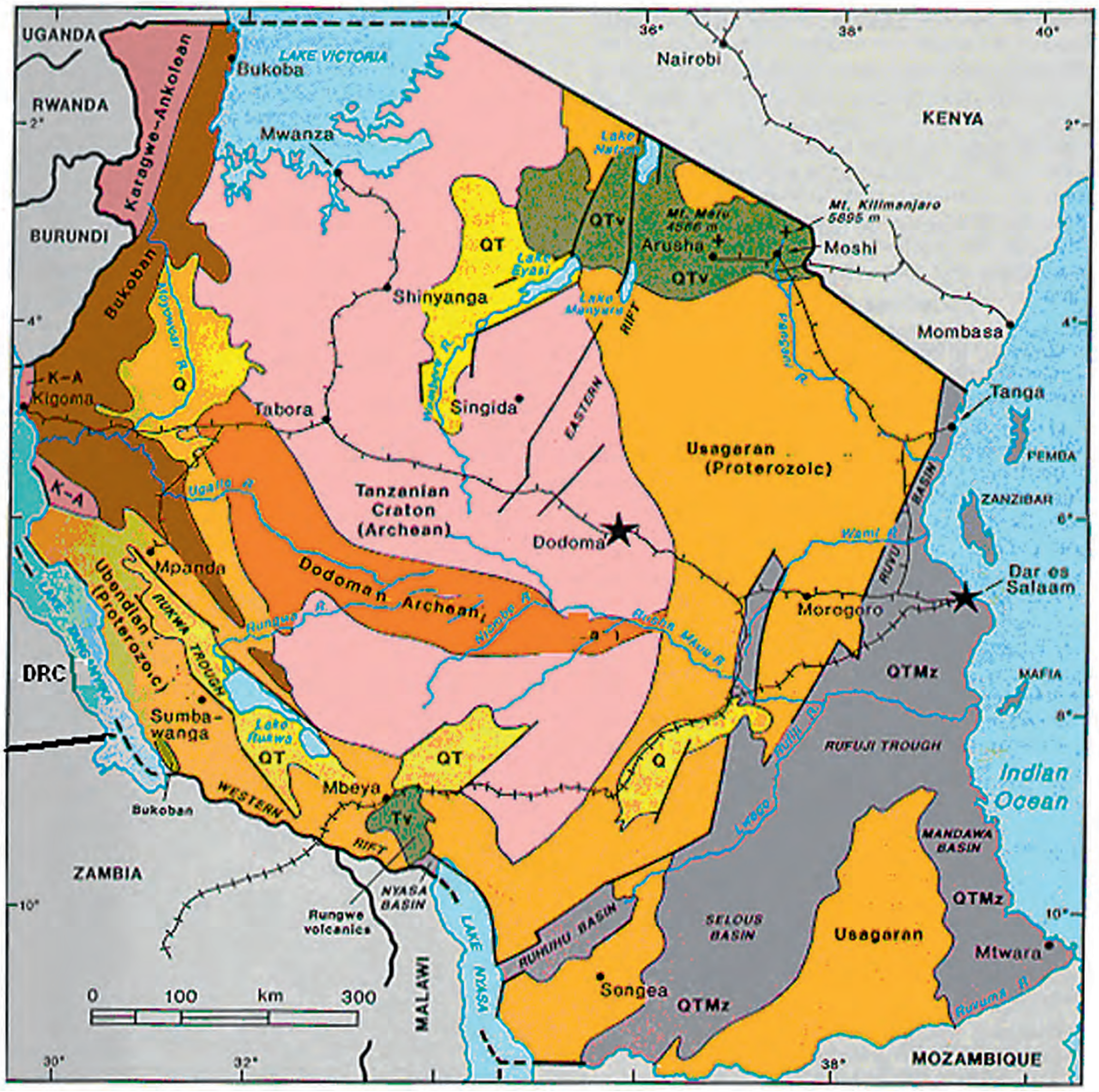


Figure 2: Simplified Geological Map of Tanzania.

(iii) Neogene to Quarternary continental formations in isolated basins and river channels composed of clays (red soils, ochre, kaolin, bentonites, meerschaum, bauxite), limestone, evaporates (gypsum and halites) and sands; volcanic rocks ranging in composition from lavas (basalts, andesites, and phonolites) good for aggregates, apatite and niobium-bearing carbonatites (good for fertilizers), tuffs, ash and pumice (good for production of pozzolana cement) and dimension stones; volcano-fumarolic exhalative deposits (mainly sulphur and fluorites).

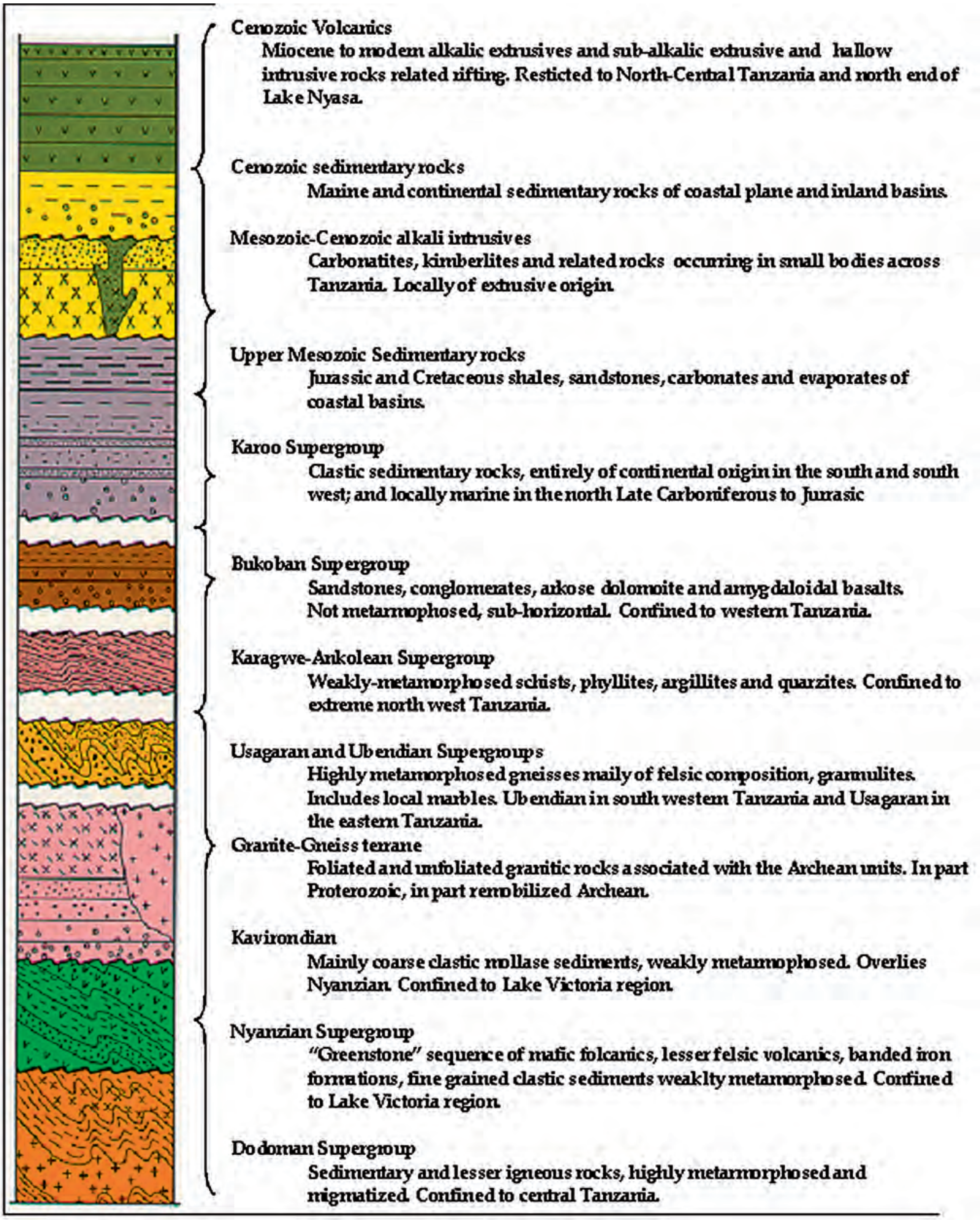


Figure 3: Geological Units of Tanzania.

GEOLOGICAL DATABASE

Tanzania possesses a geological and mineral database, which is virtually complete for work done since the mid 1930s. Such a comprehensive collection is a major asset in the evaluation of the country's mineral resources.

The Geological Survey of Tanzania (GST) at Dodoma, within the Ministry of Energy and Minerals, manages this database. GST is currently establishing a fully computerized geological database, and is updating some of the data.

Another valuable data source in Dar es Salaam is the Southern and Eastern African Mineral Centre (SEAMIC), a regional geoscientific agency which has published a number of reports on mineral resources. It also possesses a modern rock mechanics laboratory. Additional geological data is available at the State Mining Corporation (STAMICO), Tanzania Petroleum Development Corporation (TPDC), Geology Department, University of Dar es Salaam and other Government agencies.

The databases available at the Geological Survey in Dodoma include the following:

- Topographic Maps. Topographic maps at various scales, covering most of the country, are on file in Dodoma. Maps at the scale of 1:50,000 are available for most of the country. Topographical maps may be purchased at the Surveys and Mapping Division, Ministry of Lands and Human Settlement.
- Aerial Photography. The whole country has been covered by aerial photography at varying scales (Figure 4). A library of aerial photographs is available for review at the Geological Survey Dodoma. Aerial photographs can be purchased at the Survey and Mapping Division in Dar es Salaam.
- Landsat. Images can be purchased directly from international agencies such as NASA (USA), RCSSMRS (Nairobi, Kenya) and SPOT (Toulouse, France).
- Geological Maps. Geologic maps at various scales cover over 85 % of the country. Of the 322 Quarter Degree Sheets (QDS) covering the whole country, 48 % have been mapped and published at a scale of 1:125,000 (Figure 5); 29 % have been published at a scale of 1:100,000, and 3 % published at 1:250,000. Five percent (5 %) of the geologically mapped QDS are not yet published.
- Geophysical Surveys. Countrywide airborne geophysical maps including magnetic, electromagnetic (VLF-EM), and radiometric (Figure 6) are archived at the Geological Survey in Dodoma. Raw data is available for magnetics only. The data was acquired by Geosurvey International GmbH in 1977-1980 and totaled over one million line-kilometres, with a terrain clearance of 120 m. Flight lines were mainly E-W at a spacing of 1 km with tie-lines at a 10-km spacing. The maps cover 322 Quarter-degree sheets at 1:100,000 scale.

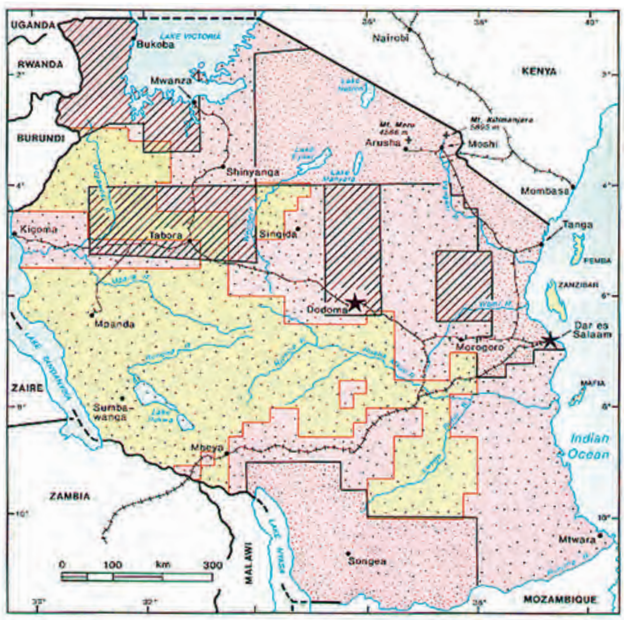


Figure 4: Coverage of Aerial Photography in Tanzania.

In addition to the Geosurvey work, a number of other surveys have been made over specific targets, the majority of them in the Archaean greenstones. Detailed surveys, flown at a line spacing of 250 m and altitude of 90 m above ground level (a.g.l.) were also undertaken over five selected areas, namely Mwadui, in search of kimberlite pipes, and Kabanga investigat-

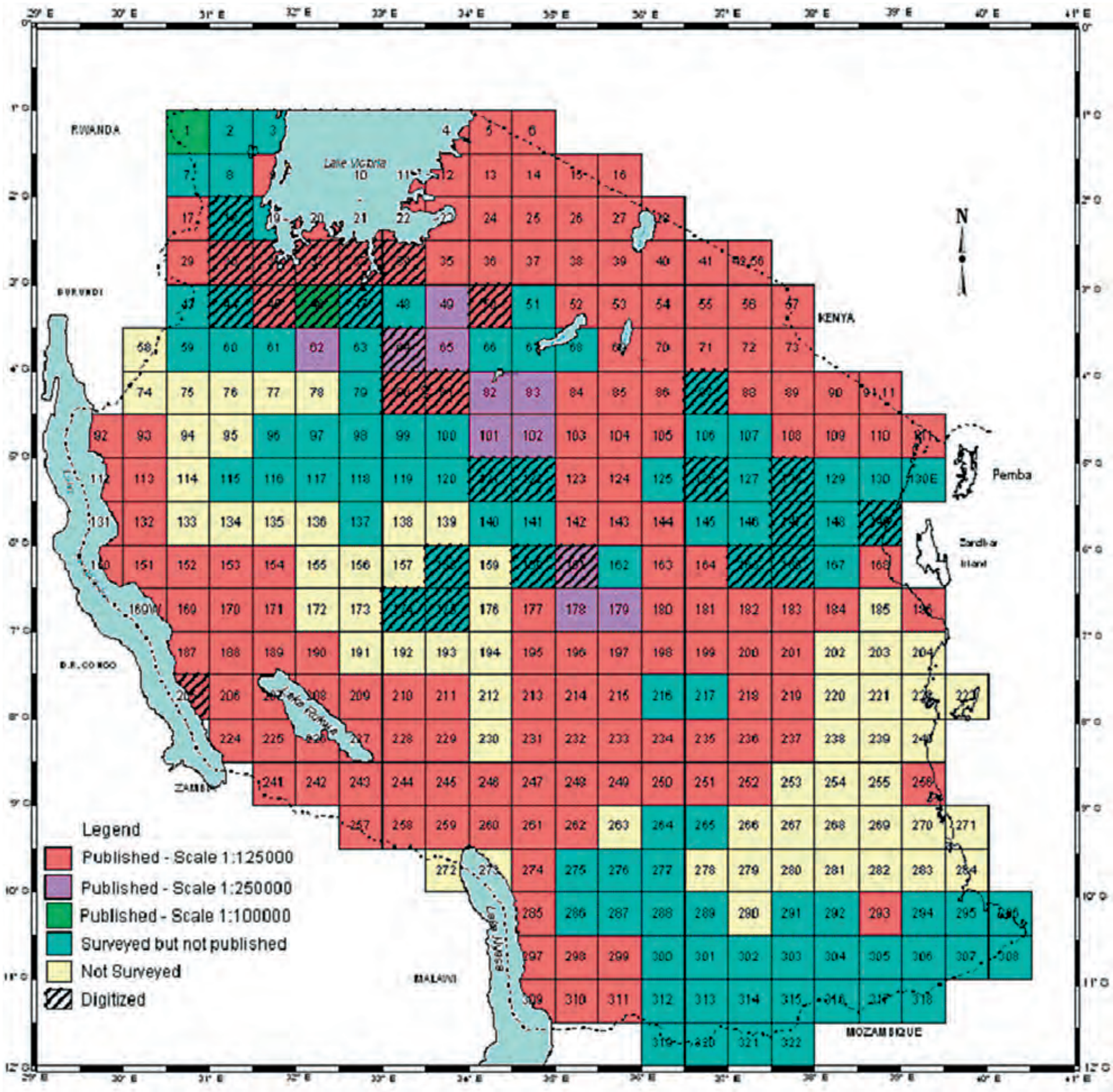


Figure 5: Progress of Country-wide Geological Mapping of Tanzania.

ing for nickel associated ultramafic bodies; also uranium, in the Chaya, Manyoni and Kwa Mtoro areas in Central Tanzania. Inventories of airborne geophysical surveys in Tanzania have been published. These reports summarize airborne geophysical surveys from as long ago as 1951.

Other detailed surveys have been conducted by the following:

- BGR (1988): Helicopter-borne geophysical surveys over the Siga-Mabale Hills greenstone belt;
- BHP (1995): Helicopter magnetic surveys over the Kagera concession area;
- RTZ Mining Exploration (1995): Airborne magnetic and radiometric surveys over Tabora East; and
- TANZAM 2000 (1999): Detailed fixed-wing geophysical surveys (Triaxial Gradiometer, 256 channel Radiometrics and Geoterrex Geotem EM) covering an area of 3587.32 km^2 over their concession west of Bulyanhulu towards Biharamulo.

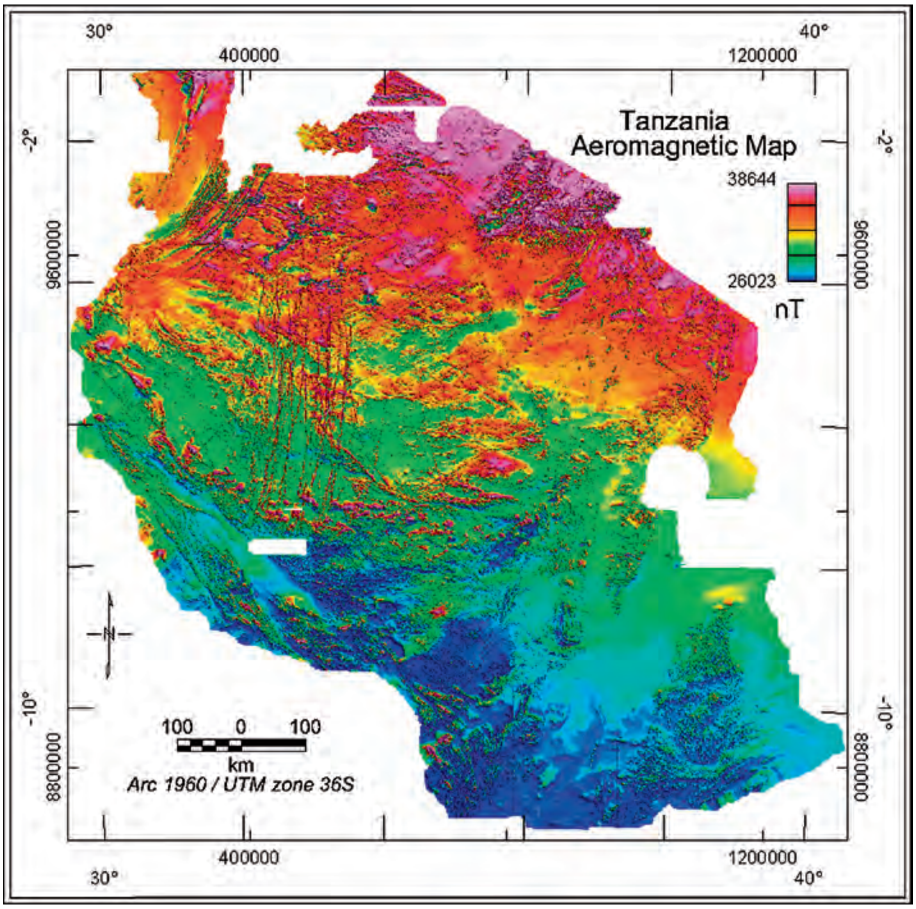


Figure 6: Countrywide Total Field Aeromagnetic Map of Tanzania.

Recently, the Government in collaboration with the Nordic Development Fund conducted high-resolution airborne magnetic, radiometric and electromagnetic surveys in selected areas including parts of Kahama, Biharamulo, Mpanda and Mara.

Geochemical Surveys: Reconnaissance geochemical surveys have been conducted on more than 70 % of the land area of Tanzania. The surveys were particularly on base metals such as copper, silver and zinc. Other elements including gold, nickel and some rare earth elements were also included in some surveys depending on the purpose of the survey (Figure 7). In addition, there have been several surveys in selected areas conducted by companies and the Geological Survey in collaboration with the BGR (German-Tanzanian Gold Project) and Geological Survey of Finland (GTK).

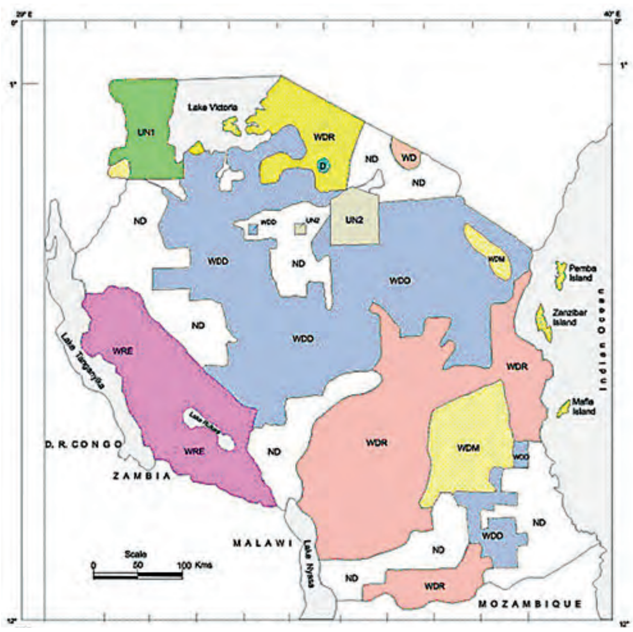


Figure 7: Map showing Areas of Reconnaissance Geochemical Surveys in Tanzania.

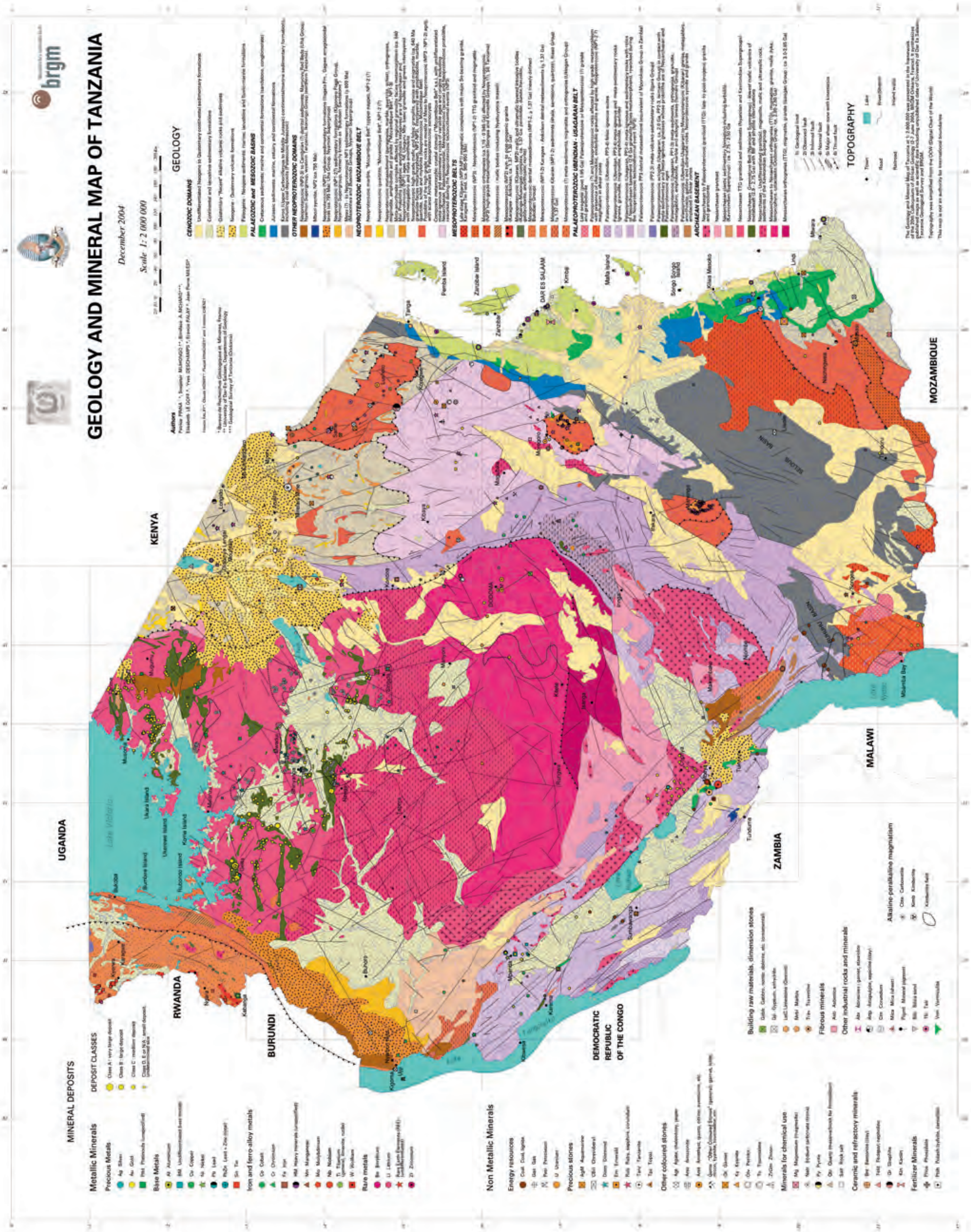


Figure 8: Geology and Mineral Map of Tanzania.

MINING INDUSTRY

HISTORY OF MINING

There are three distinguishable periods in the mining history of Tanzania:

(i) German Administration 1884 – 1918
(ii) British Administration 1919 – 1961
(iii) Post-Independence Period 1961 – Present

The Post-Independence Period is further divided into two distinct eras: the command economy era (1967 – 1989) and the market economy era (1990 – Present).

GERMAN ADMINISTRATION (1884 – 1918)

In pre-colonial times, limited mining was going on in the country targeting minerals such as iron ores which were used to make spears and other gadgets; soda ash, known as *magadi* in Kiswahili; common salt and various clays like red ochre used by the Masai tribe, and clays used for pottery making.

The earliest organized prospecting and mining in Tanzania took place during German colonial time. Garnet mining was started in 1900 at Namaputa, followed by graphite mining at Nambirane-Mhulu by Lindi Schuerfgesellschaft. Mica mining commenced in 1902 in the Uluguru Mountains; three companies were involved, namely, Ostafrikanische Bergwerks- und Plantagen Aktien-Gesellschaft at Kibuku; Deutsch-Ostafrikanische Plantagen- und Bergbaugesellschaft at Msani, and Morogoro-Glimmerwerke.

Gold Mining was undertaken at Sekenke by Kironda-Goldminen-Gesellschaft. Mining was also carried out in the Lupa Goldfield, mostly through alluvial workings, and at Kilimafedha in the Musoma-Mara Greenstone Belt. Between 1903 and 1916, salt was produced at Uvinza by Central-Afrikanische Seen-Gesellschaft.

BRITISH ADMINISTRATION (1919 – 1961)

After the First World War, Tanzania, then called Tanganyika, came under British rule. In the first three years, that is 1919-1921, mineral exploration and development was suspended to allow the enactment of a Mineral Prospecting & Mining Law and its regulations. In 1923, the Geological Survey was established at Dodoma.

Between 1922 and 1930, the key minerals produced were gold, diamonds, tin, ochre, mica and salt. Gold production came from the Sekenke Mine and the Lupa Goldfield. Gold mining in the Musoma – Mara area started in a small way in 1923. Cassiterite was discovered in 1924 at Kyerwa in the Karagwe area which attracted several mining companies to investigate the area, with the hope of finding extensive alluvial deposits. Following disappointing results, most companies withdrew, leaving behind small-scale exploitation.

In the 1930s, intensive exploration took place in the country. The campaign led to the establishment of the Kiabakari Mine in 1935; the Geita Mine in 1939; the Buhemba Gold Mine in 1939 and the New Saza Mine in 1939. Gold production peaked at 141,346 ounces (approx. 4.4 tons) in 1941.

Lead concentrates have been an important mineral export since 1950, and from 1956 to 1959, their value (partly because of the copper, gold and silver they contained) was second only to that of diamond exports. Production came from the Mukwamba Mine of Uruwira Minerals Limited at Mpanda.

Diamonds were first produced from Mabuki in 1925 and from the Shinyanga and Nzega areas from 1937. Diamond production at Mwadui, Shinyanga began in 1940 but picked up significantly in 1956 following the commissioning of a dense media separation plant.

From 1935 to 1947, salt production in the country averaged around 10,000 tons per year, with Nyanza Salt Mines (Tanganyika) Limited at Uvinza being the largest producer. The other production came from coastal salt works and inland salt lakes and salt pans.

Mica production in the Uluguru Mountains was continued under British rule. From 1935 to 1942, production ranged between 10-35 tons a year, rising sharply in 1944 to 127 tons. Thereafter, the production varied between 45-100 tons annually.

During the British Administration era, exploration and mining were undertaken by private companies just as in German colonial times. The role of the Government was to regulate, monitor, promote and facilitate the private sector, particularly foreigners, in the exploitation of minerals.

POST INDEPENDENCE PERIOD (1961 – PRESENT)

The change of administration from British rule to national rule was accompanied by a change in economic policies. Most mines closed down: Geita Gold Mine (1966); Kiabakari (1966); Nyasenero (1970); Buhemba Mine (1970); Mara Mine (1970); Phoenix (1965); and Mukwamba Mine (1961) which was also affected by a fall in metal prices.

(a) Ujamaa and the Arusha Declaration (1967 – 1990)

In 1967, the Government launched the Ujamaa and the Arusha Declaration, a form of African Socialism and Self-Reliance policy stressing whole or partial public ownership of major means of production in the economy. The Policy led to nationalization of various economic ventures, including some mines (mostly gemstone mines). An exception was Williamson Diamonds Limited at Mwadui which continued to be a 50-50 % joint venture company between the Government and Wilcroft Company Limited, a subsidiary of De Beers.

Following mine closure, there was a sharp decline in mineral production figures with the exception of diamonds. Gold production dropped from around 3 tons in 1960 to 0.5 tons in 1968 and to 10 kg in 1970. Tin production decreased from 74 tons in 1972 to 2 tons in 1983, but this was also due to the effects of the Uganda-Tanzania War.

The new path of economic development led to the establishment of wholly Government-owned public corporations and companies such as the State Mining Corporation (STAMICO) in 1972. Enactment of a new Mining Act followed in 1979.

As a result of the Arusha Declaration, the Government assumed the role of owner, developer and operator of mines while, at the same time, maintaining the functions of a regulator, promoter and service provider. STAMICO depended on Government funding to undertake exploration and develop mines. This proved inadequate. However, STAMICO managed to commission the Minjingu Phosphate Mine in 1984 and the Chinese-assisted Kiwira Coal Mine in 1989. The country had widespread artisanal and small-scale mining activities particularly in gemstones and gold.

(b) Market Economic Era (1990 – Present)

From 1986, major economic reforms were undertaken by the Government which culminated in the enactment of the National Investment (Promotion and Protection Act), 1990, in favour of private sector investment in all sectors of the economy. A one-stop centre, the Investment Promotion Centre (IPC) was established. It was renamed the Tanzania Investment Centre (TIC) in 1997.

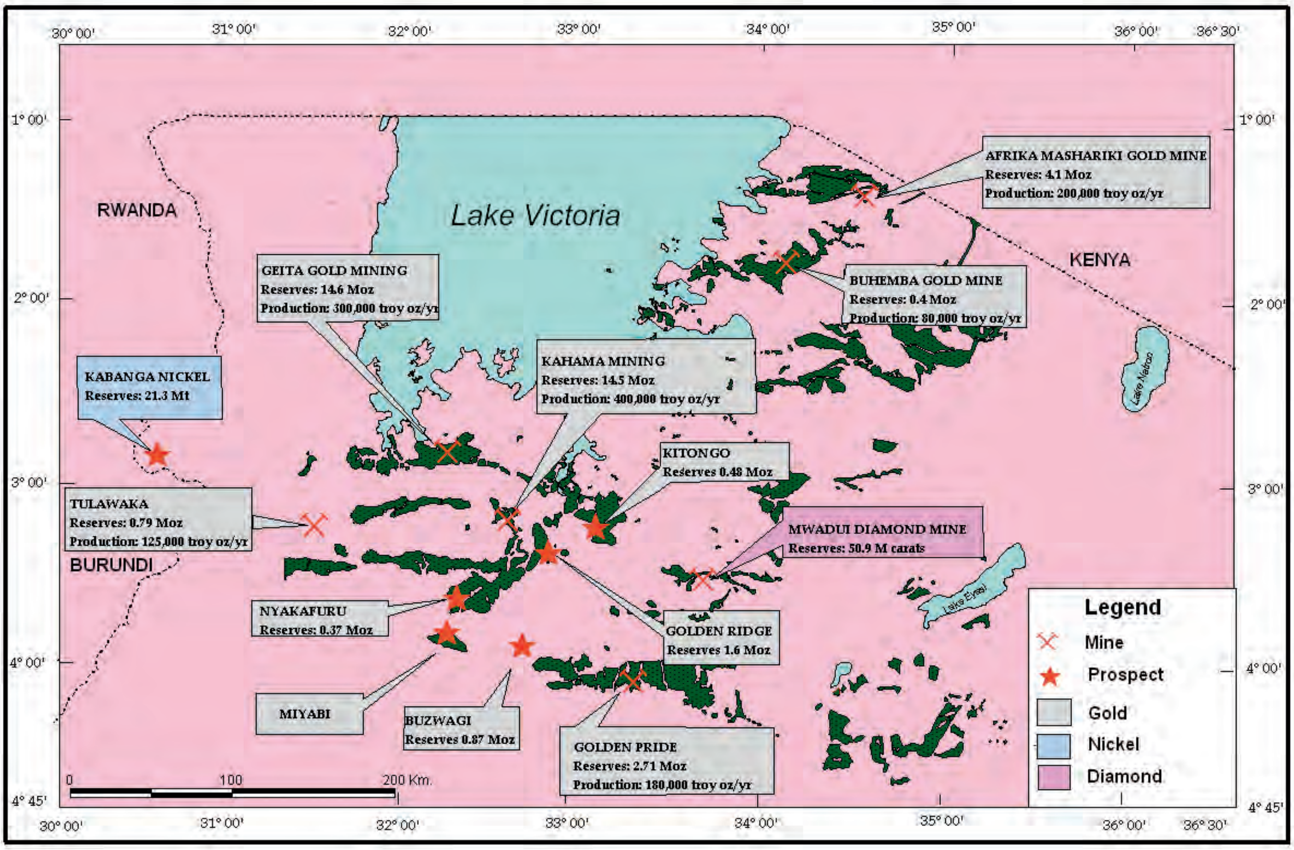


Figure 9: Mines and Prospects around the Lake Victoria Region.

With respect to mining, a new Minerals Policy was issued in 1997, with the key objective of attracting and enabling the private sector take the lead in exploration, mining, mine development, mineral beneficiation and marketing. The role of the Government is now to facilitate and regulate, with no mandatory state participation in mineral ventures.

In 1997, legislation on a targeted fiscal regime for the mining sector was passed by Parliament. The following year, a new Mining Act was enacted. These moves, coupled with the fact that Tanzania is a politically stable and peaceful country, has resulted in an unprecedented rush for mineral rights. Prospecting and mining licences increased from just nine (9) in 1990, to 250 in 2001, and over 4,590 by December 2006. Targeted minerals include gold, base metals, uranium, coal, platinum group metals and diamonds. Foreign exploration and mining companies, mostly from Australia, Canada, South Africa and Europe are now present in the country.

Over the past ten years, five gold mines have come into production. The first mine, the Golden Pride Mine, was inaugurated in November 1998. It is owned by an Australian company, Resolute Limited. The other mines that followed are: Geita Gold Mines owned by Anglogold Ashanti (August, 2000); and three mines belonging to Barrick Gold Corporation; the Bulyanhulu Mine (July, 2001); the North Mara Mine (September, 2002); and the Tulawaka Mine (June, 2005). The Tulawaka Mine, is jointly owned by Barrick Gold Corporation and Northern Mining Exploration, also a Canadian company. Another gold mine, the Buzwagi Mine, owned by Barrick Gold Corporation is under construction. Figure 9 shows current gold mines and their estimated resource.

The contribution of the mineral sector to the Gross Domestic Product (GDP) has, accordingly, been rising. It was 1.7 % in 1997, increasing to 3.5 % in 2005. The contribution of mineral exports to the country's total export values has also risen sharply from a mere 0.04 % in 1999 to 42.40 % in 2005. Total mineral exports were worth US-$ 720.42 million in 2005, with gold contributing 88.88 % from the export of 47.247 tons of gold worth US-$ 639.63 million.

In Tanzania, artisanal and small-scale miners constitute quite a substantial sub-sector, numbering about half a million people, according to some estimates. They are mostly involved in mining gold and gemstones, and in the production of salt and construction materials. The Government has committed itself to transforming and upgrading them through a range of measures including:

- facilitating the availability of affordable mining equipment and consumables;
- promoting partnership between them and large-scale investors for technology transfer and optimum resource exploitation; and
- providing expansion services and training in mining, mineral processing and marketing.

MINE SUPPORT SERVICES

Some services available in the country for the mining industry include:

- Geological, geophysical and geochemical services at Geological Survey of Tanzania (GST) in Dodoma.
- Analytical and assay services as well as mineralogical, petrological and gemological studies at GST laboratory in Dodoma.
- Geological and geophysical services from both the University of Dar es Salaam and from the Southern and Eastern African Mineral Centre (SEAMIC).
- Drilling services from the State Mining Corporation (STAMICO) and private contractors;
- High quality rock mechanics test facilities at the Southern and Eastern African Mineral Centre (SEAMIC) Headquarters in Dar es Salaam;
- Analytical and assay services at Southern and Eastern African Mineral Centre's (SEAMIC) laboratory and the University Dar es Salaam (Dar es Salaam) as well as SGS, Humac, and ANALABS in Mwanza;
- Geological consultancy services are available from individuals and institutions.

ENVIRONMENTAL PROTECTION

Environmental impacts associated with mining activities result from the extraction of mineral resources, the use of minerals, and the disposal mineral products. The amounts of metal extracted from one metric tonne of typical ores range from as much as 250 kg for iron ores to as little as 1 g for gold ores. The amounts of waste left for disposal are greater than the quantities of the metals extracted. The two primary means of solid mineral extraction are underground and surface mines. Liquid minerals, gas, oil and water are extracted by wells.

Mining activities have serious consequences for the environment – locally and globally. Environmental impacts associated with the extraction of mineral resources include:

- Destruction of natural habitats at the mining site and at waste disposal site.
- Destruction of adjacent habitats as a result of emissions and discharges.
- Adverse changes in river regime and ecology due to pollution, siltation and flow modification.
- Alteration of water tables.
- Soil contamination from treatment residues and spillage of chemicals.
- Changes in landform.
- Land degradation due to inadequate or non rehabilitation after mine closure.

The processing of metalliferous ores to extract metals creates large quantities of rock, and the smelting and refining of ores release large amounts of atmospheric pollutants. Notable pollution sources are:

- Drainage from mine sites, including acid mine drainage and discharge mine water.
- Sediment runoff from mining sites.
- Pollution resulting from mining operations in river beds.
- Effluents from mineral processing operations.
- Leaching of pollutants from tailings residues, disposal areas and contaminated soils.
- Air emissions from minerals processing activities.
- Dust emissions from sites close to residential areas and habitats.
- Oil and liquid spills.

IMPORTANCE OF ENVIRONMENTAL PROTECTION

Tanzania has achieved global fame for its spectacular flora, fauna and scenery. Approximately 16 % of Tanzania's land lies within National Parks, Game Reserves, and the Ngorongoro Conservation Area. These preserves include examples of all of Tanzania's diverse natural splendor, from rain forest in Gombe Stream National Park to desert in parts of the Serengeti, to alpine highland in the Kilimanjaro National Park, and to game-covered savannah in a number of preserves.

Fortunately long term provisions have been made for preserving this heritage through the establishment of preserves and by enactment of legislation. In addition to the preserves there are many Forest Reserves scattered about the country. These reserves were established in an attempt to reduce the deforestation problems. Mining is not allowed in National Parks or in Conservation areas. It is allowed only by written consent of the Authority for Game Reserves, when it can be demonstrated that a mining operation could operate for the overall benefit of the country.

The Mining Act, 1998, and the Environmental Management Act, 2004 require an environmental impact statement and Environmental Management Plan to accompany applications for Mining Licences. The National Environment Management Policy of 1983 covers environmental matters. A National Environment

Management Council has been established to regulate environmental management issues including those related to mining.

The most important environmental clauses spelt out in the in the Mining Act, 1998 include:

- Environmental Impact Assessment (EIA)
- Environmental Management Plan (EMP)
- Mine Restoration Bonds.

INDUSTRIAL MINERALS IN TANZANIA

DEFINITION

An industrial mineral according to the *Glossary of Geology*: “is any rock, mineral, or other naturally occurring substance of economic value, exclusive of metallic ores, mineral fuels, and gemstones; one of the non-metallics.”
An even shorter definition is: Industrial minerals are non-metallic and non-fossil fuel rocks, minerals, and sediments that have an industrial use.
Probably most geologists and engineers would accept these simple and straightforward definitions, at least as a general statement.

On analysis, however, at least one anomaly crops up, i.e., what is metallic and what is non-metallic? Bauxite and ilmenite, an important heavy mineral, certainly qualify as metallic ores, but both are also raw materials of important non-metallic substances; hence they are included in this brochure. The same is true for rare earths. All the individual rare earths elements are metals but most of them, at least by weight, are used in the glass industry. Hence rare earths are also called industrial minerals and are described in this publication.

Gemstones, however, which normally are also counted among industrial minerals and rocks, will not be included in this study. The reason for this is the extreme wealth of Tanzania in a variety of gemstones making it one of the countries richest in gemstones in the world. No comprehensive report on this natural wealth of Tanzania has yet been written but it ought to be at least as voluminous as this investor’ s guide.

USES

Industrial minerals are the workhorses of our world. Without them, life as we know it today would simply stop.
Let us just take a soft drink bottle as an example. For the production of the glass you need silica sand, soda, lime, dolomite and feldspar as basic components. The melting furnace needs to be cladded with refractory bricks, which can be made out of sinter magnesia – made from magnesite – or alumina-zirconia-silica – made from bauxite-zircon-quartz. The melting furnace will be made out of steel. For the production of steel, however, you do not only need iron ore and coal but also fluxes, the most important being fluorite. We do not know all the ingredients of the soft drink but at least the water used has to be purified e.g. by using diatomite. The bubbling gas is carbon dioxide, which is a natural gas. The boxes where the bottles are transported are made out of plastic. This is a petroleum product. For drilling for oil and gas, however, you need a heavy fluid with high viscosity. This is produced by using barite and bentonite. Now you have the soft drink in the bottle in the transport box. Because you do not want to go to the factory to get your soft drink, it has to be brought to your favourite shop or bar. The most convenient way to do so is by truck. Well, now you might think, that the truck is made out of steel plates and rubber for the tyres only. But how about the windows and the headlights, which are made out of special glass again. And your truck should have brakes with brake linings made out of graphite. For welding steel plates you need welding rods, which are made out of rutile, which is a heavy mineral. Okay but now you finally have the

soft drink in your favourite bar. Its walls will be made out of bricks. Did they use clay bricks, lime sand bricks or lightweight concrete blocks made out of cement and pumice? Most probably you will not be able to find out because the walls are painted. The paint is made out of water, ground calcium carbonate, fillers, like scrap mica or talc, clay minerals, and titanium dioxide, produced from ilmenite, to guarantee the best white colour. Enjoy your drink – in a developing world which needs industrial minerals and rocks everywhere.
By the way: this brochure itself could not have been produced without the extensive use of various industrial minerals.

Because the uses of industrial minerals and rocks are numerous and are growing every day, only the most important applications are mentioned at the beginning of each commodity chapter. Most potential investors in the industrial minerals of Tanzania will know what they can use each commodity for. Potential investors, who do not know and are just looking for a suitable investment, should get very familiar with their mineral of choice, or they might miss a very important niche in the market.

ECONOMIC IMPORTANCE OF INDUSTRIAL MINERALS IN TANZANIA

The occurrences of industrial minerals and rocks in Tanzania are numerous and abundant. The variety of minerals for construction purposes, for improvement of soil and for use as fertilizer is particularly manifold. These minerals are the ones of most importance for the development of Tanzania in the near future. However, there are other industrial minerals which are more suitable for export because beneficiation is highly complicated and therefore extremely expensive. Also because of quality or quantity restrictions not all of the deposits of industrial minerals mentioned in the text can compete with deposits of the same minerals in neighbouring and more distant countries. For this reason and to give both the interested reader and the potential investor a general overview of the industrial mineral potential of Tanzania the following list has been prepared.

Important deposits of industrial minerals in Tanzania mainly for export

- Merelani graphite deposit (no production of graphite)
- Longido anyolite deposit (in production)
- Lewale blue marble deposit (no production)
- Various other dimension stone deposits (some in production)

Possible important deposits of industrial minerals in Tanzania which need more investigation but might be suitable mainly for export

- Wigu Hill rare earths deposit (no production)
- Nyarumba Mountain garnet deposit (no production)
- Tambi garnet deposit (no production)
- Ndololo graphite deposit (no production)
- Lossogonoi and Dudumera anyolite deposits (no production)
- Bahi Swamp salt brine (no production)
- Lake Balangida salt brine (no production)
- Mother liquors of coastal solar salt production (no production)
- Various mica deposits (no production)

Deposits of industrial minerals in Tanzania of relevance not only for Tanzanian industries but also suitable for export to neighbouring countries

- Sengeri fluorite deposit (no production)
- Lindi-Kilwa rock gypsum deposit (no production)
- Pugu Hills kaolin/silica sand deposit (no production)
- Minjingu phosphate deposit (in production)

Deposits of industrial minerals in Tanzania of relevance for Tanzanian industries

- Itigi gypsum deposit (in production)
- Makanya gypsum deposit (in production)
- Msagali gypsum deposit (in production)
- Mkomazi gypsum deposit (in production)
- Chimala kaolin deposit (no production)
- Malangali kaolin deposit (no production)
- West Mount Meru pumice deposit (small-scale production)
- Holili pumice deposit (in production)
- Rungwe pumice deposit (no production)
- Scrap mica from tailings of old mica workings (no production)
- Various dolomite deposits for many uses (no production)
- Various limestone deposits for cement production (in production)
- Various limestone deposits for production of GCC (no production)
- Various feldspar and nepheline syenite deposits for many uses (no production)

Deposits of industrial minerals in Tanzania of relevance for local production of fertilizers or soil improvement

- Msagali mbuga soft dolomitic limestone deposit (no production)
- Sagara mbuga soft dolomitic limestone deposit (no production)
- Lashaine forsterite deposit (no production)
- Shingo Hill zeolite deposit (no production)
- Mapogoro zeolite deposit (no production)
- Various magnesite deposits (no production)

Other deposits of industrial minerals in Tanzania of relevance

- Various soapstone deposits for production of sculptures for sale to tourists (no production)

ABRASIVES, NATURAL

GENERAL INFORMATION AND USES

Natural abrasives cover a group of minerals, which can be used for sand-blasting, water-jet cutting, sanding, or polishing of other (softer) minerals or products. These minerals are feldspar, magnetite, olivine, staurolite, ilmenite, perlite, silica sand, limestone, dolomite, garnet, and corundum, with garnet the most important one. Corundum, chemical formula Al_2O_3, is also in high demand, but natural corundum is now always substituted by synthetic corundum, which in general is of better quality and cheaper to produce. Alluvial garnet/corundum from placer deposits should be distinguished from crushed garnet/corundum from hard-rock deposits although the quality of the final products will be the same.

RELEVANT OCCURRENCES IN TANZANIA

While **corundum** deposits are limited worldwide, numerous small deposits have been mentioned in Tanzania because corundum is a typically metamorphic mineral and most of Tanzania is made up of metamorphic rocks. Corundum was mined in Tanzania between 1943 and 1944. Very detailed information on the various deposits is available from reports on file in the GST archives.

- Corundum was first described from an east-west trending belt south of Dodoma, which contains four separate deposits. These deposits are at Gobi Hill (6° 15’ S, 35° 44’ E), Ilende Hill at Matumbulu (6° 15’ S, 35⁰ 47’ E), Panangwali Hill (6° 15’ S, 35° 51.5’ E), and Malamo Hill (6° 15’ S, 35⁰ 57’ E). Some 13 tons of corundum were taken out from Ilende Hill with even smaller amounts mined from Malamo Hill which is now worked out. Corundum occurs as purplish-brown crystals surrounded by a “shell” of green micaceous material of variable thickness. The thickness of the corundum “eggs” varies between 1 and 25 cm. The corundum at Ilende Hill contains 1.7 wt.-% Fe_2O_3.
- A fifth occurrence is situated at the eastern end of the Mlali Hills, 50 km by road east of Kongwa and 53 km from Mpwapwa (6° 29’ S, 36° 45’ E). This is a small deposit of pink and brittle corundum crystals with rutile inclusions in fine-grained biotite-gneiss. The corundum contains between 1.9 and 2.3 wt.-% Fe_2O_3. Resources are given with only 250 tons of recoverable crushed and 30 tons of alluvial corundum.
- Another corundum deposit in the Dodoma District was situated some 4 km SE of Mleha Hill and about 22 km east of Itiso. Most of this deposit was worked out during World War II.
- Good alluvial corundum is also said to originate from Nohiri Hill, 25 km west of Keza, Biharamulo District, Kagera Region, but no details or reserve figures are known.
- Around 600 tons of corundum was mined from surface soils in 1962/63 and 1965/66 at Matale north of Mvomero in Mvomero District. No other information is given on this deposit.

Garnet, which is also a typical metamorphic mineral, has been reported from many places from nearly all over Tanzania.
The most important occurrence is at Namaputa (11° 4.372’ S, 38° 57.442’ E), in the most southern Masasi District of Mtwara Region.
In this area garnet was mined at several locations between 1896 and 1911 and again with interruptions since 1927. Here garnet occurs as beautiful large red crystals of pyrope-rich almandine in highly weathered gneiss. This garnet, of which most is gem-quality, was originally mined only for the production of jewellery in Imperial Germany and the British Empire. After being tested favourably for the use as an abrasive in 1955 more than 400 tons were exported to England from 1956 to 1959. Only a few hundred tons of garnet are said to remain in place, which currently are still being mined

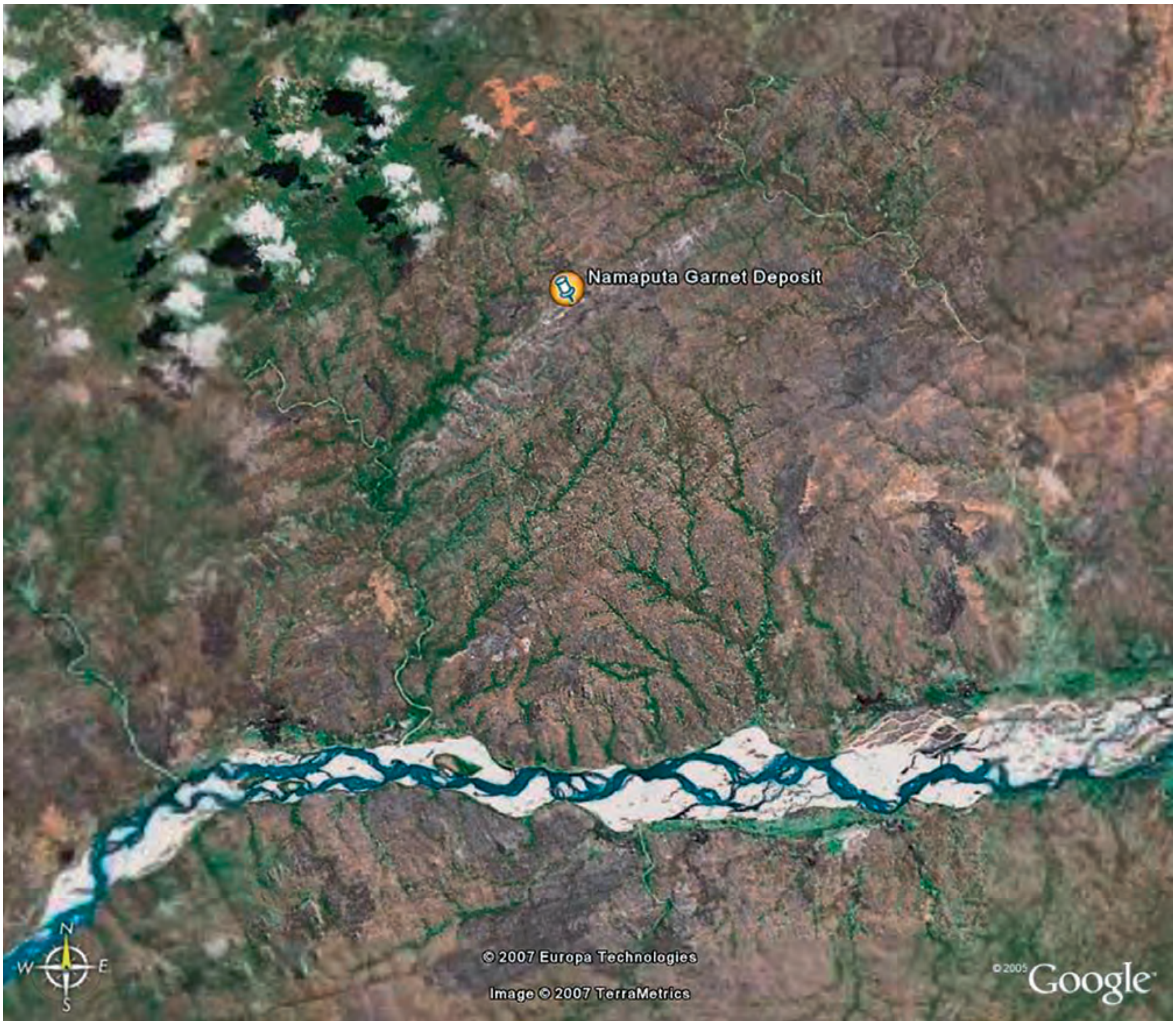


Figure 10: Satellite image of southernmost Mtwara Region with the Namaputa garnet deposit just a few km north of the Ruvuma River, which forms the border to Mozambique (Photo courtesy of Google Earth).

by a few dozen small-scale miners. Although there are some tailings of garnet of non-gem quality and although there is hardly any more interest from customers in red garnet at all, local small-scale miners are not interested in producing garnet for the abrasive market.

Other deposits of garnet in Tanzania are:

- Nambunju Mine in Lindi District. There is an old mine (9° 47' S, 38° 56' E) situated a few km south of the Mbemkuru River at a point 88 km from its mouth. During the period from 1920 to 1925, several tons of garnet was taken out from a quarry with a shaft, which is said to have reached down to 30 m. The garnet was sold as semi-precious stones, with the mine now worked out.
- Lolobukoi (4° 3' 35" S, 37° 35.5' E), about 13 km west of Same in Pare Mountains. Here a thin layer of garnetiferous soil and gravel overlies very hard garnetiferous gneiss. Resources are estimated to be 13,500 tons of alluvial garnet. However, the material tested contained too many impurities to be acceptable as abrasives. The same applies to Ngaragahashi 6.5 km north of Lolobukoi.

Figure 11: Highly weathered gneiss containing garnet at Namaputa.

- Kichaa Hill, 11 km SW of Same, consists of garnet-hornblende gneiss with sandy garnet-bearing soils evenly distributed around the base of the hill. The garnets are of fair size and good quality but the sand deposit is less than 30 cm thick. It contains very low percentages of garnet and so resources are estimated to be rather small, may be 100 tons.
- At Buiko, approximately 24 km SW of Mkomazi also in Pare Mountains, there is a garnet-rich eluvial layer overlying garnetiferous schist. Only 700 tons of garnet could be mined by small-scale miners from this place.

- Sangaruma (4° 49' S, 38° 1.5 ' E), which is on the west bank of the Pangani River, 19 km south of Buiko on the Tanga Railway line. Here garnet occurs in three ways: as masses of garnet rock; as pea-sized garnets scattered through a 3 m thick schist layer of undetermined extent; and as eluvial garnet in the soil overlying the garnetiferous schist. No exhaustive survey has been made but it has been estimated that at least 20 kt of garnetiferous schist, in which there is 45 % recoverable garnet, underlie the eluvial ground, which itself should yield nearly 1.5 kt.
- Garnet deposits also occur on Nyarumba Mountain (7° S, 36° 18' E), approximately 10 km south of Rudi Village in Mpwapwa District of Dodoma Region. This mountain area measuring 4.0 km x 1.5 km consists of massive dark greenish grey eclogite containing between 20 and 35 % garnet with an average diameter of 1.5 mm. Stream beds draining the east side of the hill, where the garnet content in the eclogite reaches 50 %, contain sands of almost pure garnet. Sand resources have been estimated to be at least 10 kt. There is also an estimated 10 million tons of garnetiferous soil and overburden containing 15 vol.-% garnet. This weathered garnet, however, was tested and was found not to be suitable for blasting as it pulverizes too rapidly and has a low hardness of only 6.
- Garnet-rich rock is developed 5 km north of Tambi, 50 km east-SE of Mpwapwa in Dodoma Region in skarns formed by the metamorphism of an impure limestone. Many residual blocks of almost pure garnet rock can be seen around the hillside, but as no test pits were dug nothing is known about the size of this hard-rock deposit.
- Pyrope garnets are said to occur at Chanika Village which can be reached from Mvomero or Berega, Morogoro Region. No more information is available.
- Almandine garnets and corundum were reported to occur at Kisitwi and Mamhondu in Kilosa District on Kimolo-Virundiro ridge (6° 15' S, 36° 56' E). The garnets occur in migmatitic biotite gneisses associated with kyanites and mica pegmatites.
- In Uluguru Mountains, where there are many outcrops of garnetiferous rocks, only two occurrences of alluvial garnet have been recorded. One occurrence is near Hundusi in Mkengere Valley. In the very remote Mbakana Valley north of Kikese, there is an extensive deposit of eluvial soil which contains about 75 vol.-% garnet. The main impurity is quartz which could easily be removed during dressing.

In Tanzania no beach sands rich in garnet are known (see: Heavy Minerals).

REQUIREMENTS AND EVALUATION

For use as a natural abrasive garnet (and corundum) have to be very clean, coarse, uniform, and unweathered. Mineral grains must be uncoated, may not have inclusions and must have a very low radioactivity (<500 ppm U+Th). Dressed concentrates need to have a very narrow grain size curve and may not contain too much free quartz (<1 %) or soluble chlorides (<25 ppm). Placer/hard-rock deposits should have reserves of at least 1 million tons of useable minerals with transportation costs to the nearest harbour also being of great importance. Because the reserves in Tanzania are much smaller than these specifications natural abrasives in general are of no interest to Tanzania. However, as there is always an exception to a rule, potential investors might focus on some deposits and questions:

– How many bags of exceptionally coarse and high-quality garnet from Namaputa (tailings) may be produced and what are the costs to transport them to Mtwara harbour?
– What are the real reserves and qualities of garnet (alluvial and hard-rock) at Sangaruma?
– What are the real reserves and qualities of garnet at Tambi?

RELEVANT LITERATURE

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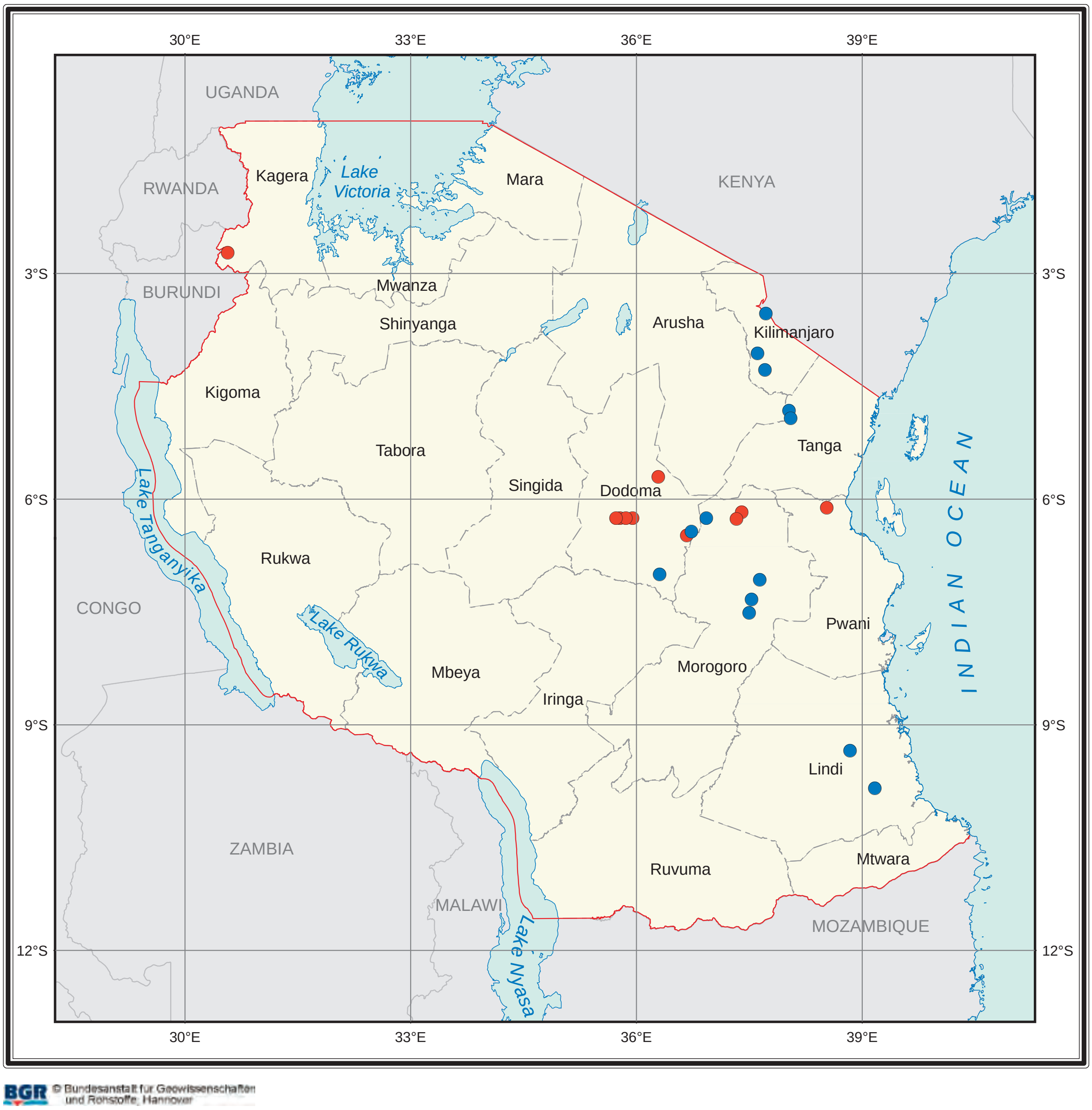
Williams, W.R. (1954): The garnet deposits at Nyarumba Mountain in the district of Mpwapwa.- Geol. Surv. Tanganyika , Rep., WRW/10: 8 pp., 2 maps, 7 app.; Dodoma (unpublished).

Whiitingham, J.K. (1953): A Survey of the corundum deposits in Central Province, Tanganyika Territory.- Geol. Surv. Tanganyika, Rep., JKW/7: 25 pp., 6 fig., 1 map; Dodoma (unpublished).

Occurrences of Natural Abrasives in Tanzania



Scale 1 : 10,000,000

0 100 200 300 400 500 km

Legend

- Corundum
- Garnet

ASBESTOS

GENERAL INFORMATION AND USES

Asbestos is a collective term for fibrous minerals, some belonging to the serpentine group (serpentine, chrysotile), others to the amphibole group (crocydolite, anthophyllite, amosite, tremolite, actinolite) of minerals. Asbestos is non-flammable, flexible, acid-resistant, and possesses high tensile strength in one direction. For these reasons asbestos was used extensively in earlier decades in all kinds of building materials, and in brake linings. It was then realised that asbestos fibres are all highly toxic, causing pulmonary damage and cancer even after short exposure and at low dose rates. Because only chrysotile does not persist in the lungs after inhalation chrysotile is the only asbestos fibre still commercially exploited, but only for very special applications like chrysotile cement.

RELEVANT OCCURRENCES IN TANZANIA

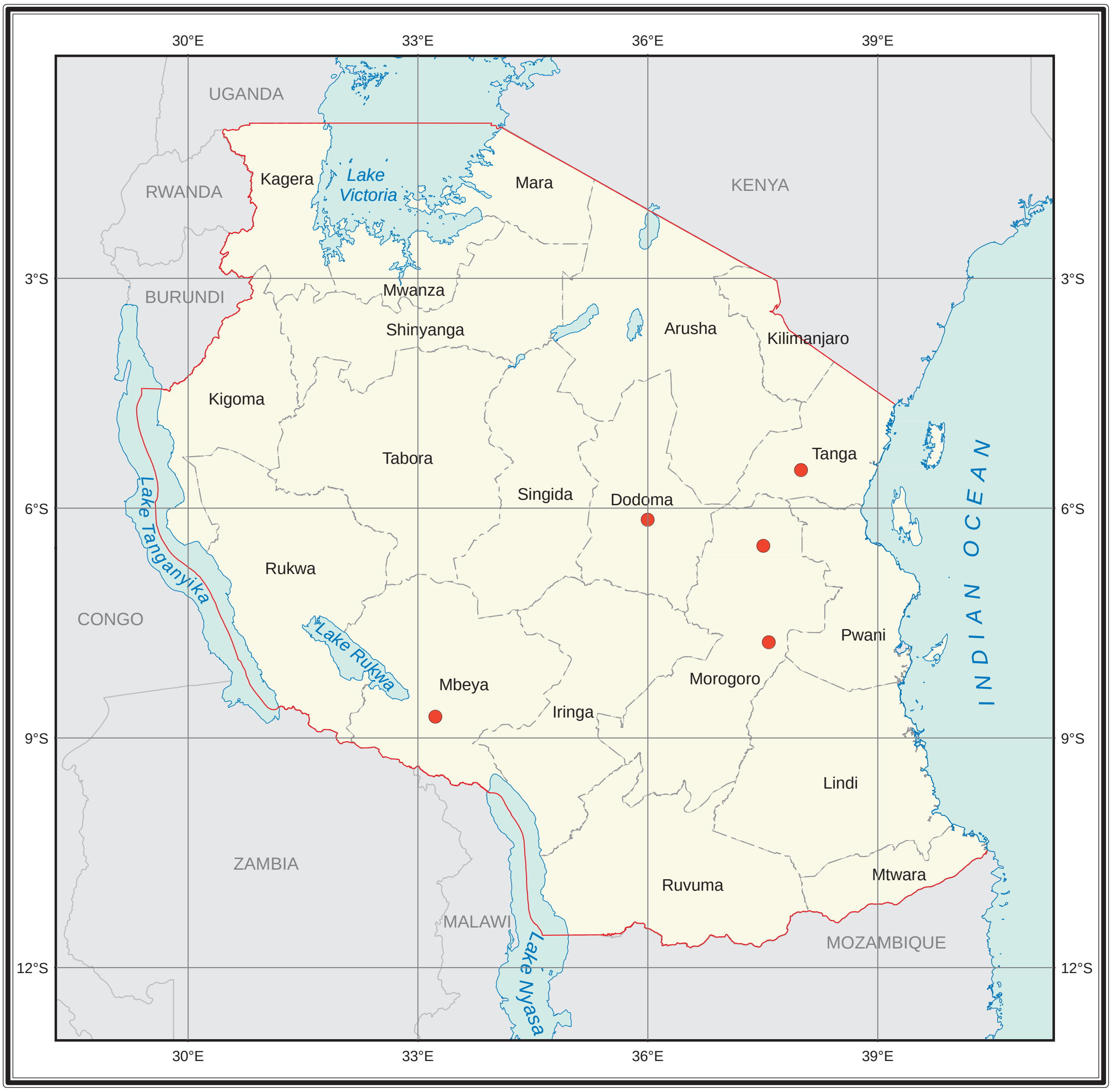
Reports on natural occurrences of asbestos in Tanzania are numerous. Only those where chrysotile asbestos were analysed are given below:

- SW of Kilosa near Buga in the Usagara Mountains chrysotile can be found in reddish loam of a decayed serpentine with fibres up to 12 cm length. The quantity available is said to be poor.
- Good fibre chrysotile comes from Magamaba in the Handeni District, possibly from Msoto Hill.
- Chrysotile is said to occur on Kikaza Hill 1.5 km from Kikombo.
- Chrysotile was reported from a hill near Lock's Nsamya Reef in Lupa Goldfields.
- Chrysotile was also found at the north pier of the Mikese-Kisaki road bridge over the Ruvu River.
- Possible chrysotile veins at Mwahanza north of Dodoma were later shown to be anthophyllite.

EVALUATION

In contrast to earlier decades asbestos is no longer a commodity of broad interest. Because the deposits of chrysotile asbestos are also rare and small in Tanzania, potential investors would be wise, not to waste their valuable money on this industrial mineral.

Occurrences of Asbestos in Tanzania



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● Asbestos

BARITE

GENERAL INFORMATION AND USES

Barite, i.e. barium sulphate ($BaSO_4$), which mostly is mostly used to increase the density in drilling fluids but also as a filler in paint and paper or for the production of heavy-weight concrete, is not a very common mineral in Tanzania.

RELEVANT OCCURRENCES IN TANZANIA

Barite generally occurs as a gangue mineral with quartz, galena and other carbonates (e.g. siderite) in a number of the mineralized gold and base metal veins in the Western Rift zone of Tanzania, especially in the Lupa Goldfield and SE of the Mpanda Goldfield. It has also been reported from the Musoma Goldfield.
Veins containing barite are said to be up to 10 to 20 cm wide and up to 10 m long. Another mode of occurrence is in sedimentary rocks, e.g. as veinlets in dolomitic limestones in the Kigoma and Handeni (Lukinguru River) areas, and as nodules (up to 15 cm in diameter) in certain Karoo sandstones in the Katewaka Coalfield of SW Tanzania.

Barite also forms as an accessory mineral in carbonatites, e.g. in Nguala carbonatite, and in Wigu Hill carbonatite. Just recently a discovery of barite dykes each about one metre thick was reported from a hill neighbouring the Sengeri fluorite deposit (see Fluorite).

EVALUATION

None of the aforementioned occurrences has ever been sampled or looked at in detail. This means that nothing is known about the quality of the barites in Tanzania. Because resources seem to be very limited, only small-scale mining in high-grade areas may bring satisfactory, but limited results. The Sengeri barite deposit, however, might be suitable for commercial scale mining together with the Sengeri fluorite deposit.

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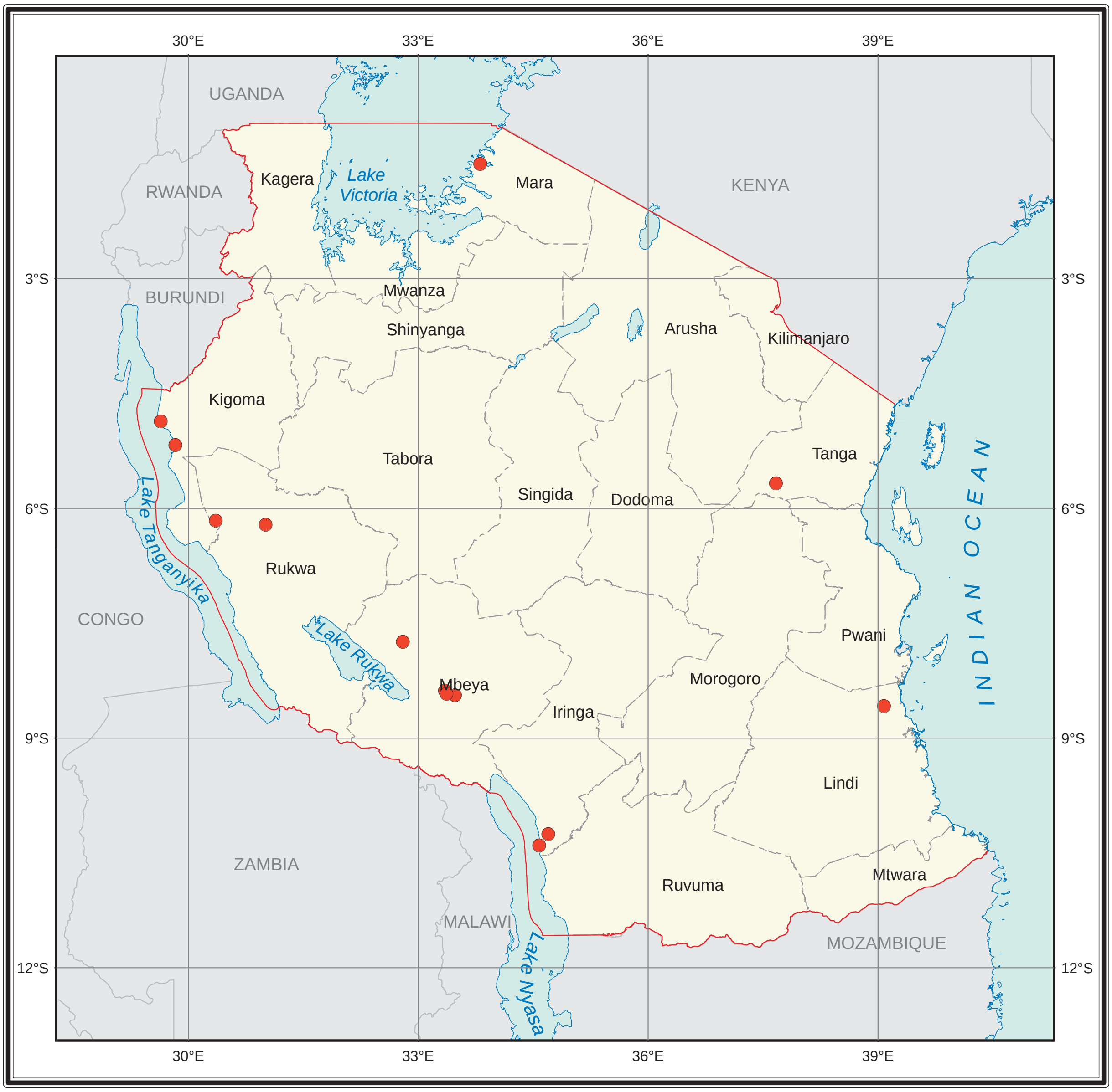
Occurrences of Barite in Tanzania



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● Barite

BAUXITE

GENERAL INFORMATION AND USES

Bauxite is a mixture of hydrated aluminium oxides. It is most favourably formed under near surface conditions in humid rain forests in tropical and sub-tropical regions. More than 90 % of the bauxite mined in the world is used for the production of aluminium metal. Important non-metallic applications are in the refractory and ceramic industries, and in the production of abrasives, chemicals and flame retardants. It also should be mentioned that laterite, an Fe_2O_3-rich and Al_2O_3-rich soil, is a valuable building material (road construction, civil and structural engineering), as it hardens extremely and irreversibly when aerated.

RELEVANT OCCURRENCES IN TANZANIA

In Tanzania, bauxitic material is reported from Amani (38° 38´E, 5° 05`S) and west of Mombo towards the Lwengera Valley in the Usambara Mountains. The topography of Amani is that of an undulating morphology at some 1,000 m a.s.l. dissected in some places by perennial streams and run-off from heavy rains. Both occurrences, Amani and Mombo, consist of numerous, light-coloured, irregular, concretionary nodules distributed through the reddish, somewhat lateritic soil and subsoil.
High-alumina clays, though of kaolinitic rather than bauxitic composition, also occur in the western part of the Uluguru Mountains. It is not known whether bauxite residues may be found under the soil-cover of the high forested plateau of the central Uluguru Mountains, where parts of old erosion surfaces are preserved.

With respect to alumina only the bauxite nodules from Amani have values approaching those of commercial ores (40 - 60 wt.-% Al_2O_3). A very high-grade nodule from Amani even contained nearly pure gibbsite [α-Al(OH)$_3$] with a chemistry of 66.9 wt.-% Al_2O_3, some 5 wt.-% SiO_2, and only very little Fe_2O_3. Low-grade nodules, on the other hand, contain only 20-30 wt.-% Al_2O_3, and 2-15 wt.-% Fe_2O_3. The average content of alumina in bulk samples (nodules and clay) was found to be some 26 wt.-%.

Table 1: Chemical analysis (data in wt.-%) of bauxitic material from the Usambara and the Uluguru Mountains (after Bassett & James 1951 and other authors).

	Amani nodules	Mombo nodules (1)	Mombo nodules (2)	Western Uluguru Mountains
Al_2O_3	57.72	35.14	33.04	34.2
SiO_2	10.53	26.35	43.80	39.3
Fe_2O_3	1.15	7.40	0.72	7.2
TiO_2	1.66	1.54	0.83	1.0
H_2O	26.80	22.49	16.97	18.4
total	*97.86*	*93.92*	*95.36*	*100.1*

REQUIREMENTS AND EVALUATION

In general the silica content is rather high in all locations; for bauxite ore it should be less than 8 wt.-%, and ideally less than 4 wt.-%.

High silica contents and the low average alumina contents prove that the bauxitic material from the Usambara Highlands, i.e. from Amani and Mombo, is uneconomic. The chances of finding economic resources of high-grade bauxite in the Uluguru Mountains also seem to be relatively low. However, both the bauxitic-lateritic soils from the Usambara and from the Uluguru Mountains, and possibly also from other places in Tanzania should be suitable for use as a base-layer of tarmac roads. Mixed with quick-lime and a little water, it might also be used for the production of building blocks.

RELEVANT LITERATURE

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Occurrences of Bauxite in Tanzania

Scale 1 : 10,000,000

0 100 200 300 400 500 km

Legend

● Bauxite

BENTONITE AND SEPIOLITE

GENERAL INFORMATION AND USES

Bentonite (in the UK also known as fuller's earth) is a sediment with a high proportion of smectite-group clay minerals. The physical properties (namely the swelling properties) and the chemical absorption behaviours of bentonites are dominated by montmorillonite, the most prominent mineral in the smectite mineral group. Two major types of bentonite can be distinguished, swelling bentonite with high amounts of sodium and non-swelling bentonite enriched in calcium.

Due to its unique properties, bentonite can be used in numerous applications, e.g. for the production of adsorbing materials like cat litter, purification of vegetable oil and other liquids, in ceramics, cosmetics, pyrotechnics and many others. Bentonite is also part of some disposal systems for high-level radioactive waste and is extensively used in drilling muds.

RELEVANT OCCURRENCES IN TANZANIA

In Tanzania, bentonite is said to occur in a deposit at Oldinyo Gelai in the north-western part of the Arusha District. Resources are given as some 300 kt of which 200 kt are said to be high quality bentonite. Here, bentonite occurs close to a magnesite deposit. At Oldinyo Gelai the chemical composition of this special clay varies considerably (see table 3) which makes it necessary to carry out detailed geochemical exploration. This might be the deposit which was mined by Industrial Minerals Ltd. for bentonite in the late 1950's.

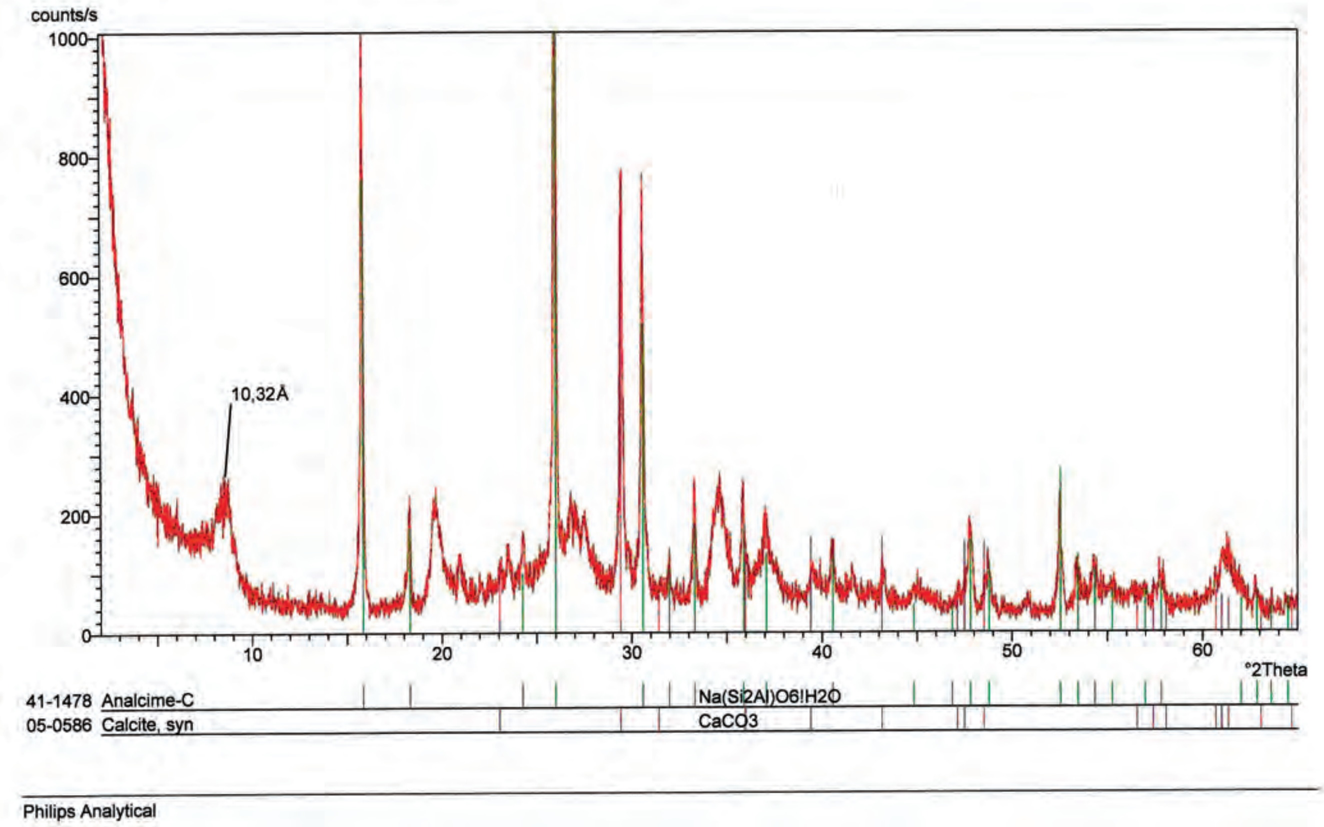

Figure 12: X-ray diffraction diagram of possible bentonite from Minjingu (BGR analysis), with many components being calcite and analcime. There is only a small hint of the presence of smectite (peak at 10.32 Å), but definitely less than 50 vol.-%.

Other areas where bentonite might be found in Tanzania are the Minjungu phosphate deposit and at Sinya.

At Minjingu greenish smectite-bearing clay occurs as an overburden in the phosphate opencast mine as a result of devitrifiation of acidic volcanic ashes. Here three samples were taken and analysed by BGR using spectroscopic and conventional x-ray diffraction methods. Only one sample of bentonite contains around 25 wt.-% smectite, which is a rather low value. The ion exchange capacity was checked using the Cu-method (VIS-spectroscopy). The total exchange capacity was defined as 24 meq/100 g. However, more samples should be tested before rejecting the possibility of a real bentonite deposit existing there. If bentonite is actually confirmed, reserves might be rather large.

The Sinya bentonite deposit straddles the Kenyan – Tanzanian border at Lake Amboseli (2° 43' S, 37° 03'E). Here the presumed bentonite, more often described as green thixotropic clay, occurs on top of the sepiolite/meerschaum layer (see table 2). However, no mineralogical analysis is available yet.

The clay mineral **sepiolite** occurs as a very light (specific gravity 0.988 to 1.279 g/cm^3) opaque mineral. The low values are due to its high porosity: it will float on water. Sepiolite is very fragile especially when fresh. When fresh, it feels greasy and really soft. Warmed or exposed to the sun it hardens out and is then also called meerschaum (see Stones, Ornamental). Because it has a hardness of only 2 to 2 $^1/_2$, it can be easily scratched by a fingernail or carved. In contact with water, sepiolite immediately foams, hence it was used as a soap by the ancient Greeks.

Sepiolite in its soft form is used for the production of waste absorbent materials, and catalysts, as a filler in paints, as a binder for molecular sieves, as a decolorizing agent for vegetable and mineral oils, as a drilling fluids for geothermal wells, and as a free flow agent in agricultural pesticide manufacture. Due to its large surface area sepiolite can also be used as a non-specific anti-diarrhoeic.

In this context, the deposits of the Amboseli Basin of Tanzania and Kenya near Lake Amboseli are of major interest. Here most of the Sinya Beds (see table 2) consist of limestone and dolomite and Mg-rich clays that are intensely deformed. These sediments were deposited in a semiarid lacustrine basin at the foot of Mount Kilimanjaro. Sepiolite and other mixed-layered clays (kerolite/stevensite) are subordinate constituents of the carbonate rocks. Clay minerals also form veins, and fill cavities in the Sinya Beds.

Table 2: Stratigraphic succession at Sinya (Sampson 1963):

Lithology	Maximum thickness observed (m)	Correlation
Impure limestones and marls	3.6	Ol Tukai Beds
--------------------Unconformity--------------------		
Green thixotropic clays (B2)	2.1	Lake Amboseli clays
Limestone conglomerate	0.2	
--------------------Unconformity--------------------		
Green thixotropic mudstones (B1)	2.1	
--------------------Unconformity--------------------		
Sepiolitic mudstones and limestones (S)	2.4	Sinya Beds
Dolomitic lacustrine limestones (L)	7.2	

Table 3: Typical chemical composition (data in wt.-%) of Tanzanian bentonites.

Locality	Minjingu					Oldinyo Gelai	
Sample #	01	X/10328/2	0611563	0611564	0611565	3	6
Ref.	Mutakyahwa (2002)	Cilek (1971)	BGR (2005)			Eastern and Southern African Mineral Resources Development Centre (1983)	
SiO_2	50.94	50.80	56.88	62.71	42.46	54.81	49.48
TiO_2	0.98	1.12	0.56	0.94	1.747	0.09	0.09
Al_2O_3	11.56	14.39	11.15	13.13	10.47	0.48	0.64
Fe_2O_3	7.09	6.98	6.06	5.99	9.70	0.13	0.16
FeO	n.d.	0.49	n.d.	n.d.	n.d.	0.20	0.13
MnO	0.11	0.08	0.15	0.09	0.17	LLD	LLD
MgO	7.43	8.00	1.33	1.76	4.76	27.58	27.95
CaO	1.80	7.91	2.32	1.36	9.24	2.56	4.14
Na_2O	2.34	0.77	3.97	3.83	7.05	3.31	3.97
K_2O	6.15	1.04	4.16	3.72	1.68	0.13	0.24
P_2O_5	0.07	1.85	0.05	0.12	0.34	0.03	0.03
LOI.	n.d.	6.89	13.00	6.08	11.62	8.27*	10.1
H_2O^+	6.57	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
H_2O^-	4.71	n.d.	n.d.	n.d.	n.d.	4.32	5.28
total	99.68	100.32	99.79	99.72	99.59	93.64	102.21
IEC	n.d.	n.d.	11.3	9.50	15.7	n.d.	n.d.

Note: LOI* = sum of Cl, F, SO_3 + CO_3; IEC – Ion exchange capacity [meq/100g $cmol_c$kg-1].

Table 4: Typical chemical composition (data in wt.-%) of sepiolite.

Locality	Amboseli Basin			
	Sinya Mine	Kenya		Tanzania
Lithology (sample #)	Meerschaum (X77696/2)	Massive white sepiolite (# 1)	Massive green sepiolite (# 6)	Amboseli clay (# 7)
Reference	Sampson (1963)	Stossell & Hay (1978)		
SiO_2	52.51	53.70	53.17	47.65
TiO_2	0.13	0.12	0.17	0.11
Al_2O_3	0.87	1.15	1.76	2.53
Fe_2O_3	0.45	0.64	0.99	0.47
FeO	0.40	0.02	0.04	0.10
MnO	0.01	0.00	0.01	0.00
MgO	22.49	23.31	24.70	22.88
CaO	0.81	0.03	0.23	1.83
Na_2O	0.65	0.67	0.45	0.82
K_2O	0.65	0.61	0.97	0.61
P_2O_5	0.04	0.02	0.04	0.10
H_2O^+ + CO_2	n.d.	9.83	8.29	11.19
H_2O^-	12.01	9.76	8.79	11.49
LOI	9.48	n.d.	n.d.	n.d.
Total	100.50	99.86	99.61	99.78

REQUIREMENTS AND EVALUATION

For industrial use, bentonite should contain 70 to 80 wt-% smectite with <80 wt-% <2 µm grain size. The minimum thickness of bentonite deposits should be >50 cm with reserves preferred to exceed 100 kt.

Due to the high amounts of magnesium in all tested Tanzanian bentonites, all of them seem to be of low quality. Therefore, local bentonites can only be used for limited applications, e.g. as fertilizers or soil conditioners. More specialized applications will require purification processes.

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Occurrences of Bentonite and Sepiolite in Tanzania

Scale 1 : 10,000,000

0 100 200 300 400 500 km

Legend

- Bentonite
- Meerschaum

BERYL

GENERAL INFORMATION AND USES

Beryl is an important gemstone, with its varieties called emerald (green, Lake Manyara deposit), aquamarine (blue), heliodor (yellow-green), chrysoberyl (light yellow-green), morganite (pink), and golden beryl (bright yellow). It is also one of the two commercial ores of beryllium metal, which, among others, is used in the nuclear industry and in high-tech alloys (especially with copper) in the electric, aeronautic, and aerospace industries.

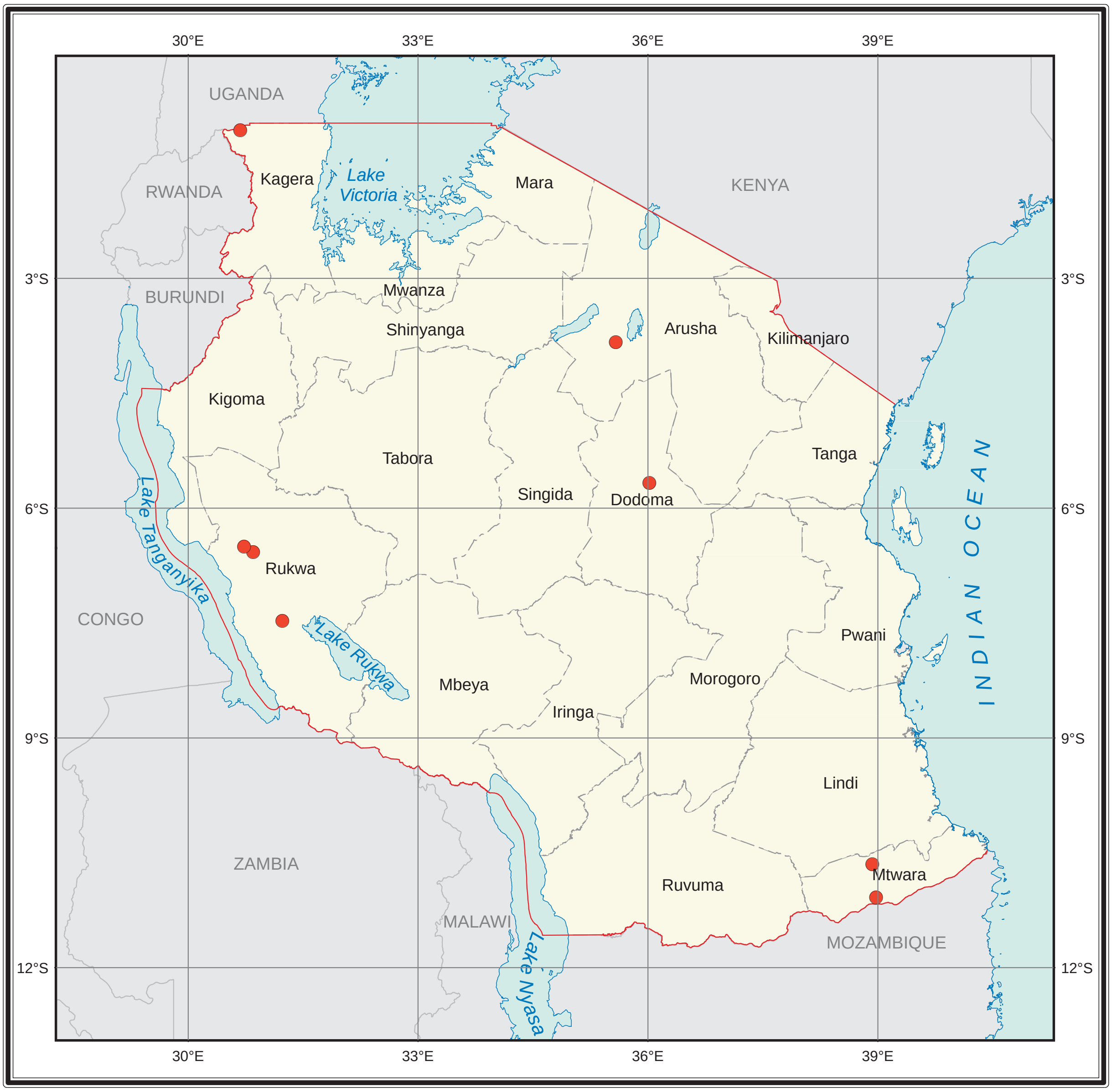
RELEVANT OCCURRENCES IN TANZANIA

The only known mode of occurrence of beryl in Tanzania is as an accessory mineral in many mica-bearing pegmatites in the country. Here it is found as clear gemstone crystals but also as massive rock. None of those mica-pegmatites have ever been worked for beryl alone. However, some 2 tons of beryl were collected over a period of years as a by-product of mica-mining from the Makanjiro pegmatite in the Masasi area, Mtwara Region, and exported in 1948/49. Another pegmatite in the Namaputa area, south of Masasi, is reported to have contained large crystals of beryl up to 45 cm in diameter, and a fair amount of beryl is known to have been recovered from the old Sibweza Mica Mine in Mpanda District. Other pegmatites containing beryl are said to occur at Sanato in the Haneti-Itiso area about 100 km NE of Dodoma.

EVALUATION

Because occurrences of beryl are already known in Tanzania and have been mined, there are chances of finding some more of this interesting and valuable mineral. Especially the vast unmapped areas in the Mtwara and Lindi Regions seem to have some potential. However, it should be kept in mind that beryl may occur in nearly all colours and can easily be confused with other minerals, like quartz or feldspar. The use of a field beryllometer in exploration is recommended. Future investors might also stay in contact with gemstone traders, who should know about new deposits of beryl gemstones entering the market.

Occurrences of Beryl in Tanzania



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0 100 200 300 400 500 km

Legend

● Beryl

DIATOMITE

GENERAL INFORMATION AND USES

Diatomite, also known as kieselguhr, is a sediment derived from the siliceous skeletons of tiny diatoms, i.e. algae, mostly living in very pure fresh-water lakes. Due to its adsorbent properties it is mainly used as a filter medium for beverages, water, and lubricants, but also as a light-weight filler, as a carrier for catalysts, as a very light insulator of heat and sound, and as a polishing abrasive. Impure diatomaceous earths are not in demand, but could be mixed with Portland cement for the construction of floors in houses or for the non-industrial basic filtration of drinking water.

RELEVANT OCCURRENCES IN TANZANIA

A large deposit of diatomite of better quality occurs in the valley of the Kagera River in the Kagera Region. This deposit lies near the Nyankanasi River port between 31° 05´ and 31° 25´ E and 1° 10´ and 1° 20´S. Here, the diatomite occurs in beds varying between 0.2 m and 1 m in thickness overlain by 2.7 to 4 m of overburden. It is very light brown or grey in colour when wet, and white when dry. Two analyses from samples from this locality were reported in the literature with A from the north bank of the river and B from the south bank, 8 km west of Kyaka. Sample C analysis in table 5 was kindly provided by Crop-Post Harvest Programme sponsored by the National Resources Institute (UK).

Other deposits of impure diatomaceous earths have been reported from:

- Mbeya, where it was once used for roofing tiles and brick making
- Bahi depression
- Rukwa Rift, below Chipoka Gorge
- Rungwa Sleeping Sickness Settlement
- in a well north of Lake Rukwa
- Makutapora, some 22 km north of Dodoma
- Ilindi, some 40 km NW of Dodoma at a depth of 0.6 to 7.5 m, where it is covered by black clay. The diatomaceous silica content was analysed to be between 3 to 22 wt.-% (42 to 57 wt.-% SiO_2)

Table 5: Chemical analyses of diatomite from the Kagera River deposit.

Sample	A	B	C
SiO_2	76.94	75.06	76.30 [1)]
Al_2O_3	11.94	13.00	9.55
Fe_2O_3 total			1.72
CaO	trace	trace	0.19
MgO	trace	trace	0.21
Na_2O	n.a.	n.a.	0.14
K_2O	n.a.	n.a.	0.83
TiO_2	n.a.	n.a.	0.45
P_2O_5	n.a.	n.a.	0.06
F(?)	1.35	1.20	n.a.
H_2O (<110 °C)	3.92	4.85	n.a.
LOI (>110 °C)	5.30	5.74	n.a.
total	99.45	98.85	89.45

[1)] Sample C contains 7.8 wt.-% (0.2 wt.-% crystobalite/opal, 7.6 wt.-% quartz) of total free crystalline silica. Amorphous silica can be calculated as 68.5 wt.-%.

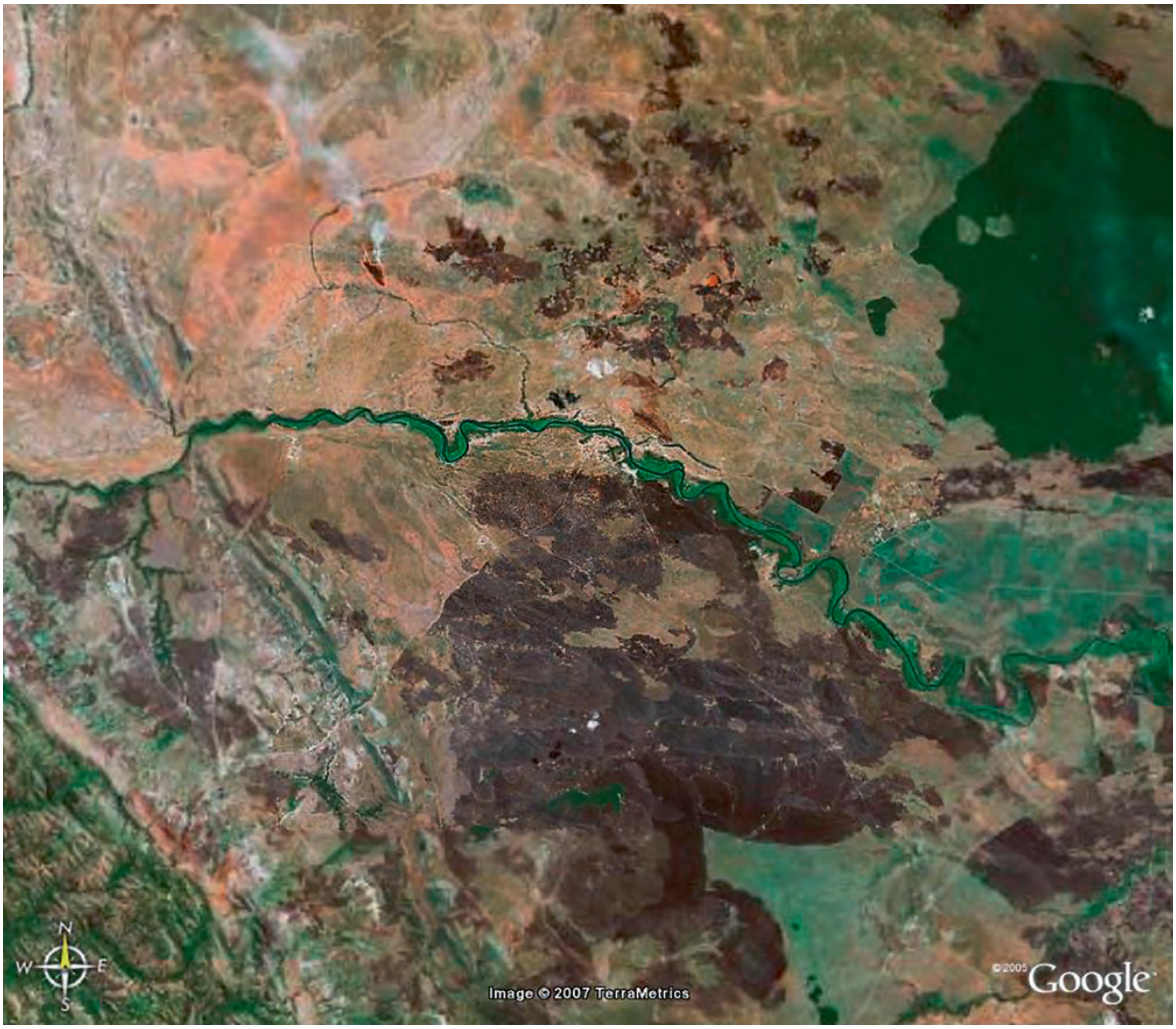


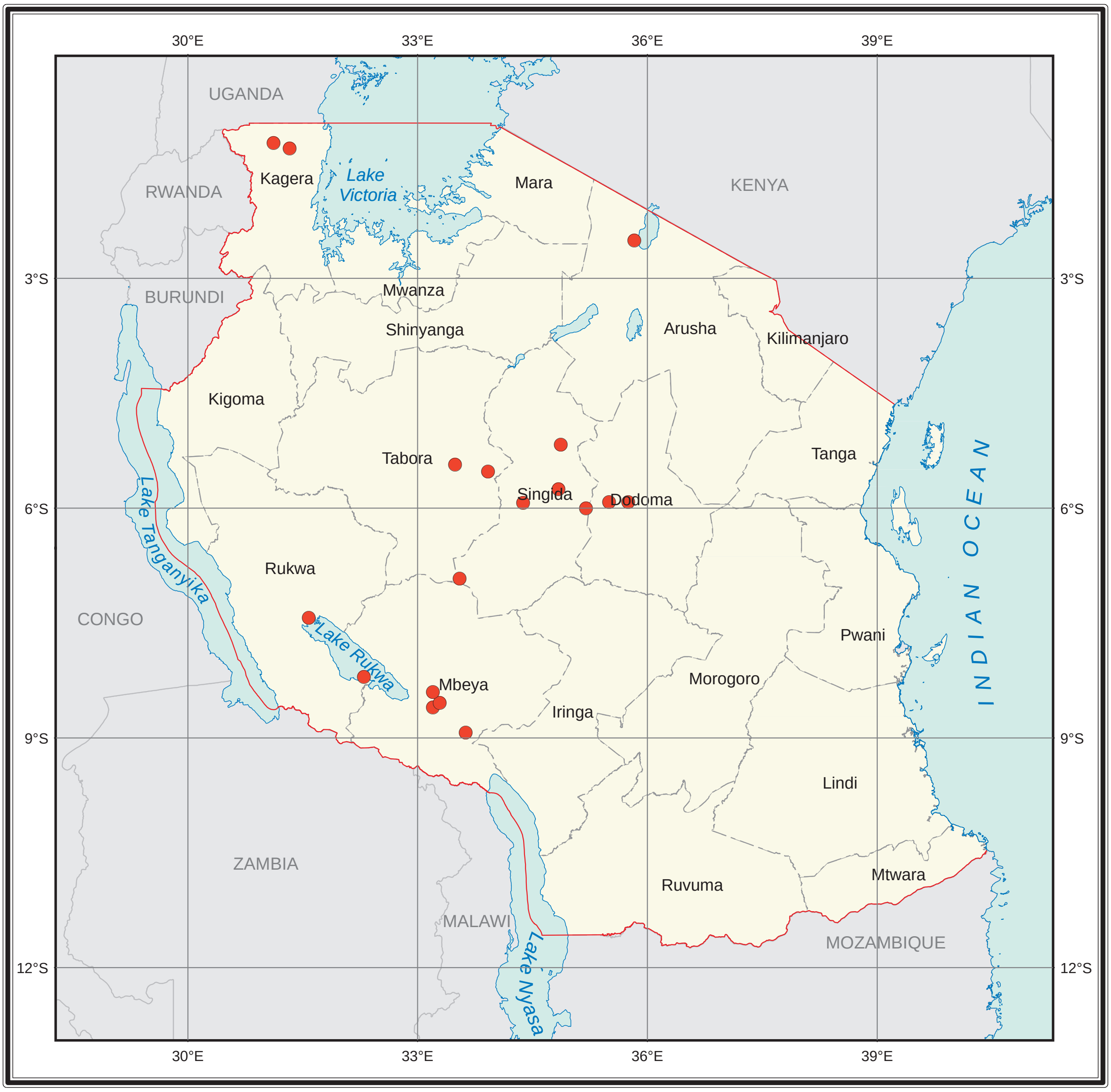
Figure 13: Satellite image of the Kagera River flowing from west to east towards Lake Victoria (Photo courtesy of Google Earth).

- on or near the Central Railway
  - ⇒ between Nyahua and Malongwe at km 745
  - ⇒ Manyoni-Singida Railway at about 13 km south of Singida

REQUIREMENTS AND EVALUATION

For industrial use, diatomite needs to contain >60 wt.-% amorphous silica. Deposits should have resources > 500 kt with a ratio overburden: diatomite not exceeding 1:1. These requirements can only be partially met by the Kagera River valley diatomite so it is suggested that all diatomaceous earths in Tanzania should primarily be used for the most basic purification of natural water.

Occurrences of Diatomite in Tanzania



Scale 1 : 10,000,000

0 100 200 300 400 500 km

Legend

● Diatomite

DOLOMITE

GENERAL INFORMATION AND USES

Dolomite, $CaMg(CO_3)_2$, is an important industrial mineral, which is used in large amounts as a refractory material, as a flux in the steel industry, as a filler in the chemical, paper, paint, and plastics industry, as a soil improver, as a building material and for making glass.

RELEVANT OCCURRENCES IN TANZANIA

Neither exact locations nor reserves have been reported on any of the dolomite occurrences in Tanzania with the exception of Chafukwa. The latter dolomite deposit lies at the foot of Chafukwa Hill in the Chimala area, just south of the Mbeya District in the Mbeya Region (8° 52' S, 34° 7' E). Here a 10 m thick massive band of dolomite can be traced for several km. The dolomite is relatively pure with only occasional some chert impurities. Chemical data for this and other deposits are given below.

Two occurrences of **soft dolomitic limestone** in Tanzania are known in the literature. One deposit is about 65 km west of Dodoma and 15 km east of Kongwa directly north of Sagara Village in the Sagara mbuga. Here a large (?) deposit of siliceous white to light grey dolomite or rather a mixture of calcium and magnesium carbonates plus amorphous silica was encountered below up to 1 m clayey overburden. The thickness of the "dolomite" is about 6 – 7 m. No reserve volume has been calculated or estimated. Chemical analyses are given in table 7.

Table 6: Chemical analyses (data in wt.-%) of dolomite deposits in Tanzania (after Kimambo, 1986, ed. and van Straaten et al., 1990).

		SiO_2	Fe_2O_3 total	Al_2O_3	CaO	MgO	Na_2O	K_2O	LOI	*total*
Chafukwa		16.88	1.03	0.13	29.14	16.32	0.02	0.01	36.40	*99.93*
Lupingu		7.22	0.84	0.44	31.18	21.04	0.22	0.20	38.78	*99.92*
Chambogo		0.70	0.40	1.57	31.08	20.19	n.d.	n.d.	45.66	*99.60*
Kudidege		3.38	1.27	1.46	31.55	20.19	n.d.	n.d.	42.16	*100.01*
Sinya		10.00	0.63	2.15	28.43	17.02	n.d.	n.d.	41.34	*99.57*
Lugoba		1.30	0.34	0.48	30.11	20.94	0.22	0.25	46.17	*99.81*
Merelani		1.92	0.35	1.05	-	19.96	-	-	44.54	-
Kigoma	Makere	3.29	0.43	0.95	-	16.17	-	-	-	-
	Simbi	1.10	0.44	0.47	-	20.77	-	-	-	-

Table 7: Chemical analyses (data in wt.-%) of soft dolomitic limestone from Sagara mbuga (after Fawley 1955):

Sample-#	CaO	MgO	sol. R_2O_3	insol.	insol. Al_2O_3	SiO_2	LOI	*total*
AF 511	23.8	15.1	1.1	26.1	-	-	33.7	*99.8*
AF 537	23.0	13.7	2.2	28.6	-	-	32.6	*100.1*
AF 538	21.8	14.3	1.7	-	1.9	26.5	34.0	*100.2*
AF 539	19.0	16.1	2.8	31.2	-	-	30.9	*100.0*
AF 512	20.8	16.9	2.4	25.9	-	-	34.1	*100.1*
AF 541	25.1	15.5	1.3	21.7	-	-	36.4	*100.0*
AF 542A	21.4	15.4	3.4	21.9	2.4	-	35.6	*100.1*
AF 543C	32.9	5.6	3.8	18.2	3.8	-	35.8	*100.1*
AF 702	27.8	12.9	2.7	18.7	1.0	-	37.0	*100.1*
AF 703	37.2	5.9	2.0	14.2	4.7	-	36.1	*100.1*
AF 704	32.2	7.2	2.1	22.3	3.9	-	32.4	*100.1*

Table 8: Chemical analyses (data in wt.-%) of soft dolomitic limestone from Msagali mbuga (after FAWLEY, 1958):

Sample-#	CaO	MgO	R_2O_3	insol.	SO_3	LOI	*total*
M 2	31.7	11.4	2.9	15.3	-	38.6	*99.9*
M 5	29.6	14.0	3.4	14.6	1.3	37.6	*100.5*
M 6	25.5	12.5	3.0	22.7	1.0	35.7	*100.4*
AF 801	25.8	11.8	5.3	17.4	-	38.8	*99.1*
AF 803	23.8	16.0	3.9	15.2	-	39.8	*98.7*
AF 809	29.1	12.3	1.4	16.2	0.8	37.8	*97.6*

Table 9: Chemical analyses (data in wt.-%) of crystalline dolomitic limestone from Shambarai.

Sample-#	CaO	MgO	R_2O_3	insol. in HCl	LOI	*total*
JG 928	27.6	18.5	1.2	11.0	41.8	*100.1*
JG 930	23.6	14.9	0.9	25.9	11.0	*76.3*
JG 934	30.5	20.6	0.7	1.6	46.6	*100.0*

The second deposit is in Msagali mbuga some 75 km east-SE of Dodoma as the crow flies. Dolomitic limestone was found west of the area of current gypcrete mining (see Gypsum for details). Here, the thickness of the dolomitic limestone varies between 1 and 3 m below 1 to 1.5 m of overburden. The composition of the dolomitic limestone is similar to Sagara mbuga. Chemical analyses of bulk samples are given in table 8.

It must be mentioned that some of the crystalline limestones in Tanzania (see Stones, Dimension) are in fact also are dolomitic limestones or even dolomites. Three analyses of such crystalline dolomitic limestone from Shambarai, some 55 km from Arusha, are given below. The inferred resources at Shambarai were estimated to be 1.5 million tons. Chemically pure dolomite has a composition of 30.4 wt.-% CaO, 21.9 wt.-% MgO and 47.7 wt.-% LOI.

REQUIREMENTS AND EVALUATION

In general dolomite should be rather pure and reserves rather large (>1 million tons). Potential investors should first define their desired market. The soft material from Sagara and Msagali should be just perfect for use as a soil conditioner and plant fertilizer, i.e. in farming, and should therefore be given preferential consideration. Many more mbugas exist in Tanzania which upon exploration should also yield many more deposits of dolomitic limestone.
For the production of refractory materials, or use in other industries, dolomite or crystalline dolomitic limestone resources close to the point of sale should be preferable: they have to be analysed, and their resources determined. Depending on the final use various chemical requirements (e.g. low Fe_2O_3, low SiO_2, low Al_2O_3, and low Cr_2O_3) will also have to be fulfilled.

RELEVANT LITERATURE

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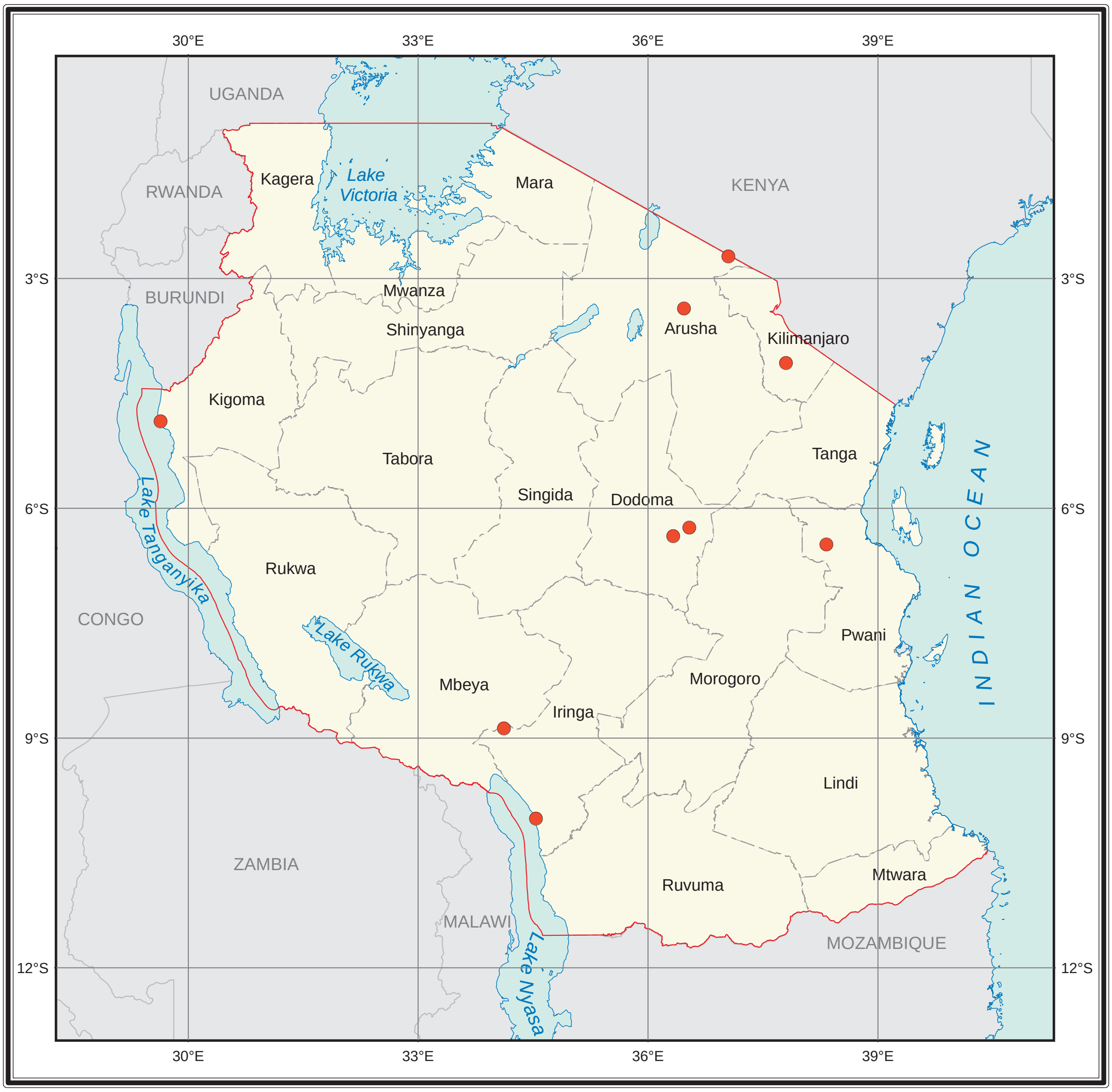
STRAATEN, VAN, P., MBASHA, M.Z., MBAWALA, F.L. & KIRANGA, O.W. (1990): Preliminary survey of liming materials in Mbeya and Iringa Regions.- Geol. Surv. Tanzania, Rep.: 13 pp., 1 tab.; Dodoma (unpublished).

Occurrences of Dolomite in Tanzania



Scale 1 : 10,000,000

0 100 200 300 400 500 km

Legend

● Dolomite

EARTH PIGMENTS

GENERAL INFORMATION AND USES

Earth pigments come in red, yellow, brown, black, and grey colours, made up of a variety of iron oxide minerals (hematite, limonite, goethite, maghemite, lepidokrokite, magnetite). Well-known names of natural earth pigments are ochre (red, gold, brown), umber, and sienna. Nearly all of the earth and mineral pigments of historical times have now been substituted by synthetic colours. However, there are still niche markets for high-quality natural earth pigments especially for use by artists, in cosmetics, and in glass production.

RELEVANT OCCURRENCES IN TANZANIA

In Tanzania, where red soils are ubiquitous, **red ochre** from Arusha and Manyara Regions was mined commercially between 1926 and 1940. The principal occurrence was at Lendekenya, at the foot of Monduli Mountain in the Monduli District. This material has a rich, dark, plum-red colour and is still extensively used by the local Masai and other tribes.
Another important deposit was even mined in colonial German times. This deposit occurs at Kagongo on the shores of Lake Tanganyika, some 25 to 30 km north of Kigoma. Here even adits were driven into the cliffs. Various colours were available. A third deposit of red ochre is known from 12 km south of Rubeho, Kilosa District in the Kaguru Mountains. Small production of red ochre was recorded from Kilangu Hill in the Same area.

Yellow ochre is much less common than red ochre. In Tanzania, yellow ochre of excellent quality and in great abundance is said to occur in the mountainous country near Tandala and Lupalilo in the Njombe District. Unfortunately this location is very remote. Other recorded places are:

- on the shore of Lake Tanganyika at Kagongo, 8 km north of Kigoma, where it occurs as a bed of decomposed shale, 1.8 to 3 m thick, associated with harder silty beds.
- together with lignite on the Noto Plateau,
- 24 km SE of Kilimantinde.

REQUIREMENTS AND EVALUATION

The value of an earth pigment depends on the brightness and intensity of its colour, on its texture, on its staining qualities, on its iron oxide content and on the relative proportion of oil which must be mixed with it to obtain the proper degree of fluidity for use as a pigment. The amount of soluble salts, MnO_2 and heavy metals, is strongly limited. For successful marketing it is necessary for producers to build up reputations for uniformity and high grade products.
Although the grades of all known deposits of earth pigments in Tanzania are said to be too poor to use commercially, this opinion is not well-founded. Potential investors should form their own opinion by re-sampling known deposits and looking for new ones.

Occurrences of Earth Pigments in Tanzania

Scale 1 : 10,000,000

0 100 200 300 400 500 km

Legend

● Ochre

FELDSPAR AND NEPHELINE SYENITE

GENERAL INFORMATION AND USES

Feldspar is one of the most common minerals on earth, with sodium, calcium or potassium feldspars finely distributed in most rocks. Mineable deposits have to be made up of potassium feldspar (orthoclase, microcline, sanidine) and can only be found associated with certain magmatic rocks, like nepheline syenites, pegmatites and within feldspar-rich sands. Potassium-rich feldspar is used in large amounts as fluxes in the ceramics and glass industries. Sodium-rich feldspar also is of interest for the production of coloured bottle glass.

RELEVANT OCCURRENCES IN TANZANIA

In Tanzania feldspars can be found in most of the mica pegmatites. In the Lupa Goldfield there are even dykes which consist of practically nothing but feldspar, petrographically called bostonites. A monomineralic feldspar dyke from Chilonwa near Dodoma was analysed and contains about 97 % potassium feldspar. Sodium-rich feldspars are much more common and have been reported from several places in the Uluguru Mountains where feldspar crystals of 1 m diameter have been found. Some chemical data on selected feldspar occurrences in Tanzania are given below.

Major occurrences of **nepheline syenite** in Tanzania are:

- The Nachendezwaya carbonatite dyke, which is 600 m north of the Songwe River and 54 km WSW of Tukuyu in the Ileje District. This dyke measures 24 m in thickness, 900 m in length and about 400 m in width. Topographically, the dyke forms three small hills. The outer two are composed of a biotite foyaite composed essentially of nepheline, biotite and microperthite, with microcline, plagioclase, calcite, apatite, sphene, vermiculite and iron minerals as accessories, and secondary cancrinite, epidote, and chlorite.
- The Mbozi syenite gabbro complex lies along the north-east edge of the Tunduma Rift valley, 5 km south of Vwawa and 98 km from Mbeya on the Mbeya-Tunduma road. It has an areal surface of about 204 km^2. Potash rich syenite is restricted to the discontinuous rim of the northern limb, and to nepheline-bearing gneisses within the southern limb. The rocks of the ring structure are strongly nephelinized

Table 10: Chemical analyses (data in wt.-%) of pegmatitic feldspars in Tanzania (after Kimambo 1986, ed.).

	Ngerengere				Chambogo	Mlali		Jumbadimwe		
	#1	Lukosi	Lukosi Kioo Ltd.	Dibwed-izelu		#1	#2	Gairo	sodic	potassic
SiO_2	60.44	65.00	65.37	63.47	64.85	64.45	65.06	65.46	65.46	65.46
TiO_2	n.d.	0.01	n.d.	n.d.	-	0.05	0.02	0.03	-	-
$Fe_2O_3^{tot}$	9.40	0.11	0.093	0.092	0.64	0.16	0.07	0.07	0.054	0.006
Al_2O_3	24.32	20.50	13.42	18.82	20.23	18.94	18.23	18.19	22.45	19.22
Cr_2O_3	-	n.d.	0.0065	0.0065	-	-	n.d.	-	-	-
Mn_2O_3	0.23	-	-	-	-	-	-	-	-	-
CaO	trace	0.85	2.65	0.76	1.02	0.50	0.29	0.47	3.80	0.14
MgO	0.25	0.05	0.01	0.01	0.55	0.19	n.d.	0.22	0.002	0.002
Na_2O	0.50	7.00	8.40	7.28	6.30 (?)	2.54	3.00	2.96	8.60	2.16
K_2O	4.30	4.65	1.28	5.52	11.10	11.62	12.00	11.38	0.84	12.75
LOI	0.30	-	-	-	0.28	0.74	-	0.39	-	-
total	99.74	98.17	97.86	96.02	104.97	99.19	98.67	99.17	101.21	99.74

Figure 14: N'gamba Hill near Vwawa.

whereas the quantity of nepheline gradually decreases outwards. The Mbozi syenite gabbro includes N'gamba Hill. This hill (09° 07.4 S, 32° 51 E) covers some 6 km² in area and reaches an elevation of 1.877 m a.s.l., i.e. 400 m above the surrounding hilly plain. It is made up of nepheline syenite only, with some sodalitic and dioritc dykes.

- The Ubende Karema syenites of which the only massif of nepheline and associated alkalic syenites is located in the NW of the right bank of the Lugusu River. This massif is irregular in shape, and some 2–3 km² of this body have been mapped. It has been established that its southern part is composed of alkaline syenites, and the northern part, which is a small pipe-shaped mass (300 m diameter), is composed of nepheline syenites. The latter are massive, grey, course grained rocks exhibiting allotriomorphic granular texture. They are comprised of large tabular grains of nepheline (60-70 %), microcline-perthite (20-30 %), and zircon (5 %). Biotite, muscovite, fluorite, apatite are accessories. Sericitization and silicification are common along jointing.
- The Mawe Hill syenites are situated near Ikumbukwa south of Igumira on the route from the Lupa to Tabora, and are symmetrically crossed by the Sipa, a tributary of the Rungwa River. The syenites cover an area of about 60 km². Upon investigation, some samples were found to contain nepheline in perthitic feldspar, others to have nepheline in plates interstitial to feldspar. Iron oxide is associated mainly with biotite and sphene. Zircons are accessories, and together with aegirite, they make up a nepheline-aegirite-syenite rock. Quartz syenites are common in the south. They are composed of microcline, microperthite and quartz as essential constituents.
- The Mount Msona syenite is located 96 km SE of Dodoma, with syenite covering an area of about 16 km². The rocks resemble the well-known aegirite-syenites of the Singida District with the exception that they rarely contain melamite and have much less sphene. They contain minor aegirite with biotite as the dominant ferromagnesian minerals. Apatite, zircon, sphene and epidote constitute the accessories.

It should also be mentioned that analcime syenitic, and nepheline syenitic flows are common at Kilimanjaro. Because they are situated within national park boundaries they should not be considered a potential commodity.

Table 11: Chemical analyses (data in wt.-%) of alkali syenites in Tanzania (after KIMAMBO 1986, ed.).

	Chunya District			Singida District
	#1	#2	#3	
SiO_2	53.62	65.70	61.38	57.08
Fe_2O_3 total	6.73	0.97	3.49	5.13
Al_2O_3	17.01	18.29	17.58	17.05
CaO	3.72	0.75	2.26	3.83
MgO	2.94	1.01	1.89	2.13
Na_2O	5.09	5.91	6.27	3.89
K_2O	8.35	8.55	8.25	9.80
LOI	1.09	0.49	0.63	1.27
total	98.55	101.67	101.75	100.18

REQUIREMENTS AND EVALUATION

For industrial use, feldspar has to be rich in potassium (>8 wt.-% K_2O), low in sodium (<4 wt.-% Na_2O), rich in alumina (>18.5 wt.-% Al_2O_3) and low both in iron (<0.1 wt.-% Fe_2O_3) and chromium (<5 ppm Cr_2O_3). Reserves need to contain at least 100 kt of recoverable feldspar. In pegmatites workable dykes have to have a thickness of 1.2 m.
Nepheline syenites may contain more sodium feldspar, not less than 60 vol.-% feldspar and not more than 5 vol.-% accessory minerals. Reserves need to encompass at least 500 kt of recoverable material. Reserves of >100 million tons are preferred.
Even keeping these restrictions in mind, there still seems to be a good chance to establish mineable feldspar or nepheline syenite reserves in Tanzania. Initially potential investors should get in touch with GST to identify high-grade feldspar dykes or pegmatites, which could be mined by small-scale miners. In a second step, the nepheline syenite bodies mentioned above should be mapped and sampled in more detail to identify reserves big enough to support local ceramics or glass industries.

RELEVANT LITERATURE

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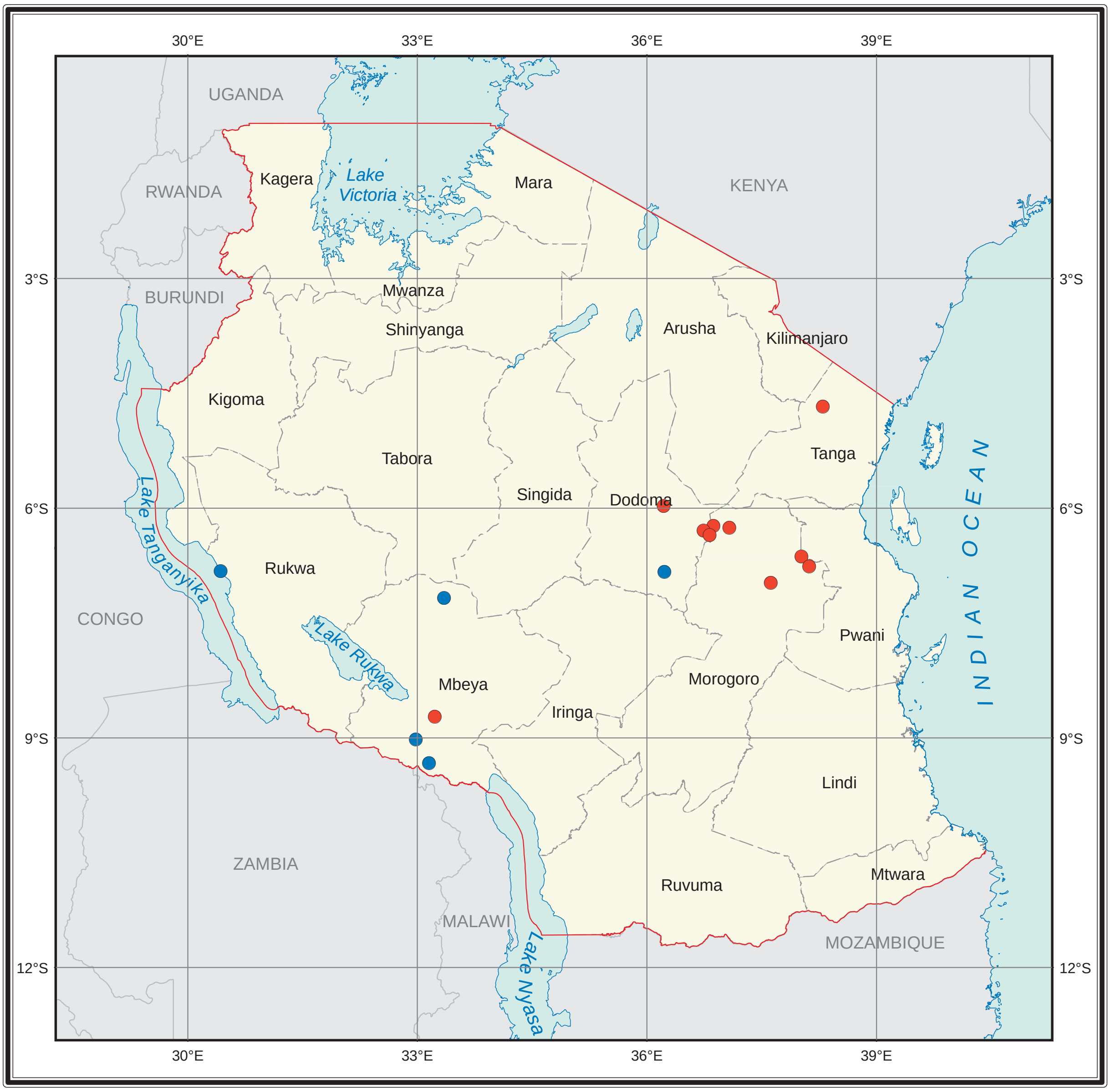
Occurrences of Feldspar and Nepheline Syenite in Tanzania



Scale 1 : 10,000,000

0 100 200 300 400 500 km

Legend

- Feldspar
- Nepheline Syenite

FLUORITE

GENERAL INFORMATION AND USES

Fluorite, with the chemical formula CaF_2, is the most common and important fluor mineral. It is used in the steel, chemical, aluminium, glass, ceramics, and optical industries. According to these main applications metallurgical-grade fluorite, acid-grade fluorite, ceramic-grade fluorite, and optical-grade fluorite can and should be differentiated.

RELEVANT OCCURRENCES IN TANZANIA

Up to very recently, no fluorite deposits were known to Tanzania, with fluorite spots reported from remote Ngualla carbonatite complex in Chunya District. In 2005, however, a presumably major fluorite deposit was identified by a common field team of Zonal Mines Office, GST, STAMICO and BGR in the Mbeya area. This deposit covers the southern halves of two adjacent unnamed hills (8° 57.73' S, 33° 11.40' E) geologically being part of the Sengeri carbonatite north of the more famous Panda Hill carbonatite complex. The hills are 3 km from the main road from Mbeya to Tunduma and only a few km west of the main goods station at Mbeya. The southern halves of these hills are obviously strongly mineralized by fluorite and will soon be explored by STAMICO in detail.
Samples analysed by BGR and Sachtleben Bergbau company gave the following results:
Mineralogy (by XRD): Fluorite, with traces of quartz, hematite, and microcline.

Figure 15: Northern side of the Sengeri fluorite deposit, which is easily accessible by car.

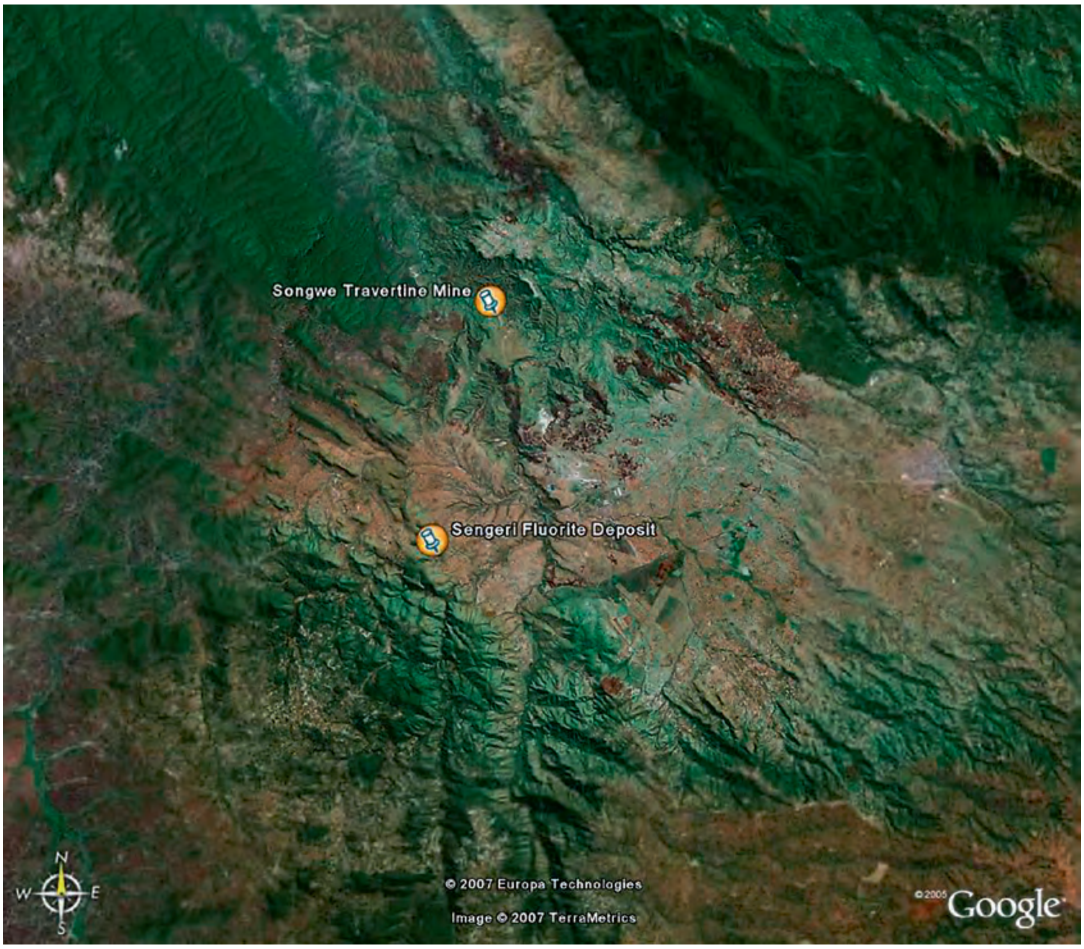


Figure 16: Satellite image of the Sengeri fluorite deposit and the Songwe travertine mine (see Stones, Dimension) to the north (Photo courtesy of Google Earth).

Figure 17: Rocks mineralized by fluorite forming part of the Sengeri carbonatite close to Mbeya.

Table 12: Selected chemistry of bulk rock analysis of samples from Sengeri fluorite deposit (BGR by XRF analysis and Sachtleben Bergbau by wet chemical analysis).

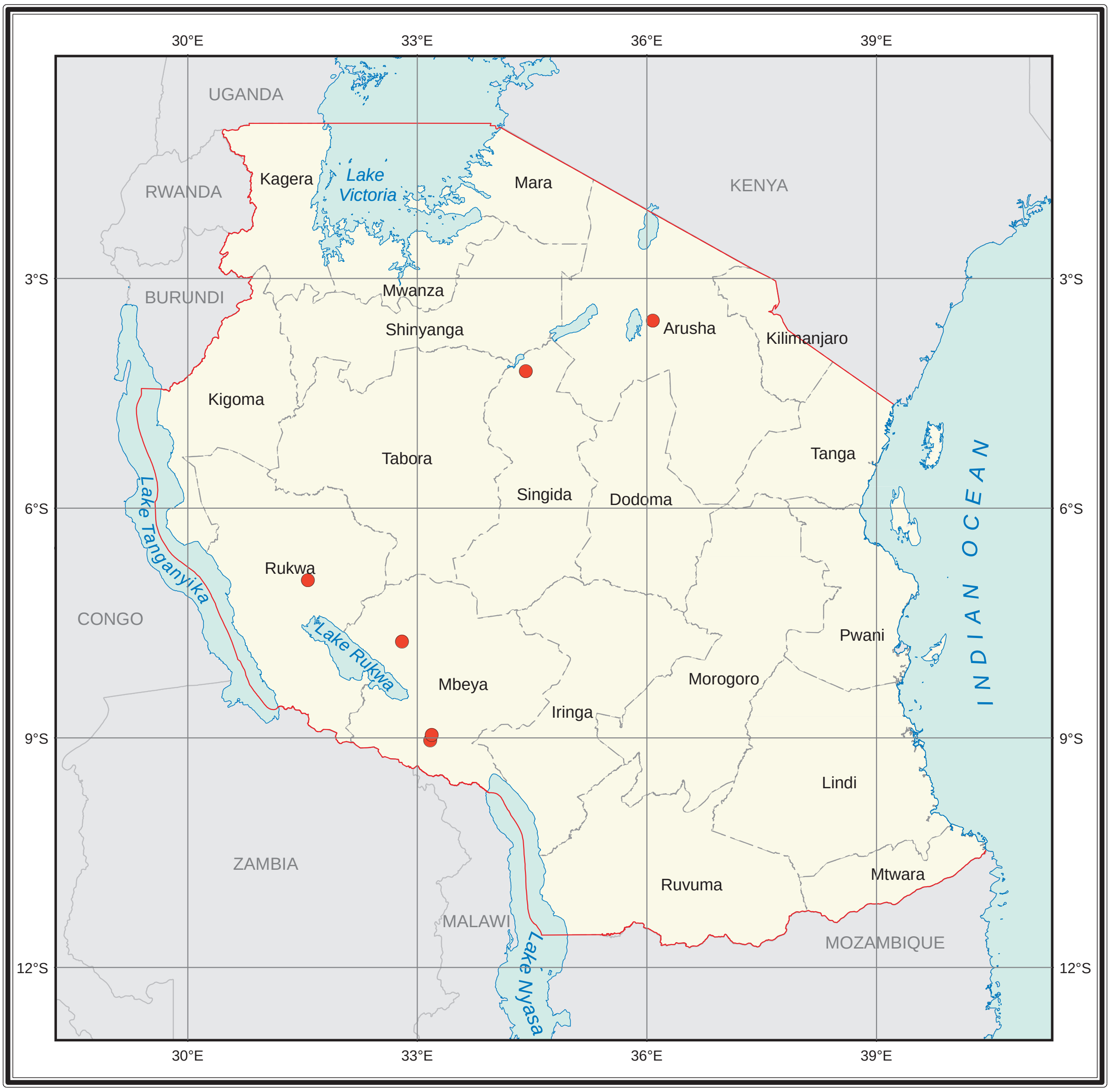
Chemistry	BGR	Sachtleben Bergbau	Limits / Ranges for applications
	wt.-% / ppm		
(F)	40.18	n.a.	
SiO_2	7.73	5.5	(<2)<5-<6(<15) (metallurgical-grade)
			<1.0-<1.5 (acid-grade)
			<2.5-<3.0 (ceramic-grade)
Fe_2O_3 total	3.92	3.49	(<0.005)-<0.50 (acid-grade)
CaO	59.70	n.a.	
MgO	0.02	n.d.	
MnO	0.02	0.18	
(SO_3)	0.02	0.117	
P_2O_5	0.044	0.075*	<0.03-<0.20 (acid-grade)
LOI	3.08	n.d.	
(As)	36 ppm	3 ppm	(<5)-<10-12 ppm (acid-grade)
Cu	11 ppm	10 ppm	
Hg	n.d.	0.1 ppm	
Pb	9 ppm	11 ppm	<2,500-<5,000 ppm (metallurgical-grade)
U	<3 ppm	n.d.	Σ<500 ppm for any commodity
Th	6 ppm	n.d.	
Zn	22 ppm	51 ppm	
Calculated			
CaF_2	82.57	82.0	>60(>70)->80 (metallurgical-grade)
			(>92)->97 (acid-grade)
			(>85)->95 (ceramic-grade)
$CaCO_3$	0.71	7.2	<2-<3 (metallurgical-grade)
			<0.50-(<1.0) (acid-grade)
			<1.0 (ceramic-grade)
$MgCO_3$	0.04	n.d.	<1 (metallurgical-grade)

* after flotation tests a value of 0.028 wt.-% was achieved

REQUIREMENTS AND EVALUATION

Fluorite deposits should contain at least 500 kt of recoverable fluorite. With respect to the different applications, there are also different chemical requirements. Both acid-grade and ceramic-grade fluorite have to be very pure. Optical-grade fluorite has to be even purer, colourless and translucent. More information is given in the table above. According to the first data available, the fluorite from Sengeri is very typical for metallurgical-grade fluorite. Potential investors should get in contact with STAMICO for further arrangements.

Occurrences of Fluorite in Tanzania



Scale 1 : 10,000,000

0 100 200 300 400 500 km

Legend

● Fluorite

GRAPHITE

GENERAL INFORMATION AND USES

Graphite is one of the two crystal modifications of pure carbon, C, the other being diamond. Graphite which is a black, very soft, and greasy mineral is very typical for metamorphic rocks whose organic content has been metamorphosed to graphite. There are three modifications of graphite in nature. One is disseminated flake graphite which is most common. The other is massive vein graphite which is very rare, currently only being mined in Sri Lanka. The third is amorphous graphite formed by the metamorphism of coal beds.
Graphite is a high-tech industrial mineral. Because it is highly refractory, it is not only used in pencils, but also in crucibles, fireproof products, brake linings, and carbon brushes. Graphite is an important constituent in powder metallurgy, in self-lubrication, in batteries and in fuel cells. It is also used in the production of special plastics and graphite dispersions.

RELEVANT OCCURRENCES IN TANZANIA

In Tanzania graphite occurrences are ubiquitous and graphite deposits are numerous. Only two deposits, however, have been mined so far: the small Nambiranje deposit in the Lindi Region having been known since colonial times, and the rather big Merelani deposit having been mined for graphite in 1995 and 1996.

Merelani is the name of a village in the northern foothills of the Lelatema Mountains about 16 km SW of Kilimanjaro International Airport which is half way between Arusha and Moshi. Here in 1967, vanadiferous zoisite gemstone, later named tanzanite, was first found in highly metamorphosed hydrothermal alteration zones and pegmatites between highly distorted kyanite-sillimanite-gneisses, graphite-gneisses, and marbles, all of which belong to the Usagaran system of Precambrian age. Since 1967,

Figure 18: Graphite ore with flake graphite piled up at Merelani.

the Merelani deposit has been mined for tanzanite by small-scale miners and various successor mining companies. Graphite was only separated by one company, i.e. GRAPHTAN LTD. in 1995 and 1996 with some 18 kt of graphite concentrate being produced and sold till the end of 1997. The current mining company, TANZANITEONE, took over operations in May 2004. However, neither this company nor any of the small-scale miners are interested in graphite any more but just keep on mining for tanzanite and tsavorite.

The rock sequence at Merelani can be divided into an upper and a lower horizon. The main graphite bearing units in these horizons are:

– Kyanite-sillimanite graphite gneiss (*Kyanite Graphite Gneiss*) with 5-12 wt.-% graphite. Graphite occurs as coarse hexagonal flakes ranging in size from 0.5 to 2.5 mm (average 0.8 mm), though flakes of 5 mm diameter or more are found within pegmatite lenses which constitute 5-10 % of this unit. Content of graphitic C varies between 5-8 wt.-% with an average of 6 wt.-%. Crushing, milling, and flotation produces a graphite concentrate with 50-60 wt.-% >300 µm size and 98.5 wt.-% C.
– Hydrothermally altered graphite gneiss (*Main Alteration Zone*) with 8-20 wt.-% graphite. Graphite occurs as disseminated flakes and aggregates of flakes varying between 0.5 and 2 mm (average 0.7 mm) in diameter, containing on average 11.2 wt.-% graphitic C. Beneficiation of this graphitic rock requires more cleaning and yields a higher proportion of fines than from the kyanite-sillimanite graphite gneiss unit. A 30-40 wt.-% yield of >300 µm size can be obtained.
– *Flaggy Biotite Graphite Gneiss* with 4-6 wt.-% graphite. This unit is the most common graphitic rock in the area. Flake size varies between 0.5 and 1.5 mm but more usually less than 1 mm in diameter. In contrast to the kyanite gneiss, flakes are smaller and occur as clumps or aggregates rather than single, clean flakes. Average grade is 4.5 wt.-% graphitic C

Mean grain size composition of graphite flakes produced from Merelani is about 35 vol.-% >300 µm, about 35 vol.-% 150-300 µm, and about 30 vol.-% <150 µm.

Graphite concentrates from Merelani bought and analysed by an experienced German graphite mining and beneficiation company gave an apparent density of 580-620 g/l, and contained 2.1-3.1 wt.-% H_2O, and 98.66-98.67 wt.-% graphitic C.

Proven reserves at Merelani were given as 7.6 million tons of graphite ore grading 5.5-11.2 wt.-% C, i.e. containing 530 kt of graphitic C. Resources at Merelani, Block C only, were calculated as 8.8 million tons of graphite ore grading 8.3 wt.-% C on average, i.e. containing 730 kt of graphitic carbon.

In south-eastern Tanzania, i.e. in the Lindi and Mtwara Regions, there are several hundred outcrops of graphite-bearing gneisses and schists of variable thickness and quality. Similar to Merelani all graphite bearing rocks belong to the Usagaran system of Precambrian age. Because the aforementioned regions were geologically surveyed only very insufficiently or not at all, only a fraction of these outcrops were investigated or looked at in any detail. The following deposits have been mentioned in the literature:

- Nachingwea (Lindi Region): Chiliogali Hills as well as numerous other outcrops are known from the Nachingwea District in the Lindi Region. Chiliogali Hills deposit is about 10 km SE of Nachingwea and about 1 km southeast of Chumbati Village. Analyses of bulk samples from the Chiliogali Hills deposit taken some decades ago gave values of LOI between 11.4 and 27.8 wt.-%. Later, between 1990 and 1992, the deposit was explored in detail by United Nations experts. According to this latter campaign

in the Chiliogali Hills there is an outcrop of graphite-bearing gneiss with an average thickness of 0.5 m, a width of 10 to 50 m, and a length of 1,000 m. This Prospect I contains graphite ore with an average grade of 13 wt.-% C and a volume of 3,750 m^3. Due to a landslide, large masses of this graphite-bearing gneiss were moved downhill on the northern slope of the hills (Prospect II). This led to an additional coverage of some 103,125 m^2 area with graphite-bearing boulders having an average thickness of 0.6 m and a volume of 61,875 m^3. Proven resources therefore can be given as about 8,500 tons of graphitic C.
A new sample from Prospect II (10° 25.098' S, 38° 44.937' E) was taken by an expert team of STAMICO, GST, and BGR geologists in 2005. It was analysed by an experienced German graphite mining and beneficiation company and gave 31.2 wt.-% LOI, 0.3 wt.-% volatiles, and 30.9 wt.-% graphitic C. This sample showed small ribbons of both vein graphite and small and weathered graphite flakes. The German mining company stated that this is a highly unusual and unique graphite ore.

- Nambiranje (Lindi Region): There are two small but good quality deposits at Nambiranje Village (9° 47' S, 38° 56' E) by the Mbekuru River. The ore is reported to be imbedded in hard quartzite which makes mining extremely difficult. The graphite vein is only 0.7 m wide and 1.8 m long. The ore contains 27 wt.-% graphite with many large flakes. The Nambiranje deposit was exploited by shallow shafts during colonial times, in 1949, in 1956, and presumably in 1960.

Figure 19: Graphite ore with mixed flake and vein graphite from the Nachingwea deposit.

Figure 20: Layer of graphite ore between marble at Malapa Hill.

- Litingina (Lindi Region): This is a small deposit NW of Litinga Hill close to Litinga Village. The graphite vein is only 0.2 m wide and imbedded in fine-grained graphitic gneiss. The ore was analysed to contain 66.5 wt.-% graphite.
- Nagaga (Mtwara Region): Deposits near Lulindi and Puteni are said to be very small but to contain coarse flakes of graphite.
- Nanganga (Mtwara Region): Mbecha-Nguni deposit at Lukuledi River. According to old investigations there used to be an outcrop of limestone rich in graphite close to Nanganga Village. LOI of the graphite ore is given as 27 wt.-%. Despite an intensive search and questioning of the local people, the outcrop could not be found anymore in 2005. Most probably it was covered by sediments after a strong shift in the course of the adjacent Lukuledi River by El Niño in 1997.
- Ndanda-Chikundi (Mtwara Region): There are graphite deposits at Chikundi-Chibwini and Chikundi-Pachani. The latter, presumably rather small deposit is at Malapa Hill, just a few hundred metres north of the main road from Lindi to Masasi and between Chikundi und Ndanda Villages. Interbedded within steeply dipping marble there are layers of graphite-bearing gneiss some 0.05 to 0.3 m thick.

  In 2005, a representative sample (10° 30.830' S, 38° 59.018' E) of graphite ore from Malapa Hill was taken by an expert team of STAMICO, GST, and BGR geologists. It was analysed by an experienced German graphite mining and beneficiation company and gave 77.6 wt.-% LOI, 1.5 wt.-% volatiles, and 76.1 wt.-% graphitic C. This sample contained small graphite flakes with a very high C-content. Other minerals present are pyrite and feldspar which are both weathered. The German mining company stated that this graphite ore might be suitable for flotation, but due to its low content of larger flakes the concentrate would not attain a high price. The graphite might be used for milling

Figure 21: Graphite ore with mixed flake and vein graphite from Mbanga Hill near Ndanda.

and powdering.

- Ndanda (Mtwara Region): More than 40 outcrops of gneisses very rich in graphite are known at Ndanda. These graphite-bearing rocks are used by the local people to colour pottery. Up to now there has been no detailed exploration or assessment of the various outcrops. A sample was therefore taken at Mbanga Hill by an expert team of STAMICO, GST, and BGR geologists in 2005. It was analysed by an experienced German graphite mining and beneficiation company and gave 47.9 wt.-% LOI, 2.8 wt.-% volatiles, and 45.1 wt.-% graphitic C. This sample contained both vein graphite and sma ll graphite flakes. Due to the high C-content the German mining company stated this to be a very promising ore. However, the two types of graphite cannot be separated by dressing so that the resulting concentrate will have atypical parameters.

Graphite also has been reported from eastern Uluguru Mountains. Here graphite-bearing rocks, most of them highly weathered, can be found in the Matombo region (7° 5' S, 37° 50' E). The depth of weathered rock in this area reaches 15 m or more. The deposits occur over a distance of 6 km along the west side of the Mikese-Kisaki road near Mtamba Market. Individual deposits are:

- Mtamba (only third of the length of the deposit investigated containing 725 kt of ore @ 3 wt.-% graphite = 22 kt extractable graphite, 90-95 vol.-% of the flakes are of medium (0.25-0.5 mm) and fine ($<$0.25 mm) sizes),
- Mtukira (200 kt of ore @ 4 wt.-% graphite = 8 kt graphite, 128 kt of ore @ 6.5 wt.-% graphite = 8 kt of graphite, i.e. about 16 kt total extractable graphite, about 93 vol.-% of the flakes are of medium and fine sizes)
- Mtombozi (154 kt of ore @ 18.8 wt.-% graphite = 29 kt graphite and 164 kt of ore @ 12.5 wt.-% graphite = 20.5 kt graphite, i.e. about 50 kt total extractable graphite, 12-24 vol.-% of the flakes are of coarse (0.5-1.7 mm) size, and 50-60 vol.-% are of medium size),

- Kirondo (continuation of the Mtukira deposit, no resources yet established, about 3 wt.-% graphite, about 47 % are of medium and fine sizes),
- Chingo Hill/Mungwi (not investigated).

Testing indicated three main disadvantages of the Uluguru Mountains graphite deposits: the proportion of large flakes is low as given above; the flakes are book-like and interleaved with impurities, especially mica; and the material gives rise to large amounts of slime which makes flotation difficult.

Bands of graphite rocks have also been reported from many other locations in Uluguru Mountains. However, the occurrences are small and not easily accessible. Flake graphite especially has been reported from Kiroka (20 wt.-% graphite, 4 vol.-% >0.6 mm flake size), Nyingwa (14 wt.-% graphite, 13 vol.-% >0.6 mm flake size), Morningside (2 wt.-% graphite, 40 vol.-% >0.6 mm flake size), Lukui River (20 wt.-% graphite, 11 vol.-% >0.6 mm flake size), Mikese (35 wt.-% graphitic C, 1/3 crucible grade, impure, many fine flakes) and from Mgazi River (low yield).

In the Tanga District a band of hard graphitic schist up to 3 m thick can be found near Daluni about 80 km by road NW of Tanga. The graphite content of the schist is reported to be 38.5 wt.-%. While the flake content is high, the quality is reported not to be of crucible grade. No resource estimates have been given.

A bed of graphitic schist, about 20 m thick, is exposed over a length of 6.5 km at Ndololo on the Ifakara-Mahenge road about 8 km north of Mahenge. Graphite is fairly evenly distributed through the rock with occasional richer streaks and layers. Rough estimates of resources given are 4.7 million tons of ore, so resources of 700 kt of graphite in place can be inferred. Dressing tests have shown a carbon content of the heads of 15.75 wt.-% and a rate of 95.7 % extractable graphite. Impurities consist of mica and some silica.

Graphitic gneisses also are known from Idete in a mountainous area of Mpwapwa District. There are indications of graphitic rocks in a N-S striking belt 800 m wide, although only a few thin beds of up to 1 m wide have yet been exposed in Ikombo valley (6° 59' S, 36° 34' E). Ore dressing tests have shown a fairly high quality graphite with LOI values ranging from 16 to 47 wt.-%. However, the content of large flakes was found to be rather low with pitting of large flakes and interleaved micaceous impurities. Resources have been estimated as only several hundred tons of graphitic carbon.

Another graphite deposit in the Mpwapwa District is reported from the remote Nduga Village about 11 km NE of Tambi. Here the thickness and the grade of the weathered graphite gneiss are highly variable. Rough estimates of resources in place are 90 kt of ore containing about 20 wt.-% graphite, a third of which is reported to be of crucible grade.

Graphite deposits in the Kiboriani Massif (Kiboriani Mountain summit, Chunyu Hill, Kitzizi Hill) are also in the Mpwapwa District. All of them occur in schists. At Kitzizi Hill, between 0.3 and 5 m of graphite schist is exposed and contains fine-grained graphite. At the summit of Kiboriani Mountain graphite is of coarser grade, but the resources have not been estimated.

Graphitic rocks have also been reported from Mlala Plateau in western Tanzania and from Kikwina, from near Hedaru and from Kisangiro in the Pare Mountains. However, the graphite in the latter occurrences is reported not to be of crucible grade.

Numerous other place names of occurrences of graphite in Tanzania have been given by Teale & Oates (1946) and other authors all without any further economically relevant information.

Figure 22: Satellite image of Mahenge basin showing the Ndololo graphite deposit (Photo courtesy of Google Earth).

REQUIREMENTS AND EVALUATION

Minimum reserves for deposits of flake graphite to be mined in open-pits are 1 kt of graphitic carbon. To be suitable for mining, weathered graphite ore with large flakes should contain $>$2 wt.-% fixed carbon C, and unweathered ore should contain $>$5 wt.-% C. For underground mining, the minimum C-content is 20 wt.-%. Sulphides like pyrite or pyrrhotine, and intergrowths of mica and graphite are not wanted and need to be separated during beneficiation. Analyses and application tests of graphite ores should always be performed by experienced graphite mining and beneficiation companies only.

All raw graphite ores have to be milled and flotated after mining. Graphitic ore should therefore be made up of just one of the three graphite variations mentioned above because a mixed ore cannot be separated by flotation and the concentrate will have unusual parameters after dressing. While presumably there will also be customers for such mixed concentrate, marketing will be difficult and time-consuming.

Tanzania is extremely rich in graphite occurrences and graphite deposits of various sizes are numerous. However, most of the known deposits in the Mtwara and Lindi Regions seem to be of the mixed vein-flake-graphite kind. This is very unfortunate as the infrastructure around the southernmost graphite deposits in Tanzania is excellent. Because the world market is currently flooded by cheap Chinese flake graphite, mining companies will have no interest in the near future in the mining and marketing of such mixed graphite ores. However, because the deposits of graphite in southern Tanzania are abundant, it may nevertheless be worth while for anticipatory graphite companies to produce a test concentrate and try to establish a market.
In contrast, the flake graphite of Merelani has already been shown to be of good quality and could rather easily find a new market again. Above all it is up to TanzaniteOne to produce and sell this graphite once again. On the other hand potential investors might get in contact with small-scale miners and miners associations at Merelani to buy their stockpiles of graphite ore. Using this ore it should be possible to produce a well marketable graphite concentrate which can then be exported to interested beneficiation companies overseas.

The Ndololo graphite deposit might also be worth looking at in detail, because the resources seem to be large and the quality to be good. However, no detailed and conclusive analyses have been performed yet.

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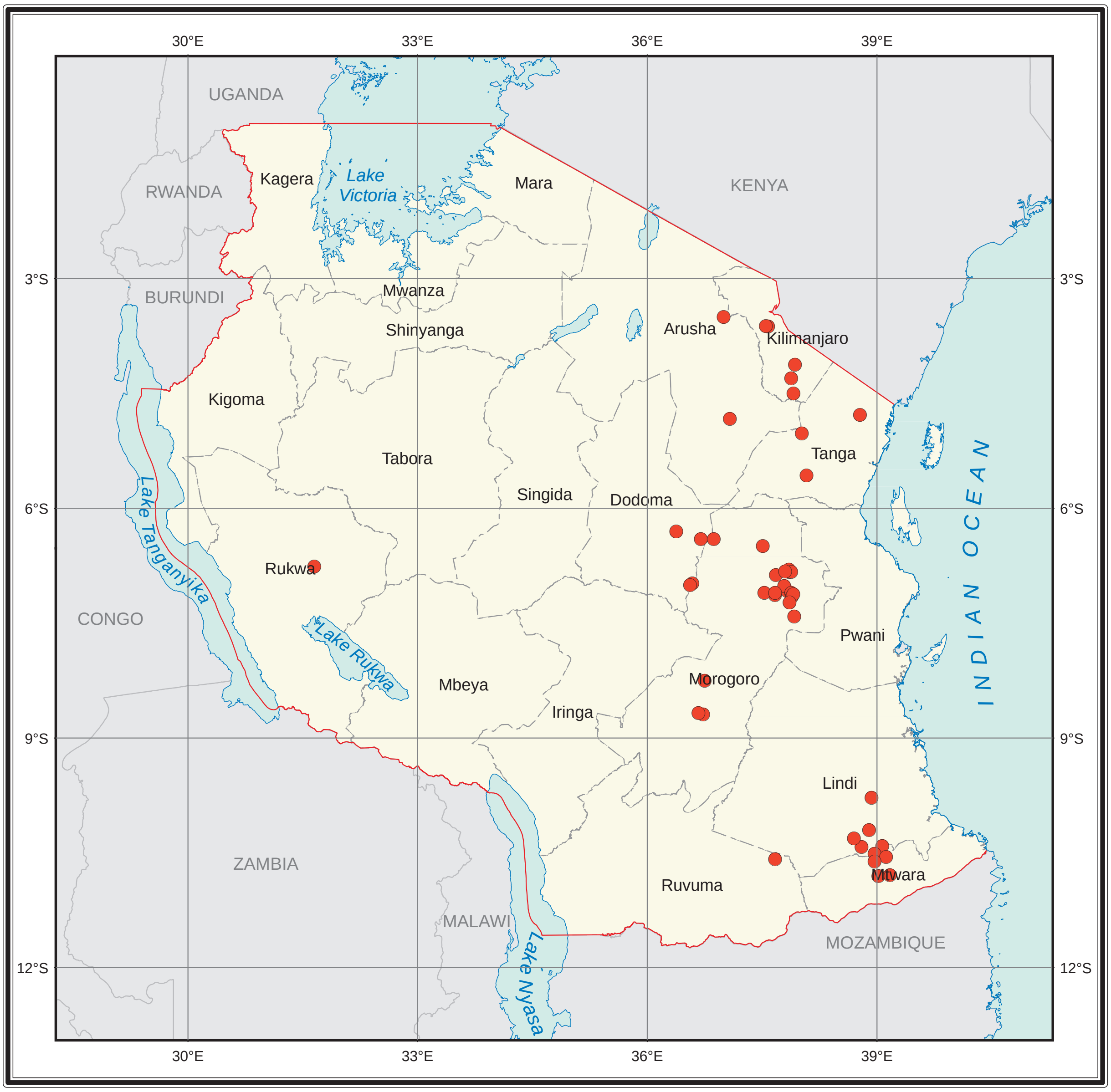
Occurrences of Graphite in Tanzania



Scale 1 : 10,000,000

0 100 200 300 400 500 km

Legend

● Graphite

GYPSUM

GENERAL INFORMATION AND USES

Gypsum, $CaSO_4 \times 2H_2O$, is a very important industrial mineral and used in a variety of building materials, like gypsum wall boards and plaster of Paris. Gypsum is also needed as a retarding agent when grinding cement clinkers, which is also the most important application in Tanzania. Some 65 kt of gypsum per year are estimated to be needed in Tanzania for this use only. However, gypsum can also be used as a fertilizer, as a carrier substance in the chemical industry, or as special filler in the paper and paint industries.

RELEVANT OCCURRENCES IN TANZANIA

Due to the importance of gypsum to the cement and building industries in Tanzania, many reports are available on the gypsum resources of the country. With one exception, all occurrences are of minor quality consisting of gypcrete, i.e. impure earthy gypsum and small gypsum crystals in a sandy-clayey matrix. So far only one rock gypsum deposit of good quality has been discovered. This gypsum might even be used for the production of gypsum wall boards, which Tanzania currently imports.

- While prospecting for oil in the 1950s BP drilled into layers of rock salt and gypsum of considerable thickness in the Kilwa-Lindi Region. During later exploration campaigns it was discovered that the gypsum is of Jurassic age and although being pure, is heavily distorted and folded due to its location on top of salt domes. The gypsum reaches the surface at only three locations in southern Kilwa District (Pindiro, Mkomore, and Mbaru/Mandawa/Nondwa). Two of these, Pindiro and Mbaru, were explored in detail by STAMICO between 1976, and 1980. The Mbaru deposit was mined out in the 1990s and its gypsum transported to Dar es Salaam for use in the Wazo Hill cement factory.
  The Mkomore occurrence is located some 11 km off the Dar es Salaam-Lindi road. It has not been explored yet.
  The Pindiro deposit lies north of Pindiro about 3 km north of Makangaga Village. Roads leading to this location are impassable during the rainy season with some 50 km between it and the nearest harbour (Rushungi Port). The average thickness of the gypsum beds is 6 m. The overburden ratio is high (1:5). The average content of $CaSO_4 \times 2H_2O$ in the Pindiro deposit is 83 wt.-%. The rest is shale, fine sandstone or siltstone breccia, limestone, and mudstone. The NaCl content is low (about 0.05 wt.-%). The drilling results were used to calculate probable resources of 1 million tons and possible resources of 2 million tons gypsum.
  The Mbaru deposit which lies only about 2 km from the main road from Dar es Salaam to Lindi was calculated to contain 1.2 million tons of recoverable gypsum. Purity of the gypsum strata was 85 wt.-% $CaSO_4 \times 2H_2O$.

Table 13: Chemical analyses (statistical mean of data in wt.-%) of gypsum from Pindiro and Mbaru deposits (after Shah & Kisae 1981):

	Pindiro	Mbaru
no of samples	*27*	*93*
R_2O_3	1.18	n.a.
CaO	30.65	26.24
MgO	1.13	n.a.
SO_3	38.66	n.a.
NaCl	0.056	n.a.
acid insol.	6.27	4.89
LOI	21.98	18.51
calculated		
$CaSO_4 \times 2H_2O$	82.9	85.5

Figure 23: Map of gypsum deposits in the Kilwa District (after Shah & Kisae 1981).

Figure 24: Tilted layer of gypsum in the mined-out Mbaru open-cast gypsum mine.

- Several small gypsum deposits (Lasa, Bendela, Station) are located at Mkomazi about 160 km NW of Tanga and about 64 km SE of Same. This area has been mined since 1952 and for many years used to be the most important supplier of gypsum in Tanzania. Gypsum was also exported to Kenya and Uganda. The average gypsum content is said to be 63 wt.-% with massive compact nodular gypsum containing 78 to 82 wt.-% $CaSO_4$ x $2H_2O$. The thickness of the overburden is about 1 m. Most of the gypsum still produced is delivered to the Tanga cement factory.

  Other gypsum deposits of similar type but even better quality are said to occur at Mnazi some 50 km NE of Mkomazi, and at Bendera, about 22 km from Mkomazi Railway station. No reserves or other details are known.
- The Makanya gypsum deposit (4° 34.5' S, 37° 73.1' E) is located some 25 km south of the town of Same and some 10-15 km west of the railway line from Dar es Salaam to Arusha. It was discovered in 1929. While today there is just a vast plain with inselbergs formed by gneisses of Precambrian age, in Plio-Pleistocene time there was an extensive saline lake. Here silty-clayey sediments were deposited together with brecciated earthy gypsum and a gypsum layer up to 50 cm thick below some 2 m of overburden. While in the basin there has never been any exploration by drilling, the top layers are well known from pitting and trenching. However, because the basal layer never was encountered, the total thickness of the gypcrete strata remains unknown. "Calculations" of the total gypsum resources are also quite variable with estimates ranging from 1.2 to 4.8 million tons. The average content of $CaSO_4$ x $2H_2O$ in the gypcrete is said to be 66 wt.-%. Massive boulders of gypsum within the gypcrete were analysed and contained up to 83 wt.-% $CaSO_4$ x $2H_2O$. Similar to all other gypcrete deposits in Tanzania secondary selenite formation is quite common.

Mineralogy (by XRD): Gypsum, with very minor amounts of calcite and quartz, as well as traces of albite and palygorskite.

Table 14: Chemical analysis (data in wt.-%) of gypsum bulk sample from Mkomazi deposit.

R_2O_3	CaO	MgO	SO_3	acid insol.	LOI	*total*	$CaSO_4$ x $2H_2O$ (calculated)
3.8	22.7	1.8	32.3	14.4	15.4	*90.4*	69.4

Table 15: Chemical analyses (data in wt.-%) of gypsum layer samples from Makanya deposit (various authors).

Sample-#	#1	#2	#3	bulk sample
SiO_2	11.5			
Al_2O_3	3.2			
Fe_2O_3	0.5			
R_2O_3	-	4.51	3.43	2.3
CaO	29.4	27.20	27.63	23.8
MgO	0.5	0.63	1.00	1.1
SO_3	33.9	34.06	32.58	32.9
acid insol.	-	9.21	11.11	23.3
LOI	20.2	24.07	24.11	16.1
total	*99.2*	*99.68*	*99.86*	*99.5*
Calculated				
$CaSO_4 \times 2H_2O$	72.7	73.1	69.9	70.7

Table 16: Selected chemistry of bulk rock analysis by XRF of high-grade gypsum sample from Makanya gypsum deposit (BGR analysis).

Chemistry	wt.-%	Limits / Ranges for applications
SiO_2	10.78	
Al_2O_3	1.46	<0.15 (gypsum wall boards)
Fe_2O_3 total	0.69	
MgO	0.64	<0.1(<0.05) (gypsum wall boards)
CaO	29.12	
Na_2O	0.19	<0.06
K_2O	0.26	
(SO_3)	34.97	
(Cl)	0.04	<0.01
Sr	0.52	
LOI	20.75	
total	*99.78*	
Calculated		
$CaSO_4 \times 2H_2O$	77.05	>80 (gypsum wall boards)
		>70 (retardant in cement making)

Artisanal mining of gypsum at Makanya on behalf of license holders has been going on for decades and continuously opens up new areas. Average current annual production from this site can be estimated to be around 60,000 t of raw gypsum. Most of this gypsum is used as a retarding agent in the cement factories at Tanga (230 km away) and Mbeya (1,050 km away). Before transportation however, the gypcrete has to be ground and cleaned by sieving to remove dirt.

Recently a similar deposit of much higher grade was said to have been found at Mwanga, some 50 km from Moshi. Here a 1.5 m thick bed of gypsum is reported to occur. No more details are known yet.

- The Msagali gypsum deposit lies some 75 km east-SE of Dodoma as the crow flies (6° 09.572' S, 36° 47.074' E). It was discovered by GST when checking Msagali mbuga for

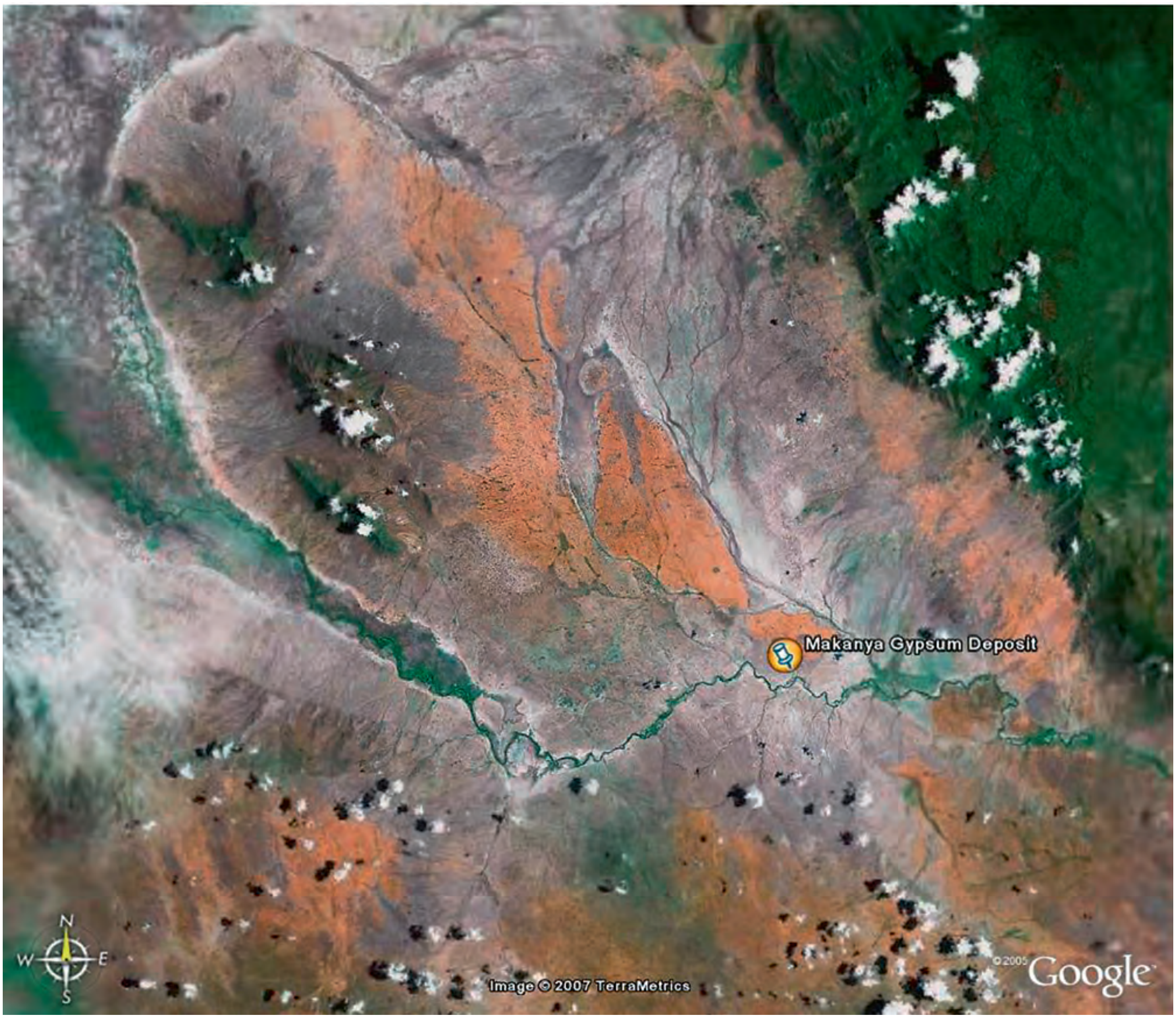


Figure 25: Satellite image of desiccated Pangani Lake showing the Makanya gypsum deposit in lower right side (Photo courtesy of Google Earth).

Figure 26: Artisanal mining of gypsum at Makanya.

limestone in 1953. Only impure dolomitic limestone, clay and gypsum were discovered. Soon afterwards, gypsum mining started by small-scale miners. A Tanzanian mining company as the license holder took over some years ago. Similar to conditions at Makanya the gypcrete at Msagali was deposited in a Pleistocene lake. Below an overburden of generally 0.6 to 0.9 m, at most 1.2 m, there is a layer of gypcrete some 2 to 4 m thick. Although this layer contains large amounts of gypsum crystals, the average content of $CaSO_4 \times 2H_2O$ in this strata is said to be just 25 wt.-%. This low value needs to be rechecked.

Figure 27: Gypcrete wall in the Msagali open-pit mine.

After clearing the top soil, the rock is mined by using excavators, dozers, and caterpillars. At a central place the gypcrete is sieved into sizes >4 inches (>10 cm), 1 to 4 inches (2.5 – 10 cm), 1 to 3/4 inches (2.5 – 2 cm) and <3/4 inches (<2 cm). Because the latter grain size contains the least amount of gypsum crystals it is discarded. Small-scale miners are employed for handpicking gypsum crystals out of the coarser size fractions. After sieving the crystals are washed several times to get rid of any adhering clay and silt. Clean crystals are dried and packed for shipment by truck or the nearby railway line. Both cement factories in Wazo Hill and Mbeya are supplied. Because mining is possible during dry season only, only about 20 kt of gypsum are produced annually.

- The Itigi gypsum deposit is about 170 km by road west of Dodoma, close to Itigi station on the Central Railway. It was first described in the mid 1920s by a chief engineer of Tanganyika Railways. Similar to the other mbugas mentioned above gypsum occurs as gypcrete, gypsiferous clays and gypsum bands within a clayey matrix. At Itigi, the granitic bedrock is overlain by an angular conglomerate bed, which is overlain by well-defined beds of mottled white and brown gypsiferous clays, the total thickness of which varies from 4 to 6 m. The gypsum content of the clays (6 – 22 wt.-%) shows a marked decrease from the top to the bottom of the sequence. The clays are covered with medium-hard, white to light-grey, slightly silty or clayey fine-grained gypsum. This gypcrete contains small gypsum crystals, large selenite crystals and gypsum nodules. The concentration of $CaSO_4$ x $2H_2O$ varies between 30 and 70 wt.-%. At some places, close to the surface and below the silty soil, white to cream-coloured, powdery gipsite is developed. This stratum has a thickness of 0.5 to 1.5 m. Because it is the best quality material, very often containing >80 wt.-% $CaSO_4$ x $2H_2O$, most of it has already been mined out. Chemical analyses of Itigi gypsum samples are given below.

Table 17: Chemical analyses (data in wt.-%) of gypsum from the Itigi deposit. $CaSO_4$ x $2H_2O$ has been calculated.

sample #	CaO	MgO	R_2O_3	acid insol.	SO_3	LOI	*total*	$CaSO_4$ x $2H_2O$
GC 319	15.1	0.5	4.7	44.1	17.6	17.8	*99.8*	37.8
GC 324	23.4	0.5	3.2	21.2	31.8	19.4	*99.5*	68.2
GC 332	16.6	0.3	3.9	39.7	20.8	18.4	*99.7*	44.6
GC 333	14.8	0.3	4.6	45.0	17.7	18.0	*100.4*	38.0
GC 339	18.7	0.2	4.4	33.2	25.6	18.4	*100.5*	54.9
GC 345	19.6	0.9	4.9	29.8	25.2	19.4	*99.8*	54.1
GC 362	25.4	0.7	3.2	15.7	33.7	20.7	*99.4*	72.3
GC 425	19.6	0.9	6.0	29.8	24.7	19.1	*100.1*	53.0
GC 428	22.6	0.0	1.7	26.7	28.5	19.9	*99.4*	61.2
GC 430	23.6	0.0	1.1	25.5	29.8	20.3	*100.3*	64.0

Most of Itigi gypsum is used as a retardant in the Mbeya cement factory. Other applications are the production of plaster of Paris and blackboard chalk in Itigi town. For this processing only high-grade selenite crystals are used, which after calcination and crushing give a very pure white plaster of Paris. Chalk is moulded using this plaster of Paris in a different manual labour factory.

Crystals of gypsum were also found between the Songwe and Longozi Rivers and in lake beds near Lupa Falls in the Chunya District, Mbeya Region. These small occurrences have no commercial relevance.
Other occurrences of gypsum reported in the Tanzanian literature are Masimani Hill, Hedaru, and Mazinde. No information at all is available on these occurrences.
A gypsum occurrence mentioned in the literature close to Mtegu on the road from Mtwara to Lindi proved to be limestone.

REQUIREMENTS AND EVALUATION

According to official production statistics between 23 kt and 73 kt of gypsum were mined in Tanzania each year between 2000 and 2005. Gypsum is a highly sought after and valuable commodity in Tanzania as demand is rising steadily and imported gypsum is quite expensive. Good quality gypsum will always fetch a good price in Tanzania!
For use as a retardant, a minimum of 70 wt.-% $CaSO_4$ x $2H_2O$ has to be guaranteed at all times. Fe_2O_3, Al_2O_3, chloride, sodium, and any other soluble salts are not wanted. MgO has to be <3 wt.-%. For the production of gypsum wall boards, the $CaSO_4$ x $2H_2O$ content has to be >80 wt.-%. Neither anhydrite, free quartz, soluble salts nor clay minerals are wanted. The content of swelling clays must be <1 wt.-%. Carbonate content has to be low. Chloride must be <100 ppm and Na_2O <0.04 wt.-%.

For all applications, a steady supply of material of constant quality is desirable. Reserves should contain at least 100 kt of mineable raw gypsum.
Potential investors should not focus on the already known gypsum deposits, which are currently being mined in Tanzania. Rather scarce information on other gypsum deposits should be verified and mbugas should be explored. Apparently high-grade gypsum can only be found in the Kilwa-Lindi Region. Here, however, cost-intensive exploration is required to evaluate the prospective area.

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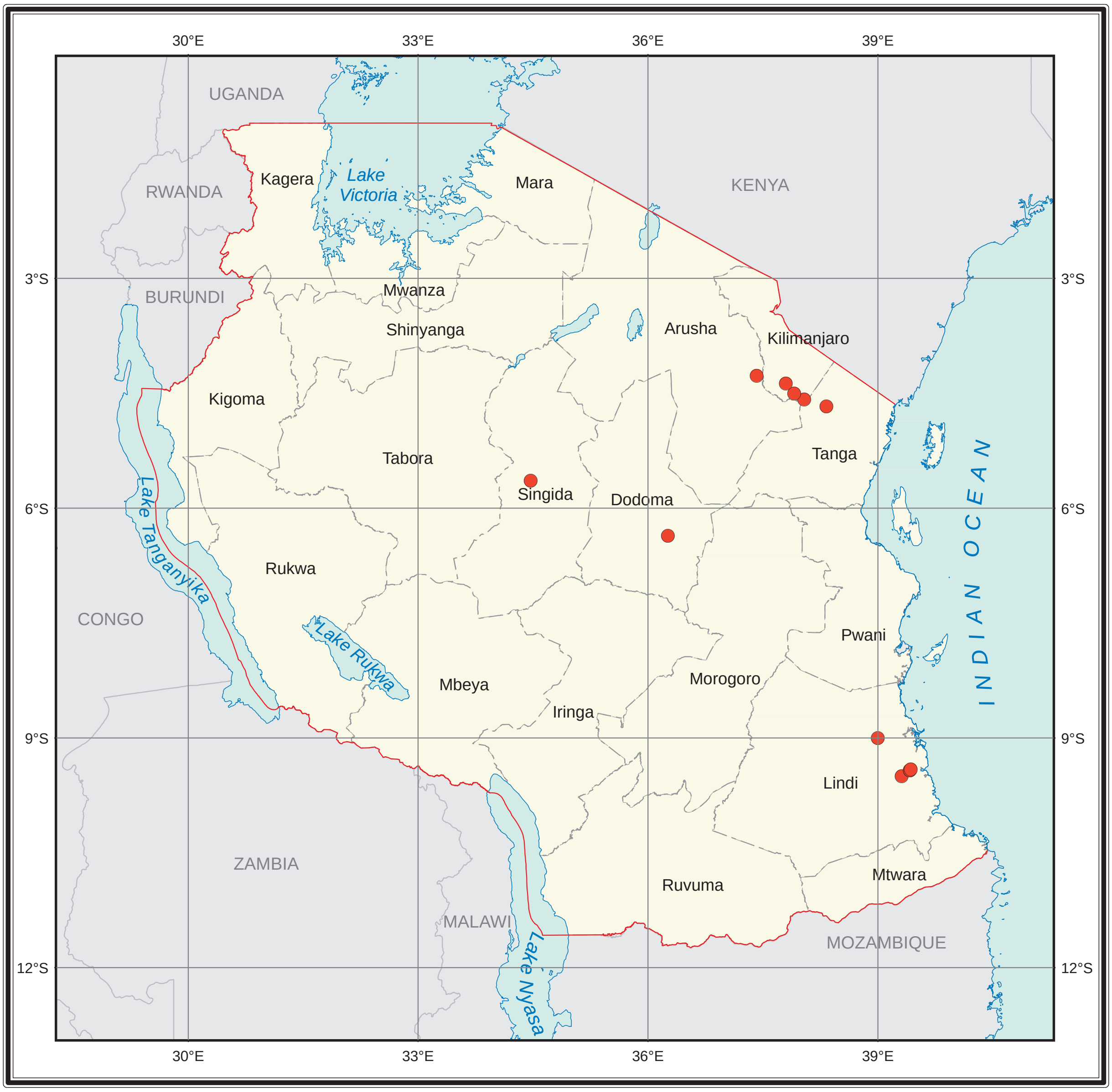
Occurrences of Gypsum in Tanzania



Scale 1 : 10,000,000

0 100 200 300 400 500 km

Legend

● Gypsum

HEAVY MINERALS

GENERAL INFORMATION AND USES

Heavy minerals constitute all minerals with a density eceeding quartz, with economic deposits called placers. Although there are important placers of gold, diamonds and other gemstones, as well as of tin-minerals and tungsten-minerals in Tanzania, this report only considers placer deposits of non-gemstones and minerals with mostly nonmetallic applications. These minerals in decreasing rank of value are zircon, rutile, ilmenite/leucoxene, garnet (see Garnet), staurolite, kyanite and other aluminium-silicates (see Kyanite and Related Minerals). Monazite and rare xenotime from placers no longer constitute valuable minerals, because monazite mostly is highly radioactive and categorized nowadays as a contaminant. Applications for the other minerals are numerous, ranging from the production of glazes and white pigments to the manufacture of welding-rods and construction of nuclear power plants.

RELEVANT OCCURRENCES IN TANZANIA

Because there are world-class heavy mineral deposits of international importance in Mozambique, Kenya, and even in small Malawi, heavy mineral rich sediments in Tanzania have also attracted the attention of geologists and mining companies for decades: because heavy mineral enrichments on beaches between Dar es Salaam and north to Bagamoyo are visible to the naked eye, this area was the first to attract some interest.

Trenches in recent berms were dug to a depth of 2 m, and 400 samples taken from those trenches and along the beach surface. The richest concentrations were found north of big river mouths. The overall composition was said to be fairly constant with grades varying locally and seasonally. Successful mining operation was though possible during erosive periods and on a small-scale basis.

These first reports drew the attention of mining companies. As a result, not only this area but all of the Tanzanian beaches were explored for potential heavy mineral deposits and new samples taken from several locations. This revealed that the information given in the old reports was wrong: the concentrations were actually

Figure 28: Coastal dunes at Msimbati in Mnazi Bay-Ruvuma Estuary Marine Park.

much lower and economic heavy minerals were hardly enriched. However, in 1973 a pilot plant was erected at the Silver Sands deposit (reserves of 11 kt of economic heavy minerals) and small amounts of ilmenite, rutile and zircon concentrates were produced.
After all these new investigations, only one area in Tanzania was still said to be economically mineable. This was the Msimbati South deposit in the Mtwara Region. Here a high dune with a length of 2.4 km and a width of 450 - 650 m was said to contain reserves of some 33.5 million tons of sand with a concentration of about 2 wt.-% economic heavy minerals. Absolute reserves were calculated to be some 470 kt of ilmenite, 70 kt of rutile and leucoxene, and 60 kt of zircon. Recently the Mnazi Bay-Ruvuma Estuary Marine Park was established around the Msimbati dune comprising some of the most beautiful and untouched beaches in Tanzania. For this reason a final assessment was desirable and the potential deposit was therefore visited in 2005 by a joint field team of GST, STAMICO and BGR experts. A representative sample was taken and gave the following results:

Mineralogy of heavy mineral fraction (BGR analysis):

72.7 %	hornblende
16.4 %	epidote
4.5 %	ilmenite (economic)
3.4 %	leucoxene (economic)
3.0 %	garnet
traces:	magnetite, kyanite, tourmaline, pyroxene, apatite
traces:	rutile, zircon, cassiterite (economic)

The percentage of economic minerals (ilmenite, leucoxene, rutile, zircon, cassiterite) of about 8 % of the heavy mineral fraction (8.5 wt.-%) is very low. The absolute content of economic minerals in the deposit (33.5 million tons of sand) is therefore only about 230 kt, which is only a third of the amount previously calculated and which is much lower than the minimum requested by international mining

Table 18: Grain size distribution of ore sand from Msimbati dune (BGR analysis).

Grain Size (mm)	wt.-%
>0.420	0.119
0.420-0.355	1.176
0.355-0.300	5.715
0.300-0.250	18.018
0.250-0.212	27.889
0.212-0.180	17.381
0.180-0.150	17.614
0.150-0.125	8.442
0.125-0.106	2.430
0.106-0.090	0.787
0.090-0.075	0.315
0.075-0.063	0.083
0.063-0.053	0.025
0.053-0.045	0.012
<0.045	0.013
mean	*206.3 µm*

Total heavy mineral content: 8.5 wt.-%

companies of 1 million tons of economic minerals. This means that the Msimbati heavy mineral deposit is also not worth mining!

REQUIREMENTS AND EVALUATION

Because the mining company reports are usually kept confidential, new companies again and again try their luck by assessing the potential of the heavy mineral deposits on Tanzanian beaches. So far none of those has been successful.
Potential investors, which do not believe the old reports, may focus their intention on raised terraces and dunes to the north of old river mouths. Both basic and very sophisticated exploration tools have and must be used for prospecting. Deposits must have reserves of at least 1 million tons of recoverable economic heavy minerals, with the suite preferably rich in zircon, and rutile. Potential local investors should be aware that heavy-mineral mining requires a great deal of financial strength!

Occurrences of Heavy Minerals in Tanzania

Scale 1 : 10,000,000

0 100 200 300 400 500 km

Legend

● Heavy Minerals

HELIUM AND OTHER NATURAL GASES

GENERAL INFORMATION AND USES

The noble gas **helium** is the second most abundant element in the solar system. The dominant ^4He isotope is formed in stars by nuclear fusion processes and as α-particles during the decay of U, Th and their daughters. Due to its volatile nature, helium is also found in the atmosphere. However, presently the world's supply of helium comes almost exclusively from natural gas production where helium is a major by-product. Due to its special physical and chemical properties – low molecular weight, inert gas, low solubility, high diffusivity, extremely high thermal conductivity and exceptionally low boiling point – helium is used for a wide range of applications such as welding and thermal cutting, laser technology, magnetic resonance imaging, semiconductor processing and in the research and development of materials and cryogenic physics.

RELEVANT OCCURRENCES IN TANZANIA

Two locations in Tanzania are known as natural gas reserves. These are the Songo Songo and the Mnazi-Bay gas fields. However, no significant amounts of helium have been reported from these gas fields so far. Yet, due to the hydrothermal reservoirs related to the East African rift structure Tanzania is rich in hot springs producing gas, of which two groups can be distinguished:

1. Hot springs with high N_2 release often enriched in helium,
2. Hot springs releasing highly CO_2-enriched gases.

Almost all of Tanzania's hot springs have been described by Walker (1969), whereas their gas composition has been reported by James

Figure 29: Makwehe hot spring in Rungwe volcanic area, Mbeya Region, releasing extremely CO_2-rich gas forming travertine.

(1967). According to these sources the Maji Moto Musoma hot spring releases 200 l gas/h containing 13.2 to 13.5 vol.-% helium, and Nyamosi hot spring releases gas with 17.9 to 18.2 vol.-% helium. The Mponde hot spring shows an output of gas with 4.4 to 10.2 vol.-% helium. It should be mentioned that gases emitted with the brines at Uvinza (see Salt, Sodium Chloride) contain 2.5 vol.-% helium, 1.2 vol.-% argon, 1.7 vol.-% carbon dioxide, and 94.6 vol.-% nitrogen.
Much more common are hot springs with high CO_2 emissions. E.g. the Songwe River hot springs are known for their high CO_2-contents of >95 vol.-% at a gas flow of 1,000 l/h. In the Rungwe volcanic area (the source region of the CO_2 being released by the hot springs) the nearly pure CO_2 gas is further purified by a Tanzanian company and used for producing sparkling soft drinks like Coca-Cola® etc.

REQUIREMENTS AND EVALUATION

While helium especially is highly in demand in developed countries, potential investors should be aware that all the discharge data from Tanzanian hot springs is pretty old and gas flow and composition – if known at all – may have changed considerably in the meantime.
Because helium is not easy to analyze, some money has to be spent on new and reliable analyses. In general, natural gas sources are considered to be profitable with an He content of >0.3 vol.-% and a discharge of >2,500,000 m^3 helium/yr. While the annual discharge volume required might be much smaller when using gases with a high He content, a high production rate will still be very difficult to achieve in Tanzania.
Possibly helium can be purified from gases separated in geothermal power plants. However, no reliable calculations can be

Table 19: Hot springs with gas occurrence in Tanzania

Location				Comments
Name of source	Latitude	Longitude	Gas	
Rungwe District				
Songwe River	8° 52´ S	33° 10´ E	>95 vol.-% CO_2	
Kyejo crater	9°156´ S	33° 46´ E	>98 vol.-% CO_2	Gas gathering by drill holes, Tanzanian company TOL Limited
Nyamosi			17.9 to 18.2 vol.-% He	
Maji Moto District				
Maji Moto	1° 37´ S	34° 20´ E	13.2 to 13.5 vol.-% He	bore holes
Gonga	5° 24’ S	35° 26’ E	8.9 vol.-% He	64 km NE of Saranda
Hika			6.7 vol.-% He	11 km north of Saranda
Mponde River Group				
Mponde	5° 18´ S	35° 05´ E	4.4 to 10.2 vol.-% He	~48 km north of Saranda
Takwa			7.0 vol.-% He	
Manyeghi			4.4 to 6.7 vol.-% He 1.2 to 1.6 vol.-% Ar 89.3 to 93.0 vol.-% N_2 0.6 to 1.8 vol.-% CO_2	gas sampling by ~320 m deep diamond-drill holes, ~137 km NW of Dodoma
Sambaru				
Isanja				~72 km north of Saranda

made without new and reliable data!
Partners for exploration and purification may be found in industrial gas companies in Europe, South-Africa or Asia, but not in North America which is rich in helium-bearing natural gas wells itself.

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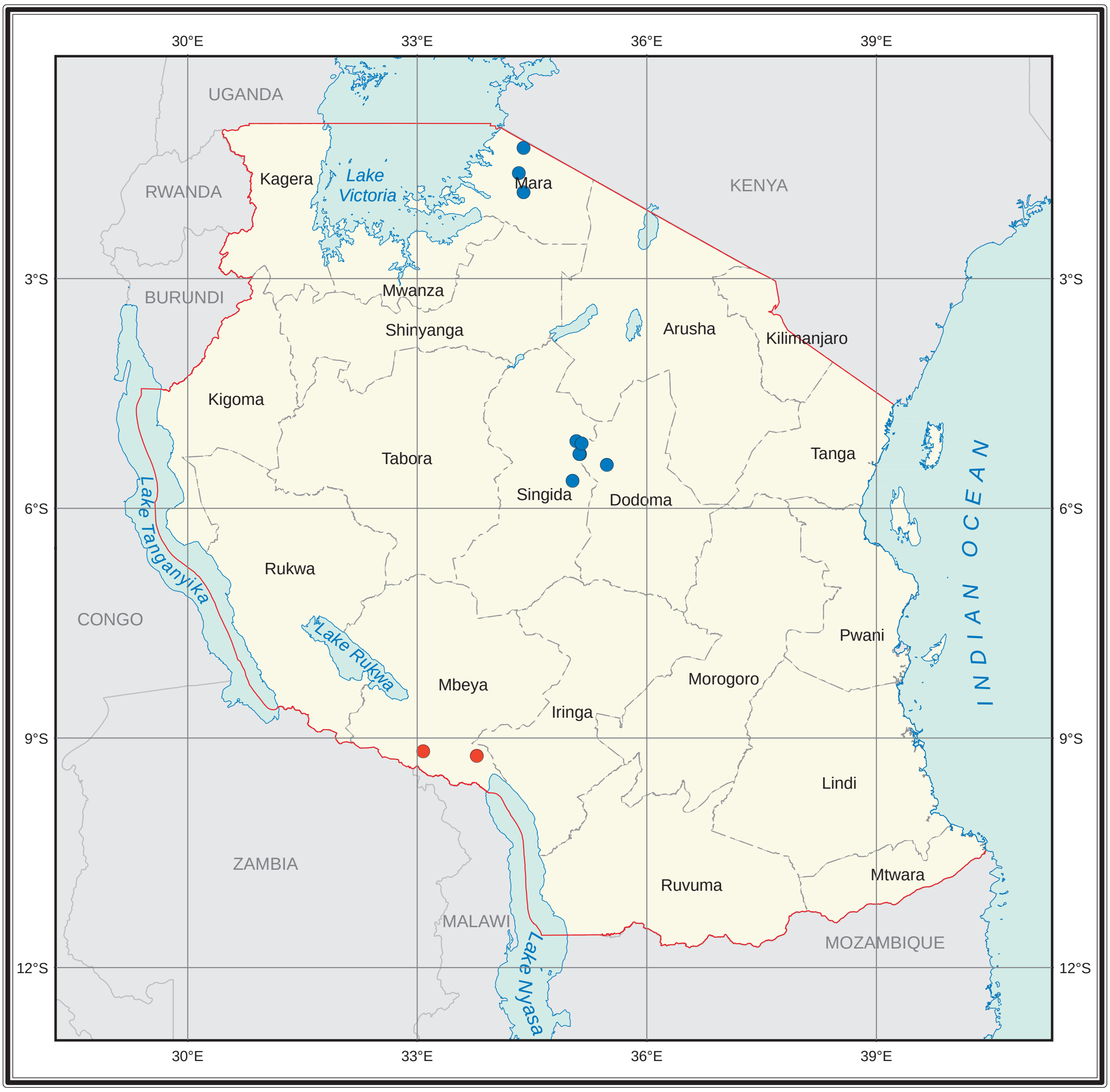
Occurrences of Helium and Other Natural Gases in Tanzania



Scale 1 : 10,000,000

0 100 200 300 400 500 km

Legend

- Carbon Dioxide
- Helium

KAOLIN

GENERAL INFORMATION AND USES

Kaolin, also known as china-clay when occurring in primary deposits, is a commodity made up primarily by clay minerals of the kaolin group. These minerals, the most important being kaolinite, are very rich in silica, alumina and water. Kaolinite is fine-grained, chemically inert, white, coating, soft, non-abrasive, plastic, and refractory. Kaolinitic clays are also called ball clays. The largest use of kaolin is in the production of paper, as it is a key ingredient in creating glossy paper. It is also used in ceramics, medidine, bricks, coated paper, as a food additive, in toothpaste, in cosmetics, and in numerous other applications. An interesting recent use is as a specially formulated spray applied to fruit, vegetables, and other vegetation to repel or deter insect damage. Kaolinitic clays are used in ceramics, as feed additives for animals, and as fillers in chemicals.

RELEVANT OCCURRENCES IN TANZANIA

In Tanzania there are three big deposits of kaolin and some smaller ones.

- One of the most important kaolin deposits in East Africa is in the Pugu Hills, some 20 km west of Dar es Salaam. The infrastructure in the Pugu Hills area is now excellent, except at the former STAMICO mine, which needs improvement. The hills have a well-defined plateau at its eastern edge bounded by a prominent escarpment trending NNE for 8 km. Most of the plateau is covered by thick rainforest (see fig. 30). The Msimbazi River crosses the hills in a deeply incised valley along which the railway line to Morogoro was constructed. Faults divide the area into blocks which are upthrown to the west and thus form escarpments and valleys.
The Pugu Hills are made up from a succession of Neogene sediments, the middle part of which are white kaolin sandstones. They are of shallow-water deltaic origin. The soft friable kaolin sandstone sequence is up to 75 m thick and is overlain by a hard massive kaolin sandstone up to 30 m thick. The combined medium thickness of both sequences is about 80 to 100 m.
The average mineralogical composition of the kaolin sandstone is reported as: 35-37 % kaolinite, 57 % quartz (see Silica Sand), 4 % chalcedony and colloidal silica, 1 % muscovite, 1 % sericite, and 1 % heavy minerals (goethite, hematite, hornblende, magnetite, garnet, epidote, kyanite, apatite, rutile, anatase, andalusite, zircon, and tourmaline). The clay fraction is mainly composed of kaolinite, hard nodular clay with chalcedony and colloidal silica. The clay fraction of the upper massive kaolin sandstone is reported as sonsisting of 91.6 % kaolinite, 4.5 % quartz, 2.4 % mica, 1.6 % goethite, and 0.6 % anatase.

Table 20: Chemical analyses (data in wt.-%) of Pugu Hills washed kaolin samples (various authors, areas and exploration campaigns) and of commercial kaolin produced by Pugu Kaolin Mines Ltd. (last row) (from Salim 1992).

SiO_2	TiO_2	Al_2O_3	Fe_2O_3 total	MgO	CaO	Na_2O	K_2O	LOI	*total*
48.53	0.79	35.68	1.01	0.22	0.40	0.06	0.12	13.08	*99.89*
48.02	0.55	36.38	1.42	0.02	0.09	0.06	0.18	13.48	*100.20*
50.46	0.90	34.06	1.45	0.08	0.11	0.08	0.36	12.37	*99.87*
46.70	0.13	36.33	1.77	0.26	0.08		0.26	13.35	*98.88*
46.80	1.06	36.49	1.52	0.05	0.06	0.04	0.10	14.30	*100.42*
52.40	0.53	33.10	0.14	0.02	0.03	0.10	0.14	12.34	*98.80*

Table 21: Typical grains sizes (data in wt.-%) and average reflectometer values (data in %) of kaolin from the different sandstone sequences at Pugu Hills (from SOLESBURY 1964).

Kaolin from	<1 µm	<2 µm	<5 µm	<10 µm	>10 µm	Reflectometer value
Hard sandstone	74.7	82.3	92.5	97.0	3.0	79-80
Soft sandstone	42.4	56.6	81.0	94.4	5.6	81-85

Table 22: Basic properties of Pugu Hills kaolin (Pugu Kaolin Mines Ltd.) (after SALIM 1992).

<table>
<tr><th colspan="2">Property</th><th colspan="2">Method / Conditions</th><th>Value</th></tr>
<tr><td colspan="2">Whiteness</td><td>based on barium sulphate standard</td><td></td><td>85 %</td></tr>
<tr><td colspan="2" rowspan="2">Fineness</td><td rowspan="2"></td><td><45 µm</td><td>96 wt.-%</td></tr>
<tr><td><63 µm</td><td>98 wt.-%</td></tr>
<tr><td colspan="2">Abrasion</td><td>at 1000</td><td></td><td>32.9 mg</td></tr>
<tr><td colspan="2" rowspan="2">Viscosity</td><td rowspan="2">66.6 % solids, Calgon 0.2 %
Brookfield Sp 3</td><td>100 rpm</td><td>200 cP</td></tr>
<tr><td>10 rpm</td><td>110 cP</td></tr>
<tr><td rowspan="6">Ceramic properties</td><td>Specific surface area</td><td></td><td></td><td>13 m²/g</td></tr>
<tr><td>Modulus of rupture, dry</td><td></td><td></td><td>0.35 MPa</td></tr>
<tr><td>Water absorption</td><td>after firing at 1,250 °C</td><td></td><td>20 %</td></tr>
<tr><td>Optimal addition of deflocculent</td><td></td><td></td><td>10.4 ml/kg</td></tr>
<tr><td>Necessary water content</td><td></td><td></td><td>48.8 %</td></tr>
<tr><td>Casting speed</td><td></td><td></td><td>5.3 mm²/min</td></tr>
</table>

The kaolin sandstone occupies an area of some 20 km (N-S) x 6 km (E-W). Total kaolin resources are estimated at about 2 billion tons! The original reserves in the former STAMICO license area were 1.2 million tons. The ratio of overburden/kaolin at this site are 0.40 m^3/t with some 60 % of the kaolin sandstone being pure enough to be exploited commercially.

Mining at Pugu Hills started in 1942 for local use, and for brick and tile manufacture. Various mining companies mined the resource in different areas with interruptions until 1994. The last mining company was STAMICO which did basic exploration work in 1979 before erecting a modern separation plant at 6° 52.596' S, 39° 4.927' E. Both kaolin and silica sand were produced. Kaolin was sold to former rubber and pharmaceutical factories and silica sand to a former glass factory in Dar es Salaam. Pilot plant tests have proven that kaolin products for rubber, paper, ceramics, and cement industries can easily be produced. Upon reprivatization the STAMICO plant and license were sold, but the mine has not re-opened yet.

- The second very important kaolin deposit is south of Chimala (8° 55.41' S, 33° 58.02 E), Makete District, Mbeya Region, 16 km south of the Iringa-Mbeya road. Here, large areas of the gentle valley slopes of the Ndumbi and Ruaha Rivers E and NE of Matamba (Uwanje Plateau) are covered with a thick blanket of kaolin. Three separate deposits can be differentiated: Ilunga River, Nyamagove River area, and Northern area. At Ilunga River, white, pink, and red kaolin rapidly alternate in vertical sections. The thickness of the kaolin is about 15-20 m with an overburden of 0.2 m. At the Nyamagove River, the kaolin is primary and originated from altered leuco-gabbro. The original thickness of the kaolin was 40 m, but its best part

Figure 30:
Satellite image of the Pugu Hills showing the former STAMICO kaolin mine (Photo courtesy of Google Earth).

Figure 31:
Outcrop of kaolin sandstone in the former STAMICO kaolin mine in the Pugu Hills.

has been denuded. However, the remaining kaolin shows an advanced phase of weathering with only rare pink interlayers. In the northern area, kaolin occurs in the drainage basins of the Ipande and Mklazi Rivers. White primary kaolin is prevalent with some pink and off-white layers, but no extensive deposits of white kaolin were found to occur in this area. Low quality kaolin occurs north of here. While the kaolin is sometimes free of impurities, in other places it is heavily contaminated by weathered gravel and roots. Quite often it is speckled with pink iron-staining. Raw material samples analyzed were reported ranging from low-grade kaolinitic clays to high-grade nearly pure kaolin. The kaolin fires pink at 1,050 °C but turns creamy white to white at 1,200 °C. The sample discs fired at the latter temperature are hard and free from cracks.

Inferred resources for washed kaolin at Chimala were reported as 44 million tons of white kaolin, and an additional 12 million tons of pink kaolin. However, the infrastructure to this hilly area in the Kipangere Range 700 m above Chimala town is poor and will be expansive to improve.

- Another occurrence of kaolinitic material is near Malangali, SW Iringa Region. It is made up of rotten granite, which in localities with high feldspar content has been almost completely kaolinized down to depths of 30 to 60 m. The material is soft and easy to mine. It is exposed in numerous erosion gullies, and can therefore be easily sampled. Some of the material is white and comparatively pure but most of it is pink and iron-stained. Mica is present in large amounts at most locations. This area has not been explored, so no resource estimates or analytical data are available.

Table 23: Chemical analyses (data in wt.-%) of raw kaolin samples from Chimala (from Geological Investigation Team of the People's Republic of China 1973).

	SiO_2	TiO_2	Al_2O_3	Fe_2O_3 total
White kaolin	47.9	0.20	33.00	0.92
Pink kaolin	43.7	0.22	36.95	1.26

Table 24: Chemical analyses (statistical mean and ranges of data in wt.-%) of Chimala washed kaolin samples (various authors, and exploration campaigns).

	Washed kaolin <53µm (n=8)		Washed kaolin (n=6)	
	Mean	Range	Mean	Range
SiO_2	46.18	43.85 – 48.02	46.11	43.06 – 48.18
TiO_2	0.11	0.00 – 0.16	0.19	0.15 – 0.45
Al_2O_3	35.67	33.88 – 38.10	34.42	29.09 – 37.31
Fe_2O_3	1.01	0.62 – 1.37	3.26	1.12 – 6.42
FeO	0.09	0.08 – 0.14	-	-
CaO	0.93	0.59 – 1.30	0.98	0.28 – 1.86
MgO	0.51	0.22 – 0.81	0.67	0.06 – 1.95
MnO	0.01	0.00 – 0.02	-	-
Na_2O	0.20	0.00 – 0.64	0.99	0.15 – 1.95
K_2O	0.01	0.00 – 0.07	0.54	0.08 – 1.50
P_2O_5	0.19	0.12 – 0.25	-	-
H_2O (<110 °C)	2.18	1.56 – 2.71	2.16	1.26 – 4.24
LOI (>110 °C)	12.71	11.29 – 13.97	11.21	9.50 – 12.78
total	99.84	99.57 – 100.15	100.23	99.50 – 100.87

Table 25: Grain size distribution (data in wt.-%) of washed kaolin samples from the Chimala area.

Sample-#	#7199	#7209	#7221	#7202	#7206	#7210
>37 µm	none	none	none	none	none	none
37-26 µm	0.06	1.61	none	none	none	none
26-13 µm	2.63	26.03	0.19	0.26	10.87	8.70
13-9 µm	13.48	20.14	6.59	3.29	38.56	18.41
9-6 µm	16.28	16.79	22.17	24.33	14.68	21.53
6-4 µm	17.23	16.03	14.68	26.59	20.77	15.07
<4 µm	50.32	19.40	56.37	45.52	15.12	36.29

Figure 32: Strong erosion gullies cutting into Chimala kaolin.

- Other kaolin deposits have been reported: they include those of hydrothermal origin in the tin veins of the Karagwe area, in certain mica pegmatites of the Bundali Hills, from alteration of potassic feldspar at Ikwamba between Uponera and Kisitwe in eastern Dodoma District, on the western side of Lake Rukwa north of Nkango Village to Mtuka River, and in the weathered feldspathic sandstones of the Ntumango-Biharamulo District. However, no detailed prospecting was done so far to ascertain their economic viability, and they are most probably not economically mineable.

REQUIREMENTS AND EVALUATION

To be economically mineable, reserves of deposits of kaolin or kaolinitic clay must be larger than 500 kt. The higher the percentage of kaolinite, and the lower the grain-size, the higher the value of the kaolin. Chemically the contents of all soluble salts and all other elements besides silica and alumina should be very low. LOI must be $<$14 wt.-%. Except for the production of paper, extremely low levels of toxic elements like F, Mn, Cu, As, Cd, Pb, Hg have to be guaranteed.
Potential customers of Pugu Hill kaolin should get in contact with the current license holder of the former STAMICO mine. For those interested in their own exploration campaign at Pugu Hill, data on the previous campaigns can be obtained directly from STAMICO. For exploration at Chimala, Malangali or any of the other minor deposits, contact GST in Dodoma.
New investors into Tanzanian kaolin should first identify customers in the local, national, regional and international markets. The economic potential of kaolin mining in Tanzania looks very promising, but because a large amount of investment is needed, sound preparations are essential.

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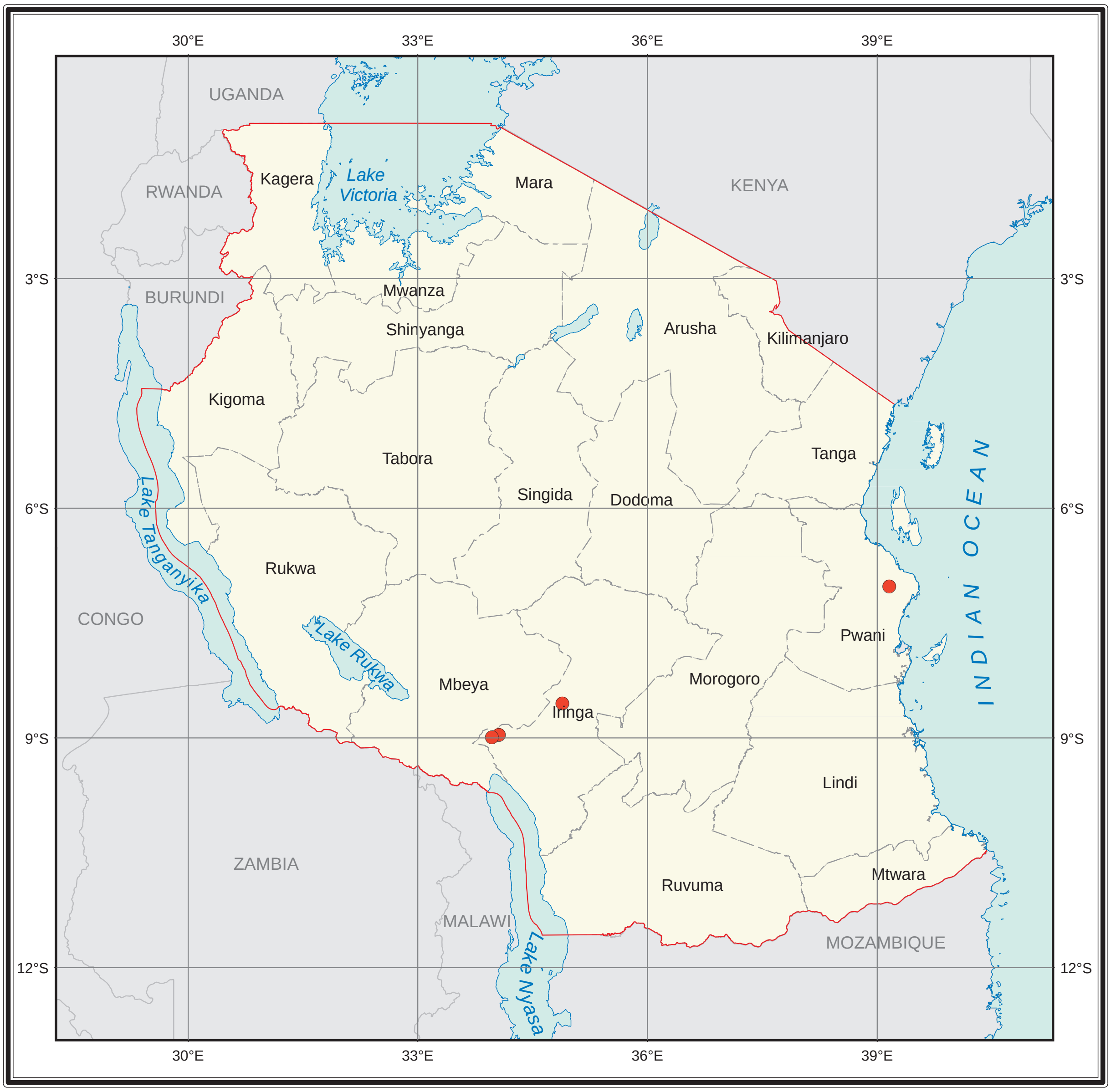
Occurrences of Kaolin in Tanzania



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Scale 1 : 10,000,000

0 100 200 300 400 500 km

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● Kaolin

KYANITE AND RELATED MINERALS

GENERAL INFORMATION AND USES

The rock-forming aluminium-silicates kyanite, andalusite, and sillimanite all have the same chemical composition, Al_2SiO_5, and possess the same economic value as refractories but only after being heated to form the new mineral mullite. Only two criteria are decisive to determine whether any of these minerals are worth mining. Firstly, the volume of reserves available, secondly the transportation costs to the nearest harbour.
It should be mentioned, however, that kyanite also forms very nice blue crystals, which in clear form, may give nice – but low-priced – gemstones. Much more often it occurs in blue massive form, which may be used as a raw material for making beads.

RELEVANT OCCURRENCES IN TANZANIA

In Tanzania, there are numerous occurrences of **kyanite**, because this is a typical metamorphic mineral and Tanzania is very rich in metamorphic rocks. Coarse-grained kyanite has been recorded from:

- Uguruwa Hill, Pare Mountains, 16 km north of Mkomasi railway station. Here a kyanite-rich gneiss band is reported to extend for at least 5 km over the neighbouring hills. Several claims were registered in the 1960s with one claim even reporting small production. A channel sample taken from the quarry face contained 84 vol.-% kyanite and sillimanite, but the rock in general is a white gneiss made up of quartz, white mica, garnet and sillimanite, in which the kyanite is closely intergrown with the other constituents.
- Chankuku, on the western scarp of the South Pare Mountains, 3 km east of Hedaru railway station of the Tanga-Moshi railway line. Here, blue kyanite occurs as disseminated crystals and occasional small masses in a white schist composed mainly of quartz, together with 25 – 35 vol.-% white kyanite and/or sillimanite. The white kyanite is massive, fine-grained and associated with quartz and rutile. Resources were calculated by GST to be only 200 tons of white kyanite and 3 tons of blue kyanite. After beneficiation a kyanite test concentrate with 30-38 wt.-% SiO_2, 1.0 wt.-% TiO_2, 58-59 wt.-% Al_2O_3, 0.5 wt.-% Fe_2O_3, 0.5 wt.-% CaO and 0.3 wt.-% MgO was produced from this deposit.
- In the Pare Mountains also at Ugweno, Chaborati and Longwana, all with low percentages of blue kyanite in a white kyanite gneiss bedrock.
- In the Usambara Mountains, three occurrences of massive blue green kyanite are known. They are Hakichoo (15 km NE of Mkomazi at the foot of the mountains), Makalungi (3 km south of Magamba Mountain and 8 km north of Lushoto), and Gologolo (3 km east of Shume on the Lushoto-Mgwashi road), all in the Lushoto District, Tanga Region. All these deposits are said to be quite small.
- At Sidi Hill some 3 km west of Mbulu Township immediately south of the Dongobesh road. White-blue kyanite crystals occur in folded muscovite-schist carrying local traces of kyanite. No reserve figures are given but they are supposed to be small.
- At Idibo (6° 2' S, 37° 4.5' E), 101 km from Kimamba on the Central Railway or just 5.5 km by rough road from the main Kilosa-Dodoma road. The latter deposit is also very small with calculated resources of only around 600 tons of kyanite.
- In the Handeni area from the Kitwai mbuga, about 96 km NW of Handeni, where several occurrences of blue kyanite have been recorded, sometimes as pure masses apparently derived from kyanite segregations.
- In the Chala-Kisi area in the Ufipa District patchy segregations of kyanite in an area

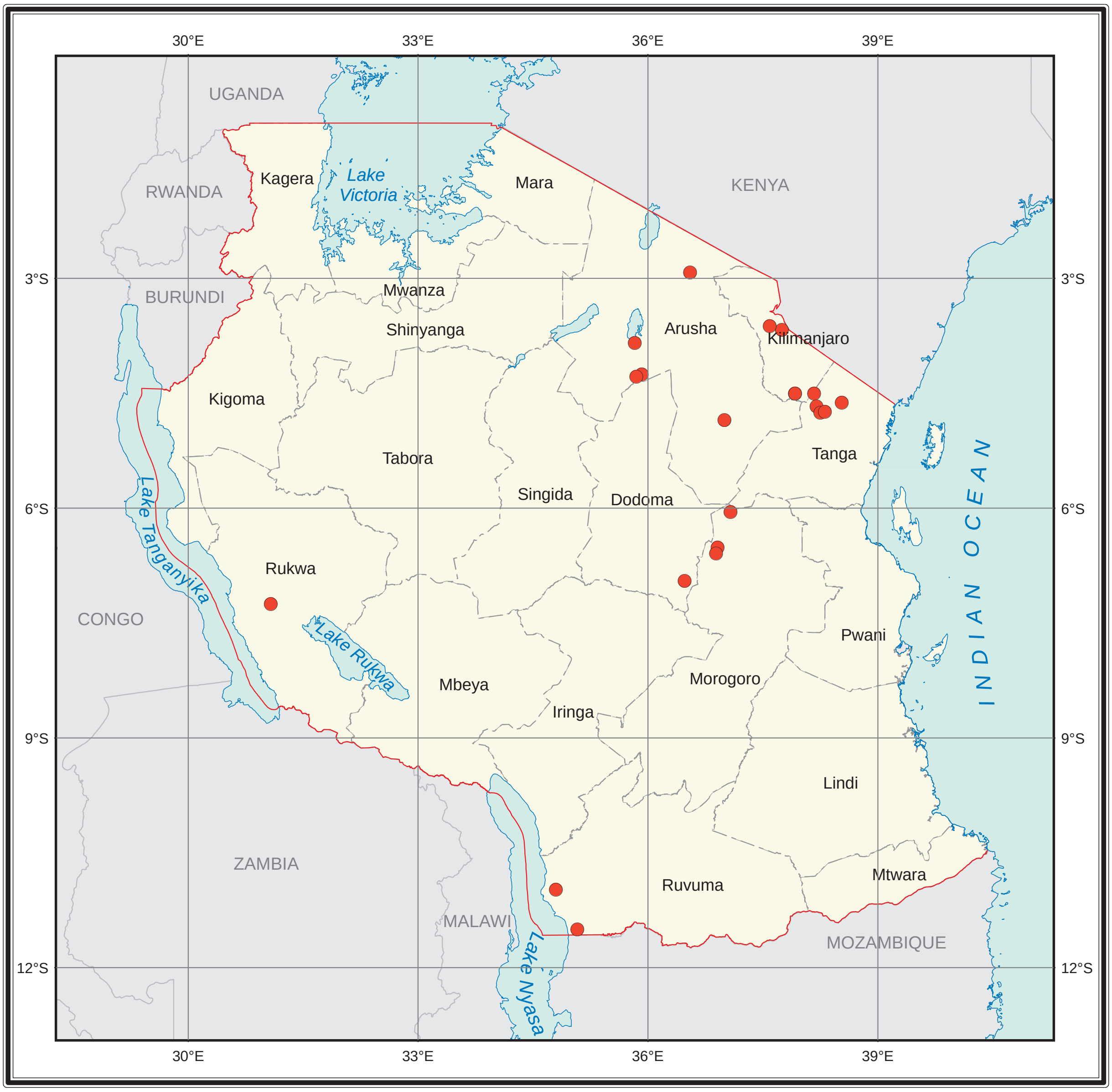
of pegmatites were reported by a mining company in 1951. Low-grade kyanite rock occurs on the northern slopes of Chala Hill, with eluvial kyanite found on top of it.

- Kyanite schist containing up to 20 % kyanite occurs on the western flanks of Kwaraha Mountain, near Babati, and near Galappo Mission.
- Kyanitiferous sands have been recorded from Galigali in the Usagara Mountains, about 50 km south of Gulwe station on the Central Railway; and from the Handeni District, south of the old mica workings at Dibugano.
- Sillimanite has been recorded in rocks from Dodoma, but no deposit is known.

REQUIREMENTS AND EVALUATION

While there are numerous old reports on kyanite-bearing rocks in Tanzania, no really big deposit has ever been described. Nowadays kyanite deposits worth mining have to have reserves of some 50 kt, and ideally 1 million tons of kyanite. These are figures which cannot be guaranteed in any of the Tanzanian occurrences. Potential investors, therefore, should not try to identify a big kyanite deposit but one with large masses of blue kyanite, which may be used to produce beads for the low-price jewellery industry.

Occurrences of Kyanite and Related Minerals in Tanzania



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0 100 200 300 400 500 km

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● Kyanite

LIMESTONE

GENERAL INFORMATION AND USES

Between 1 and 3 million tons of **limestone** are mined in Tanzania every year. The uses of limestone are numerous and are shown in the diagram on the opposite page. In Tanzania, the main uses are the production of cement and aggregates. Quick-lime is currently only produced in the Mbeya area, although it is also a very important building material, e.g. for the production of mortar. However, all these uses for building purposes will not be described in more detail in this publication. Crystalline limestone, i.e. marble, may also be suitable for the production of very nice and valuable dimension stones (see Stones, Dimension).
There is another interesting application for limestone whose relevance for Tanzanian industry was first pointed out by Spencer (2003). By making some phone calls he found out that some 15 kt of ground calcium carbonate (GCC) are currently consumed in Tanzania - all of which is imported. GCC is already used in Tanzania as a filler in paint (some 5 kt/yr.) and plastic (some 10 kt/yr.). Another important

Table 26: Specifications (standard values) for carbonate filler and coating pigments for various end uses.

End uses	Average particle size (µm)	Content (wt.-%) of particles <.. µm								
		50	44	25	10	7	6	5	2	1
„Coarse“ filler , various end uses; remission [1] ~90 %	16.5	97	-	61	-	-	-	-	-	-
Filler/extender for plastics, rubber, sealants; remission [1] ~93 %	5.5-6.0	-	-	97	-	-	46	-	23	-
Stearate coated filler for paints and plastics; remission [1] ~96 %	0.7	-	-	-	-	-	-	-	90	-
Filler for sealants, latex paint, rubber; remission [1] ~93 %	7.0	-	99	-	-	50	-	-	-	10
Filler for paper; high remission: 96 % [1]	1.5	-	-	-	99	-	-	93	58	37
Pigment for paper coating, remission [1] ~91 %	0.55	-	-	-	-	-	-	100	93	73

[1] testing method not stated

Table 27: Physical parameters for carbonate fillers and paint pigments (GCC = ground calcium carbonate /PCC = precipitated calcium carbonate) used in the paper industry.

	GCC						PCC	
	Chalk		Limestone		Marble			
Average grain size (µm)	1.5-2.4	0.7-1.5	1.1-1.5	0.6-0.7	1.2-1.6	0.4-0.8	1.5-3.0	0.5-0.7
Amount of particles (wt.-%) <2 µm	30-65	65-95	60-70	90-95	55-65	90-98	30-40	90-98
Specific surface (m^2/g)	2-4	4-9	6-8	10-12	6-8	10-16	5-11	8-16
Remission (%) ISO [1]	80-97		80-92		88-96		92-97	
Oil absorption (g/110 g)	-		15-25		15-25		30 [1]-55 [2]	

[1] ISO-remission usually 1-2 units lower than the GE-remission used in the USA (GE = General Electric)

use would be as a filler for paper production. The investment needed is moderate and test products could easily be supplied to Tanzanian customers for demonstration purposes. The industrial specifications for GCC are given below:

Figure 33: Main end uses of limestone.

Iron and steel industry	Blast furnaces	Steel works		Foundries	Cold rolling, pipe and wire works
Chemical industry and other industries	Carbide industry	Fertilizer industry	Soda industry	Coal mining	Other chemical and non-ferrous metal industry
	Glass industry, fine ceramics	Sugar industry	Cellulose, paper industry	Tanneries, dye works, etc.	Dye industry etc.
Construction materials industry	Cement industry	Refractory and ceramics industry	Lime, lime-silica brick industry	Cement and mortar industry	Artificial stone and other construction materials industry
Building industry	Building construction	Road construction	Railway construction	Hydraulic engineering, bridge construction	Earth works (e.g. ground stabilisation, erosion protection)
Agriculture	Fertilizer, soil improvement	Fertilizer processing	Animal feed	Conservation	Disease protection, pest control
Environmental protection	Treatment of drinking water and process water	Sewage treatment	Flue gas cleaning	Sludge treatment and soil remediation	Waste disposal

RELEVANT OCCURRENCES IN TANZANIA

A list of the limestone deposits in Tanzania was given in full length and with analyses by Kimambo (1986, ed.). Also, all occurrences of marble in Tanzania with chemical analyses were described by Wright (1938). The potential investor is referred to these publications, which can be studied in the GST library/archive in Dodoma.

RELEVANT LITERATURE

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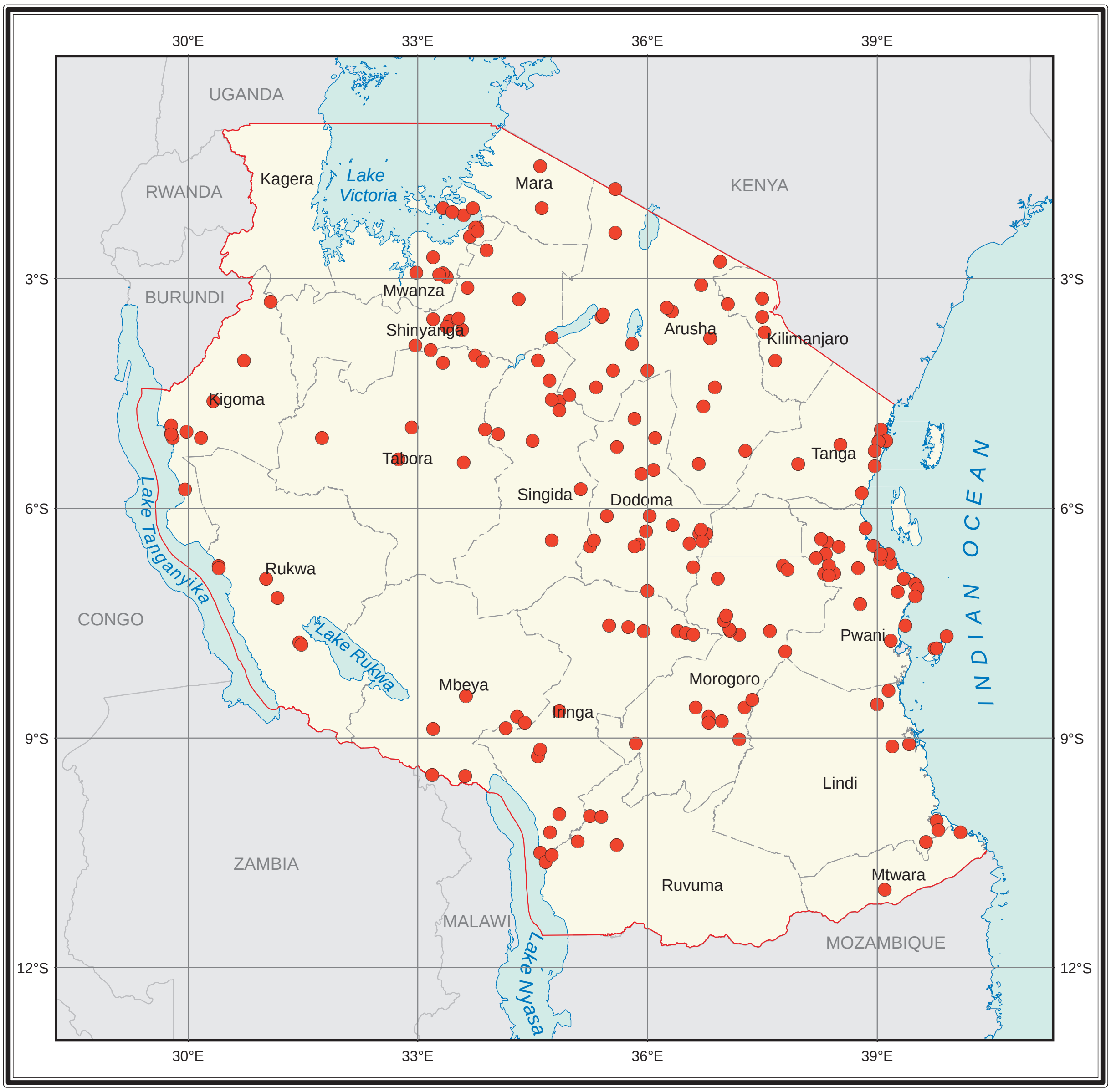
Occurrences of Limestone in Tanzania



Scale 1 : 10,000,000

0 100 200 300 400 500 km

Legend

● Limestone

MAGNESITE

GENERAL INFORMATION AND USES

Magnesite, chemically $MgCO_3$, is a magnesium carbonate, which in nature very often occurs together with other carbonates, like calcium carbonate (calcite), iron carbonate (siderite), or magnesium-calcium carbonate (dolomite). While magnesite only refers to the natural, unburned mineral extracted by mining, magnesia is the name of the calcined processed product. Raw magnesite can be used as a soil improver, as an additive in glass and ceramics manufacture, as a filler/ extender in paints, paper, plastics and rubber or as an anti-caking material in cooking salt and ammonium-nitrate fertilizer. However, most magnesite is used in calcined form (caustic magnesia, burning temperature 600 – 1,000 °C) and dead-burned form (sinter magnesia, burning temperature 1,700 – 2,000 °C). Caustic magnesia has similar and additional uses as raw magnesite, e.g. as a magnesia binder in the construction materials industry. Sinter magnesia is an important refractory material and can even be "fused" at 2,800 – 3,000 °C to get fused magnesia, which is a very special high-temperature refractory material.

RELEVANT OCCURRENCES IN TANZANIA

In Tanzania, most magnesite occurrences are of hydrothermal origin with magnesite occurring as small veins and stringers in ultrabasic rocks. Although occurrences of magnesite are numerous in Tanzania, and some even have been mined in the past, reserves are very limited. The most important occurrences are:

- Chambogo about 5 km from Mwembe Village and about 13 km SE of Same in the Pare District. The railway line from Moshi to Tanga is 7 km away. This deposit has been explored in great detail and consists of a stockwork of magnesite veins within serpentinite outcropping on a hillside. The hill measures 340 m in height, 600 m in length and 200 m in width. The maximum width of the veins is 0.3 m with about 80 vol.-% of the veins being veinlets <0.05 m thick. Average of magnesite veining is 8 – 12 vol.-% (range 0-37 vol.-%) of the rock. The magnesite is sometimes pure and white, but more often it is greyish and silicified. After calcination the colour of the snow white magnesite changes to light brown with dark brown patches. Between 1968 and 1971, proven reserves were calculated as 122 – 318 kt and probable reserves as 41 – 183 kt of magnesite respectively. Inferred resources of magnesite were estimated as 843 kt, probable resources as 1,118 kt and possible resources as 1,321-1,727 kt. I.e. total reserves may have been about 500 kt of magnesite. The Chambogo deposit was mined intermittently between 1963 and 1992 with raw magnesite above all exported to Germany and the USA. Caustic magnesia was produced on site as a feed additive and for export to England. The remaining reserves are said to be about 100 kt of magnesite.
- Merkerstein Hill, which is an occurrence in northern Arusha District, just west of Longido (see Stones, Ornamental and fig. 84). Here exceptionally pure magnesite occurs as veins filling joints and fractures in unsheared serpentinite, where its makes up about 10 vol.-% of the rock. Wider veins of this deposit were mined in the 1950s and a few thousand tons of magnesite were exported to nearby Nairobi for use in the manufacture of epsom salts and building blocks.
- A chain of nickel bearing serpentinized peridotite hills occurs in the area of Haneti and Itiso, about 100 km north of Dodoma. Magnesite veins in some of the hills are abundant with Iyobo, Mnakura Hill, Mwahanza Hill, Msani Hill and Balisa Hill worth mentioning. The veins are from 0.02 to 0.6 m in width with magnesite averaging

about 23 vol.-% of the rock at Mnakura Hill.

- Magnesite veins occur at Lobolorsoit Hill (4° 23.187' S, 37° 28.796' E) in the Kiteto District, Manyara Region about 40 km east of the road from Moshi to Korogwe as the crow flies. This deposit is in a very remote area and was explored by STAMICO in 1981/82 in detail. Veins of good quality magnesite are up to 0.4 m wide and rather irregularly distributed in the country-rock. In 1971, the inferred resources were calculated as 663 kt, with probable resources of 5 million tons of magnesite. However, due to the very irregular nature of the veins it is doubtful whether even 1 kt of magnesite can be mined economically. Mining might only be possible by small-scale miners, who would have to haul the mined material for 80 km before reaching the nearest tarred road.
- Magnesite veins have also been reported from the isolated Lossogonoi Plateau about 100 km south-SE of Moshi. The magnesite occurs as highly disseminated very fine veinlets, and as veins varying from 0.01 to 0.5 m in width. Resources were estimated as 2 kt per 1 m depth or about 150 kt to a depth of 130 m.
- The Kwepungu magnesite deposit lies about 3 km south of Kwalukombo, which is 16 km west of Mbwewe Village which is 75 km from Chalinze on the Chalinze-Korogwe road. Here, cryptocrystalline, white and hard magnesite occurs as highly irregular veins of 0.01 to 0.3 m thickness. The length of the deposit is said to be 750 m and its width is given as 300 m. The silica content decreases with depth, varying from 0.39 – 5.55 wt.-% (average 3.4 wt.-%). Probable reserves were calculated as 185 kt of magnesite.
- The production of Mgagao magnesite started in 1968. The former mine is about 34 km to the SE of Lembeni Railway station in the

Figure 34: Typical "thick" veins of light magnesite at Lobolorsoit Hill.

Table 28: Chemical analyses (data in wt.-%) of magnesite from Tanzania (various authors).

		MgO	CaO	R_2O_3	acid insol.	LOI	*total*
Chambogo (average of 8 bulk samples)		46.42	0.8	0.47	1.26	51.07	*100.02*
Chambogo (average of 10 bulk samples) *MnO = 0.01, Na_2O = 0.09		45.81	0.35	n.d. *	3.86	49.83	*99.95*
Merkerstein Hill		44.2	2.1	0.3	3.3	48.1	*98.0*
Mnakura Hill (average of 6 bulk samples)		45.28	1.53	0.72	4.82	47.78	*100.13*
Mnakura Hill (selected)	North	46.2	0.8	0.5	1.1	50.1	*98.7*
	South	46.2	0.8	0.4	1.0	50.0	*98.8*
Mwahanza Hill	bulk	42.57	2.46	1.46	2.00	51.36	*99.85*
	selected	46.51	0.74	0.76	1.34	50.98	*100.33*
Iyobo		44.79	2.40	0.56	0.12	50.62	*98.49*
Lobolorsoit		45.3	0.36	0.24 (Fe_2O_3)	4.5	?	*50.40*
Mount Gelai		44.72	0.84	1.92	0.70	51.35	*99.53*
Mount Gelai (average of 4 samples)		45.2	1.82	0.55	1.82	50.75	*100.14*
Nyota Hill		45.1	1.1	0.6	1.6	51.5	*99.9*
Kikombo	bulk	40.32	5.08	1.18	3.44	49.38	*99.4*
	selected	41.89	4.98	0.82	1.92	50.36	*99.97*
Lugalla Hills	surface	36.1	9.0	1.9	3.5	48.6	*99.1*
	depth	42.6	1.7	1.4	4.1	49.5	*99.3*
	selected	47.0	0.4	0.2	0.5	52.0	*100.1*
Lossogonoi Plateau (average of 51 bulk samples)		39.7	2.7	1.5	5.6	47.1	*96.6*

Chemically pure magnesite has a composition of 47.8 wt.-% MgO, and 52.2 wt.-% CO_2.

Pare Mountains. The size of the deposit is reported to have been 145 m x 45 m x 120 m. Numerous veins of very white, but sometimes silica-rich magnesite up to 0.6 m thick were mined for just a few years because the original resources were estimated to be about 20 kt magnesite.

- Other small to very small occurrences of magnesite veins of hydrothermal origin were reported from the Lugalla Hills in the Uluguru Mountains (about 15 vol.-% of the rock), from Nyota Hill, Mwanga District, from Vuju Mountain about 88 km SW of Handeni, from the Pangani River valley west of the Pare Mountains, from the Nsamya Hills in the eastern part of the Lupa goldfield, from 1.5 km west-SW of Kikombo, from north of Kalalani Village in the Umba gemstone mining region, from 8 km east of Nachingwea, from 1.5 km west-SW of Kikombo, and from the Ngasamo-Wamungolo Hills 137 km east of Mwanza.
- At the foot of Mount Gelai at the SE end of Lake Natron there are three patches of magnesite which were formed by chemical precipitation of magnesium-rich lava. On the surface there is a hard, ferruginous, limy capping which grades, at depth, through a hard, compact, white magnesite to soft plastic magnesite. In 1951, the inferred resources were estimated as 115 kt, of which some 1 kt were mined in the 1950s and exported to Kenya for use as chippings in terrazzo work.

REQUIREMENTS AND EVALUATION

Raw magnesite should contain >40 wt.-% MgO, and <1.5 wt.-% Fe_2O_3. Hand-picked magnesite intended for the production of sinter magnesia must contain >46.8 wt.-% MgO. Because magnesite is a low-price commodity deposits should generally contain reserves of >10 million tons.
The reserves of all magnesite deposits in Tanzania are very small. Mining of veins of magnesite can only be done economically by small-scale miners. Therefore there is only a very limited chance that any of the magnesite deposits mentioned above might be used as a commercial source for the production of caustic or sinter magnesia. Potential investors who have a wide choice of known magnesite occurrences might rather focus on the local production of raw very pure, i.e. hand-sorted magnesite as a soil improver (when finely ground for use in acid soils), or as filler in paints, paper, and rubber for the local industry.

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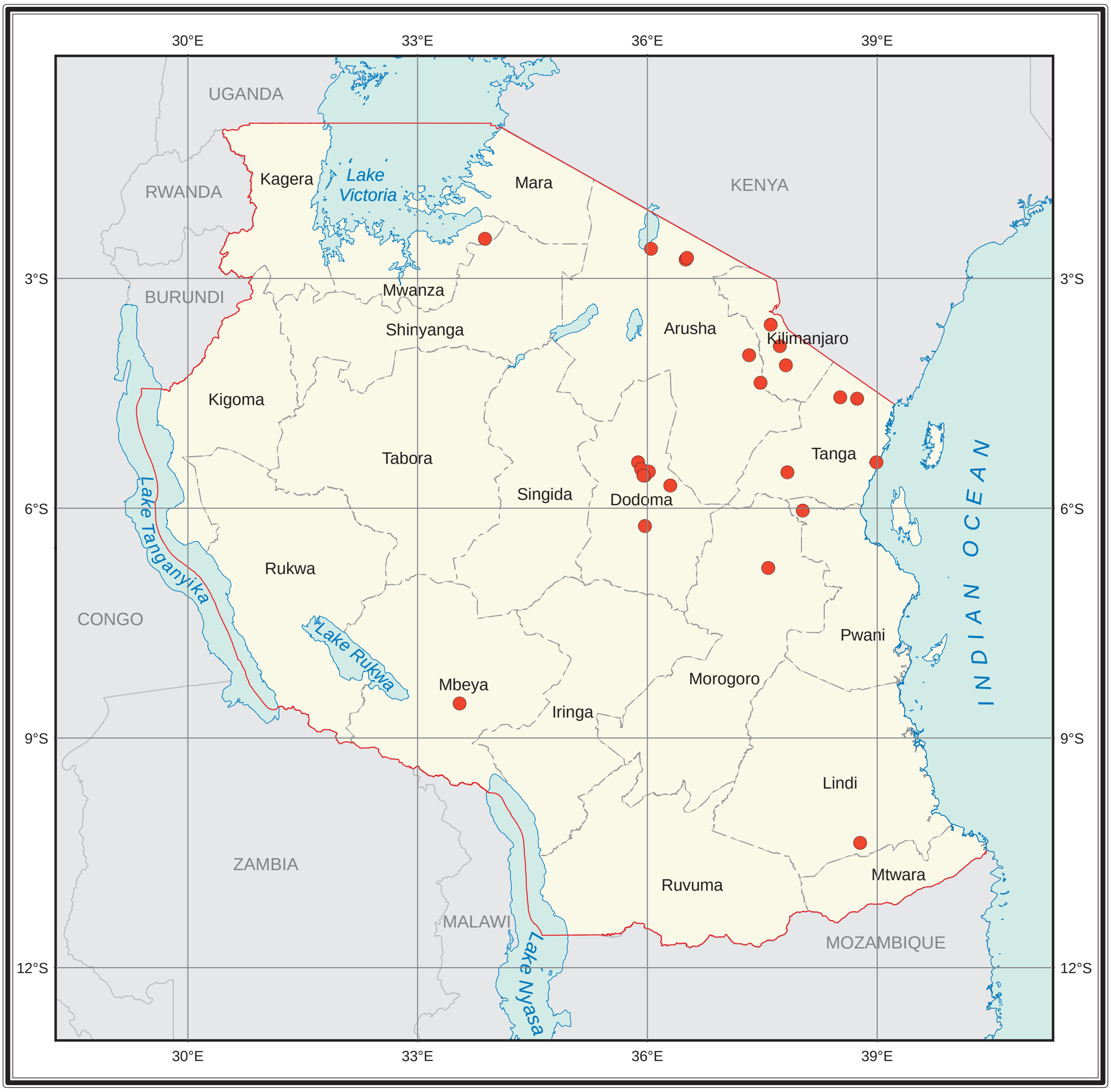
Occurrences of Magnesite in Tanzania



Scale 1 : 10,000,000

0 100 200 300 400 500 km

Legend

● Magnesite

MICA

GENERAL INFORMATION AND USES

There are several minerals in the mica group, of which only muscovite, phlogopite and lepidolite are of any importance to Tanzania.

Muscovite, also called sericite when very fine, is a light silvery glittering mineral occurring in many rocks. It has perfect basal cleavability and a pearly shimmer. Although it comes in light yellowish, light greenish, and light reddish colours most often it has a silver colour when thick and is colourless when very thin. The best quality mica in the world is said to come from Bihar in northern India and is called ruby mica. Muscovite can only be used when occurring in pegmatites where big sheets can reach more than 1 m in diameter.

Phlogopite also has perfect cleavability. It may be thicker than muscovite and most often is reddish, brownish, golden-bronze to yellowish in colour. Big phlogopite sheets are found in carbonatites and in deposits of hydrothermal origin.

Mica has always been mined and beneficiated by hand. It has a high dielectric strength and excellent chemical stability, making it a favoured material for manufacturing capacitors for radio frequency applications. Sheet mica has also been used as an insulator in high voltage electrical equipment. Because it is also birefringent it is commonly used to make quarter and half wave plates. Because mica is resistant to heat it is used for insulation purposes, and can be used instead of glass in the windows of stoves and kerosene heaters. Scrap mica produced when beneficiating sheet mica is used as an active filler in numerous applications, like asphalt, paints and lacquers, drilling mud, plastics, rubber and special paper.

RELEVANT OCCURRENCES IN TANZANIA

Tanzania has long been famous and well-known for its numerous and good-quality mica deposits, which occur in pegmatites only. Mica mining started in 1894 with the first companies entering the market in 1902. About 15 kt of rough mica were produced in Tanzania between 1894 and 1982, of which around 10 % (sheet, scrap, and flake mica) was exported to England, USA, The Netherlands, South Africa, Germany, Italy and Japan. After 1967, mica mining in Tanzania declined sharply and stopped in 1982. Because there are thousands of mica-bearing pegmatites in Tanzania, there have been hundreds of tiny to small mica workings and there remain dozens to hundreds of mica deposits which have not yet been touched.

- The most important mica mining area in Tanzania was the Uluguru Mountains with Morogoro as the mica mining capital of the country. The main concentration of mica pegmatites is in the SW of the Uluguru Mountains. They form a broad northerly striking belt between the Mgeta River and the main mountain range, extending from Mgeta to south of Kikeo. The majority of former mica workings are situated in the valley of the Mbkana River and its tributaries. The pegmatites in this area are unusual in their consistency of strike and regularity of width. They generally dip at moderate to high angles to the west. The mineral content of most of the mica-bearing pegmatites is essentially simple with muscovite and rock quartz (see Rock Quartz) being the only economic minerals. Non-economic accessory minerals worth mentioning are pitchblende, schorlite, and vermiculite. The colour of the mica varies from green to brown, ruby mica quality being known only as the outer zone of crystals which in the centre are green or brown. Some of the mica has excellent hardness and flatness, and certain mines, e.g. Lugala, have produced large

Figure 35: Abandoned Tchenzema mica mine high up in the the Uluguru Mountains.

sheets which compare with ruby mica in quality. However, quite a high proportion of the larger sizes from many other deposits is slightly wavy and sometimes cross-grained. In other pegmatites the mica, although flat, is not as hard as that of the better qualities. Staining is common: it is usually black and/ or red in colour and is often of the lattice type. In certain cases where the staining is very heavy, the mica may be opaque, even in quite thin sheets.

One of the most characteristic features of the pegmatites of the Uluguru Mountains is the development of quartz cores in the majority of the dykes. These cores frequently show on the surface as accumulations of large blocks of massive white quartz and have been one of the greatest aids for prospecting mica in the area.

- The Mikese mica field lies east of Morogoro and to the NE of the Uluguru Mountains.

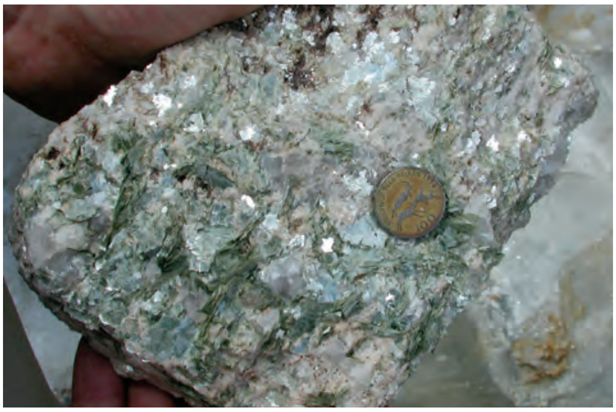


Figure 36: Small mica block with green mica from an old working at Tchenzema.

Figure 37: Small mica block with ruby mica from an old working in the Mikese mica field.

The pegmatites constituting this field occur as a belt running north-NE with quite variable strike. In general the pegmatites are shorter along strike, narrower, and much less regular in shape than the pegmatites of the Uluguru Mountains. The mica produced from the Mikese mica field was principally ruby, and not as badly stained as the brown and green mica from the Uluguru Mountains.

- At Jumbadimwe Hill to the west of the Ukaguru Mountains, fifteen pegmatites were worked to a depth of 20 m between 1930 and 1959. The pegmatites of the Ukaguru Mountains including Jumbadimwe Hill and the area around Kisitwe strike to the NE. They are generally 0.3 to 0.6 m in length and 1.5 to 4.5 m in width. High-quality ruby mica occurs irregularly as pockets, lenses and shoots. Jumbadimwe Hill is said to have been the main source of the best quality ruby mica in Tanzania. Also giant crystals of microcline, biotite, and garnet have been reported. It turned out that only those pegmatites with a north-easterly strike and with white feldspar $>$0.08 m in diameter were profitable; those with noticeable garnet were unprofitable. All surface exposures of muscovite have been worked out at Jumbadimwe Hill, though there is a strong possibility of good-quality mica remaining at greater depths.
- On the NW slope of the Mangalisa Plateau and in the Rubeho Mountains, mica-bearing pegmatites are abundant. Fair-quality ruby, brown and green mica occurs in pegmatites striking between SE and S. Spotting is common but is less pronounced in the ruby mica.
- Between Lake Rukwa and Lake Tanganyika pegmatites are found cutting a variety of metamorphic rocks. They strike predominantly NNW. In former times, the main mica output was from the Nkungi-Sibwesa area, where some of the pegmatites are up to 30 m in width and probably extend for considerable distances along strike. The mica is often of large size but is soft, wavy, and badly spotted and stained; both ruby and green mica were produced. Beryl and or-

Table 29: Chemical analyses (data in wt.-%) of green mica from the former Chambwezi Mine, Uluguru Mountains (from Sampson 1962), and of pink mica (compare with figure 36) from unnamed former working in the Mikese area (6° 45.859' S, 37° 57.779' E, BGR XRF-analysis).

	Green mica Chambwezi Mine	Pink mica Mikese area
SiO_2	41.1	47.59
TiO_2	0.00	0.50
Al_2O_3	36.8	35.21
Fe_2O_3	0.50	1.79 (Fe_2O_3 ^{total})
FeO	0.77	
CaO	0.00	0.029
MgO	1.93	1.54
MnO	0.00	0.012
K_2O	8.14	9.86
Na_2O	0.41	0.74
(SO_3)	n.d.	$<$0.01
(F)	n.d.	0.08
P_2O_5	n.d.	0.006
Ba	n.d.	3,314 ppm
Th	n.d.	$<$5 ppm
U	n.d.	$<$3 ppm
H_2O ($<$110 °C)	0.35	n.d.
LOI (>110 °C)	5.40	2.16
total	100.40	99.83

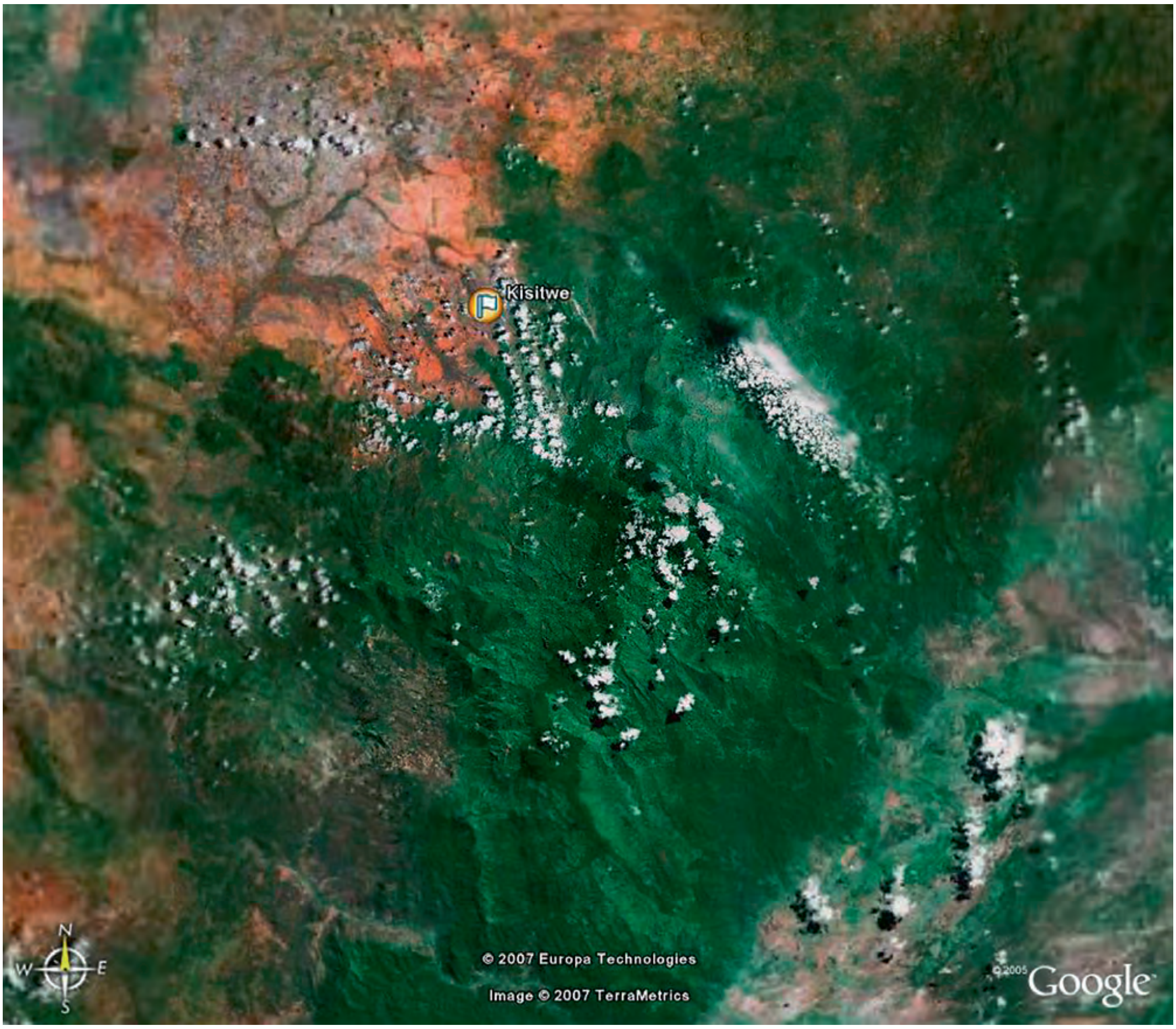


Figure 38: Satellite image of the Jumbadimwe Hill (without clouds) south of Kisitwe and west of the main Ukaguru Mountains (Photo courtesy of Google Earth).

thite are characteristic accessory minerals. Generally, the proportion of mica is higher than in the mica pegmatites of the Uluguru Mountains and some very rich pockets have been found.

- Pegmatites in the Tungwa area (Tungwa, Mchelo, Mkulwe) of the Mbeya District, near Lake Rukwa, have also yielded significant quantities of mostly green mica. Other mica is light brown in colour, has cracks and minor amounts of staining.
- The Makanjiro Mine in the Masasi area yielded a fair tonnage of mica (and beryl) prior to being worked out in 1951.
- The Usambara Mountains have produced mica of record sizes, the largest crystal weighing two tons. Sheets measuring 1.3 m by 0.75 m were obtained from the Mangoda area close to Mombo. Pegmatites have a width of 1.2 to 1.5 m and a length of 200 to 400 m.
- Others areas where good-quality mica has been mined or is said to occur are in the Pare Mountains, at Pikamiho near Songea, at Mahenge, at Mkondami in the Nguru Mountains, at Mbulu, Arusha Region, at Kabende and at Massa in the Mpanda District, at Majiane and Nampalampaka

in the Nachingwea District, at Thombe Hills in the Panda District, and in Bundali Hills, Ileje District.
- Phlogopite has been reported near Pongwe close to the Wami River in the Bagamoyo District. Several tons of phlogopite could also be handpicked from tailings of pegmatites mined north of Kalalani Village (4° 34.64‘ S, 38° 44.35’ E) in Umba area for rubies.

REQUIREMENTS AND EVALUATION

Sheet mica – both muscovite and phlogopite – should have as few colour zonations, fractures, cracks or textures, stains or spots as possible. It should not have any inclusions of air or other minerals. Sheets must be plain and hard. The best quality sheets must have a useable size $>$645 cm^2, with the shortest size $>$10.2 cm. Lowest quality sheets must have a useable size between 4.8 and 6.4 cm^2, with at least one size having a length of $>$1.6 cm. Deposits should have mineable reserves of $>$500 t muscovite or $>$50 kt phlogopite.
Potential investors may find economically mineable mica deposits in any of the regions mentioned above. Because exploration is by surface-pitting and following the mica to depth only, this is essentially a small-scale and low finance business. However, exploration may take some time because experienced geologists in the past estimated that the ratio of rich pegmatites to those which are either uneconomic or only just profitable is probably no greater that 1 % and may be even less. After establishing a source of good-quality mica, the license holder should get in touch with STAMICO or Embassies in Dar es Salaam to identify companies in SE-Asia, Europe, South Africa or North America, which might be interested in securing a new supplier.

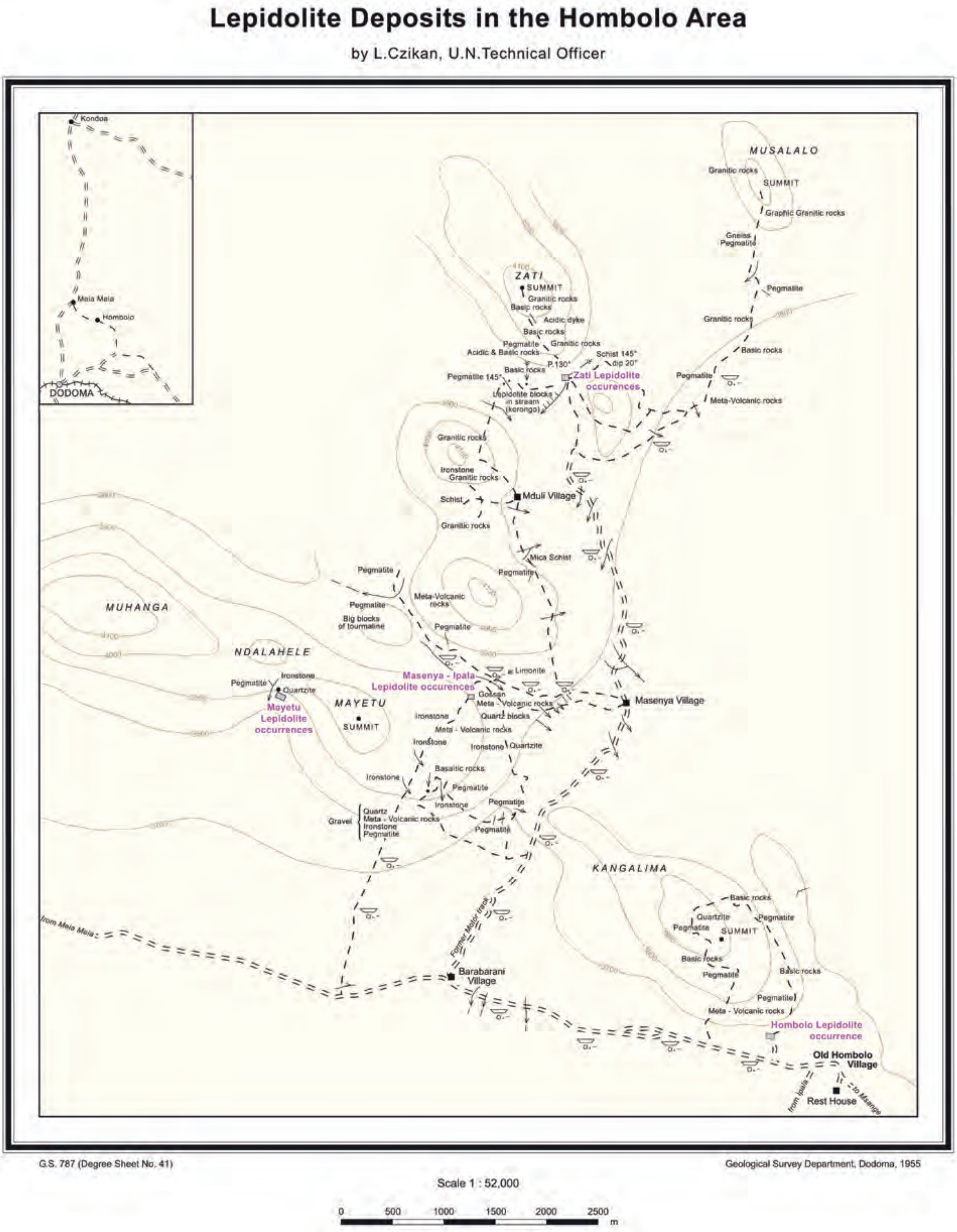
Several thousand tons of good quality scrap mica could also be collected from nearly all of the old mica workings, because in former times just a few percent of rough mica was sold as sheet mica after being hand-cut at the mine entrances.
After cleaning, crushing, grinding or milling, this scrap mica might even be used as high-quality filler in the local paint industry.

GENERAL INFORMATION AND USES

Another mineral in the mica group, **lepidolite**, was once an important raw material for the beneficiation of lithium. Lithium is a light metal, which is used in batteries, in medicine, in pyrotechnics, and in space and nuclear industries. Today, most of the lithium used comes from brines in Chile, Argentina, USA, and other countries. Lepidolite is still used in the glass industry as an ingredient of heat-resisting flint and opal glass and also as the basis for the manufacture of flux suitable for the welding of aluminium.

RELEVANT OCCURRENCES IN TANZANIA AND EVALUATION

In Tanzania, several small occurrences of this pale pinky-mauve mica are known. These are Zati, Mayetu, Masenya-Ipata, and Hombolo (5° 53.400’ S, 35° 56.907’ E), all very close to Old Hombolo Village, which is at the foot of the Chenene Range about 40 km north-NE of Dodoma. Here lepidolite (5.15 wt.-% Li_2O) occurs as small flakes together with black, red, and green varieties of tourmaline in several heavily iron-stained pegmatite bodies. Accessory minerals are rubellite, zinnwaldite, and cookeite. No reserves have yet been established, but presumably they will be rather small. Potential investors might be interested to check this area of lithium-bearing pegmatite dykes not only for lithium minerals, but also more for nice specimens of tourmaline which seem to be quite common in these pegmatites.



Legend

Pannings for gold in red ground gravel

Lepidolite occurrences — Lepidolite deposits

Traverses

Elevation in Feet

Figure 39: Map of lepidolite deposits in the Hombolo area (Czikan 1956).

Figure 40: Rock specimen from the Hombolo pegmatite showing lepidolite and green tourmaline.

RELEVANT LITERATURE

CZIKAN, L. (1956): Notes on the Hombolo lepidolite occurrence, Dodoma District.- Geol. Surv. Tanganyika , Rep., LC/1: 2 pp., 1 map; Dodoma (unpublished).

SAMPSON, D.N. (1956): The mica pegmatites.- Geol. Surv. Tanganyika , Rec., IV (1954): 21-31, 1 fig., 2 plates; Dar es Salaam.

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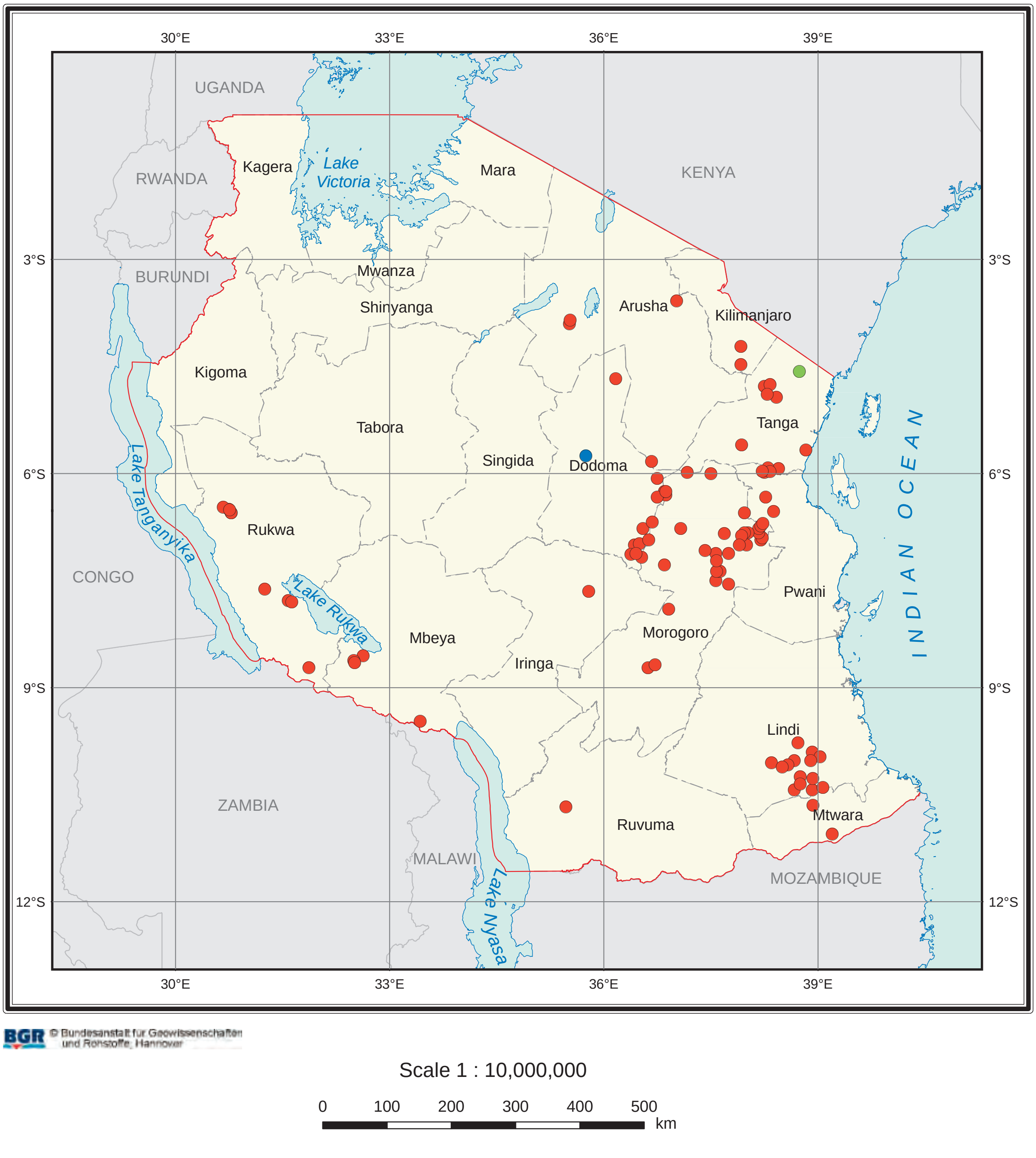
SAMPSON, D.N. (1962): The mica pegmatites of the Uluguru Mountains.- Geol. Surv. Tanganyika , Bull., 35: 74 pp., 1 fig., 6 tab., 1 map; London.

Occurrences of Mica in Tanzania



Legend

- Mica
- Lepidolite
- Phlogopite

PHOSPHATE ORES

GENERAL INFORMATION AND USES

Phosphate ores can be of magmatic or sedimentary, both marine and terrestrial, origin. Deposits of economic importance are made up of calcium-phosphate minerals, like apatite, or guano, which is dung formed mainly by birds or bats, or phosphorite, which is a fine-grained phosphorus-rich mixture of various minerals, mainly formed offshore.
The grade of phosphate deposits is given in wt.-% P (= phosphorus), wt.-% P_2O_5 or wt.-% BPL (bone phosphate of lime) which is equivalent to TPL (triphosphate of lime) or TCP (tricalcium phosphate).

	P	P_2O_5	BPL (= TPL,= TCP)
1 wt.-% P	1	2.2914	5.0072
1 wt.-% P_2O_5	0.4364	1	2.1852
1 wt.-% BPL (TCP, TCL)	0.1997	0.4576	1

Phosphorus is essential for plant and animal life, so nearly all mined phosphate ores are used for the production of nitrogen-phosphorus-potassium fertilizers. Although there are some other very minor uses of phosphates, they are of little economic relevance. In general all phosphate ores, with the exception of guano, have to be beneficiated for further use and should not be used as fertilizer in crude form.

RELEVANT OCCURRENCES IN TANZANIA

There have been many exploration campaigns for phosphate ores in Tanzania so the potential of this commodity is very well known. Phosphate may even be the best known industrial mineral in Tanzania.

Sedimentary Deposits
No major marine deposits of phosphate ore, i.e. phosphorite, have yet been found in Tanzania. However, there are lacustrine deposits of phosphate which are of great importance to the local industry.

- The Minjingu Phosphate Mine (3° 42.537' S, 35° 54.916' E) is situated east of Lake Manyara just north of the small but prominent inselberg Minjingu Kopje. The mine is about 110 km by tarmac road from Arusha. The Minjingu phosphate deposit was discovered in 1956 as a radioactive anomaly during an aerogeophysical survey.
  Two types of ore have been identified at Minjingu, the soft ore and the hard ore. The soft ore is composed of several up to 2-3 m thick, whitish-grey, coarse clastic phosphate bone beds. The coarse-clastic laminated phosphate beds consist mainly of detrital cormorant bones and the remains of cichlid fishes. The grade of most of these beds is 22-25 wt.-% P_2O_5. The hard phosphate ore is several metres thick and consists of indurated, massive, siliceous phosphates. The phosphate of the hard ore is said to have originated from the reaction of guano with carbonates, which were deposited in Plio-Pleistocene Lake Manyara. The guano was produced by cormorants roosting on the nearby inselberg Minjingu Kopje. The guano later was leached by rains and washed into the lake. The hard phosphate ore surrounds Minjingu Kopje, overlying and rapidly grading into the soft phosphates below. The grade of the hard ore averages 24 wt.-% P_2O_5. Currently mining is in fine-grained friable ore only. The areas of hard or semihard siliceous ore have not yet been exploited. Interbedded with the phosphate there are layers of olive-coloured clays (see Bentonite and Sepiolite), chert beds, and cm-thin analcime bearing volcanic tuffs. Also a clay layer of up to 2 m thickness covers the whole phosphate deposit.
  The phosphate ore mainly contains apatite/francolite (70 wt.-%), dolomite (10 wt.-%), clay minerals (7 wt.-%), quartz (5-7 wt.-%), feldspar (3-5 wt.-%), and calcite (3 wt.-%). The fluorine content is especially high (up to 4 wt.-%) in the bone beds. The uranium concentration of the phosphate ore ranges

from 100 to 500 ppm. The phosphate rock contains high concentrations of uranium (410 to 1,100 ppm), barium (1,100 to 2,100 ppm), and strontium (2,500 to 9,900 ppm). Due to the high content of uranium and its radio-nuclides, the mine workers and people living in Minjingu have an elevated risk of radiation exposure especially by α-particle inhalation in dust. Minjingu phosphate never should be inhaled.

Neutral ammonium citrate (NAC) solulibility ranges from 5.6 wt.-% P_2O_5 in the Minjingu phosphate product, to 6.1 wt.-% P_2O_5 in the soft phosphate ore. These values are very high and compare well with the most soluble phosphate ores and rocks in the world. About 70 wt.-% of Minjingu phosphate is dissolvable in 2 %-conc. formic acid. Therefore, even the Minjingu soft phosphate ores are well suited for direct application (see below).

Mining the Minjingu phosphate deposit by an affiliate of STAMICO started in August 1982. Sales of phosphate rock commenced in January 1983. Until 1990, the most important customer was the former state-owned Tanga Fertilizer Company. During the first years of production the open-cast mine operated two shifts per day 7 days per week producing up to 165 kt ore per year. The design capacity of the dressing plant, which is about 1 km from the mine, is 20 t/h or 100 kt of phosphate rock per year with a P_2O_5-content of 28-30 wt.-% by crushing, drying, and dry-screening mainly. Beneficiation removes about half the feldspar and dolomite and almost all the calcite as given above (see tables 32 and 33).

Figure 41: Satellite image of Lake Manyara and the Minjingu Phosphate Mine (Photo courtesy of Google Earth).

Table 30: Chemical composition (data in wt.-%) of Minjingu phosphate ore and phosphate rock (various authors).

	Hard siliceous ore		Soft friable ore		Phosphate rock
P_2O_5	19.63	23.48	27.55	29.76	28 - 30
SiO_2	34.26	33.42	9.09	11.68	8 - 10
Al_2O_3	0.57	1.83	1.22	0.44	1.1 – 1.4
Fe_2O_3 total	1.55	2.16	0.66	0.57	1.2 – 1.5
CaO	30.13	30.10	45.15	43.79	36 - 38
MgO	1.03		5.86		traces of Ba, Cr, Cu, Ni, Zn, TiO_2
MnO	0.04		0.08		
TiO_2	0.25				
Na_2O	2.75		1.50		
K_2O	0.86		0.64		
F	1.00	1.13	1.40	2.92	3 - 5
SO_3		0.20		0.30	
CO_2		1.60		4.43	
H_2O	0.97	1.41	2.66	3.01	3 - 4
LOI	5.09	4.00	7.57	6.40	7
total	*98.16*	*94.99*	*99.32*	*92.64*	

Table 31:
Typical grain size distribution of ground phosphate rock from Minjingu.

Grain size	wt.-%
>1 mm	0.3
0.5 – 1 mm	1.2
0.25 – 0.5 mm	9.1
0.20 – 0.25 mm	5.1
0.15 – 0.20 mm	8.3
0.10 – 0.15 mm	20.2
0.075 – 0.10 mm	14.0
0.06 – 0.075 mm	17.7
<0.06 mm	24.1

Table 32:
Chemical composition (data in wt.-%) and major minerals in the Minjingu soft phosphate ore (from Hangi 1987).

	Bulk	Apatite	Feldspar	Dolomite	Quartz	Calcite	Unassigned
P_2O_5	25.0	25.0					
SiO_2	12.5		8.07		4.43		
TiO_2	0.18						0.18
Al_2O_3	2.2		2.2				
Fe_2O_3	1.3	0.10	0.11				1.09
CaO	38.8	33.98	0.02	2.88		1.92	
MgO	2.6	0.09		2.07			0.43
SrO	1.04	1.04					
BaO	0.25						
Na_2O	1.4	0.15	0.77				0.48
K_2O	1.2		0.85				0.35
S	0.11						0.11
F	2.6	2.46					0.14
Cl^-	145 ppm						145 ppm
CO_2	6.9	0.87		4.53		1.51	
H_2O	5.8						
LOI	13.7						
total	*100.28*	*63.69*	*12.02*	*9.48*	*4.43*	*3.43*	*2.78*

Table 33: Chemical composition (data in wt.-%) of major minerals in the Minjingu phosphate rock (from HANGI 1987).

	Bulk	Apatite	Feldspar	Dolomite	Quartz	Unassigned
P_2O_5	29.0	29.0				
SiO_2	9.4		4.40		5.00	
Al_2O_3	1.2		1.20			
Fe_2O_3	0.89	0.13	0.06			0.70
CaO	41.7	38.8	0.01	1.54		1.35
MgO	3.2	0.09		1.10		2.01
SrO	1.40	1.40				
BaO	0.2					0.2
Na_2O	1.3	0.11	0.42			0.76
K_2O	0.78		0.46			0.32
TiO_2	0.13					0.13
S	0.09					0.09
F	3.1	2.75				0.35
Cl^-	127 ppm					127 ppm
CO_2	3.1	0.69		2.41		
H_2O	4.1					
LOI	10.7					
total	*96.69*	*72.97*	*5.35*	*5.05*	*5.00*	*5.91*

Figure 42: Interbedded layers of phosphate ore (light) and clay (olive) in the Minjingu Phosphate Mine.

Figure 43: Minjingu Phosphate Mine dressing plant.

Today, most of the phosphate rock produced in Minjingu is exported to Kenya (80 %) for use as fertilizer, with only minor tonnages used in Tanzania. Regrettably, production has decreased considerably and varied between only 1,100 and 6,600 tons of phosphate rock per year from 2000 to 2005. The tailings of the plant have also been analysed and are still said to contain 8.5 wt.-% P_2O_5.

Calculations of the measured resources of phosphate ore at Minjingu by various companies resulted in very different figures varying between 1.8 and 8.8 million tons. More recently resource estimates were reported as 3.3 million tons soft ore and 4.8 million tons hard ore.

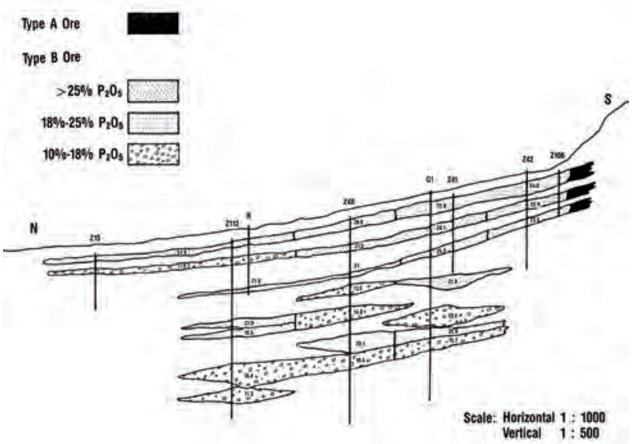


Figure 44: N-S profile of Minjingu phosphate deposit (from NN 1987).

In the lacustrine plains of Lake Manyara and Lake Burungi to the SE there are some more inselbergs with surrounding areas which have not yet been explored in detail. The most prominent hills are Vilima Vitata which are located about 12 km south of Minjingu. Here, phosphate layers up to 2 m thick, grading 20 wt.-% P_2O_5 on average, were encountered beneath 5-6 m of overburden. Other phosphate occurrences have been noted at Besi Hill, Sino Hill and other places.

- The Chali Hills phosphate deposit is at the southern margin of the Bahi depression (see Salt, Sodium other than Sodium Chloride) in Dodoma District. Here phosphate ores form a thin veneer on the base of quartzites which form the ridges about 25 m above the lake beds. Phosphate ore also infills joints in the rock. Some of this material assays at 8-10 wt.-%, others are as high as 20 wt.-% P_2O_5. Drilling in the surrounding lake beds, however, only showed one discontinuous phosporitic horizon a few metres in thickness containing less than 5 wt.-% P_2O_5. The Chali Hills phosphate deposit may be the remains of a once bigger deposit, formed in a similar way to the Minjingu phosphate deposit.

- The Chamoto phosphate occurrence is in the Mbeya District about 54 km east of Mbeya and 8 km north of Igurusi Village. The phosphoritic materials occur as 0.1-0.6 m cherty phosphorite layers and irregularly shaped phosphorite concretions at the interface between lower lake beds and overlying coarse pyroclastic rocks. It can also be found as irregularly shaped fragments within the lower part of the upper volcaniclastic sequence. The phosphorite beds grade between 16 and 36 wt.-% P_2O_5. However, resources are very low with 2 kt to 3 kt of ore only.
- The Maherera phosphate occurrence is close to the Chamoto phosphate occurrence. Interlayered within mudstone beds is a 0.1-0.2 m thick whitish calcareous bed which analyses 16-33 wt.-% P_2O_5. Similar to Chamoto, the Maherera phosphate occurrence is too small to be of economic value.
- The Gallapo phosphate occurrence is located 16 km east of Babati and south of the Minjingu phosphate deposit in the Mbulu District. It is a limestone of yet unknown origin containing 8 wt.-% P_2O_5. Full rock analyses is reported as 17.50 wt.-% $Ca_3(PO_4)_2$, 37.44 wt.-% CaO, 0.74 wt.-% MgO, 2.91 wt.-% SiO_2 and other silicates, 8.81 wt.-% R_2O_3, and 31.98 wt.-% LOI.

GUANO DEPOSITS

- The Sukumawera guano phosphate deposit is in the Songwe travertine caves in the Mbeya District and was exploited between 1934 and 1957: 2,900 tons of guano were mined. Recent investigations show small resources of guano remaining with P_2O_5 contents varying between 26 and 37 wt.-%. Older analyses show grades of 10-21 wt.-% P_2O_5. The remaining guano layer is max. 0.6 m thick and generally little more than 0.15 m thick.
- The Amboni caves are near Tanga and have much lower P_2O_5 grades of guano (0.2-2.0 wt.-%) than in the Songwe caves.
- Latham Island, also called Fungu Kizimkazi (6° 54' S, 39° 56' E) is a low-lying island about 64 km SE of Dar es Salaam. It is very small measuring only 340 m by 200 m. It is known for its seagrass beds, reefs and spectacular views of bird colonies. Due to these birds it is covered by a thin layer of guano up to 0.3 m thick which has also percolated into the underlying coral limestone. This limestone is analysed to contain 8.5 wt.-% P_2O_5 on average with resources of about 170 kt of ore. Primary guano resources only are about 3,500 tons.

MAGMATIC DEPOSITS

Magmatic deposits of phosphate ore are essentially made up of apatite which is an accessory mineral in many carbonatites in Tanzania. There are about 20 carbonatite bodies known in Tanzania, most of which have been studied for their apatite content. However, as flotation of primary apatite from solid carbonatite rock is difficult and the solubility of igneous phosphate rock is low, beneficiation of phosphates from weathered carbonatite rock or soil is of much greater commercial interest.

- The Panda Hill carbonatite (8° 58' 15" S, 33° 14' 15 '' E) is about 40 km SW of Mbeya. The infrastructure is excellent. The Panda Hill carbonatite is circular in form and measures 1.2 x 1.4 km at the surface. Due to its high pyrochlore content, the Panda Hill carbonatite is a very important source of Nb_2O_5 (0.33 wt.-%) and might be mined for this mineral in future. One of the by-products will be apatite. The average content of P_2O_5 in the Panda Hill carbonatite is 3.5 wt.-% with indicated resources of about 480 million tons of ore. A phosphate rock produced gave 36.0 wt.-% P_2O_5. There are also areas of about 35,000 m^2 in total size with residual soils more than 10 m thick. The P_2O_5 grade of this limonitic soft soil varies between 8 and 15 wt.-% P_2O_5. The calculated resources are 1.06 million tons of phosphate-rich soil in the Kunja-Mtoni areas with an average grade of 10.3 wt.-% P_2O_5. The average grade of Nb_2O_5 in the residual soil is 0.77 wt.-%.

- The Sengeri carbonatite (8° 57' 30" S, 33° 11' 30" E) lies some 7 km NW of Panda Hill. The Sengeri carbonatite is composed of two major dykes each 50-100 m wide and up to 2 km long. The P_2O_5-content of the Sengeri carbonatite averages 4.2 wt.-% with a much lower Nb_2O_5 content of 0.08 wt.-%. Because soil analysis also revealed low values of P_2O_5, the data do not warrant any follow up work.
- The Songwe Scarp (Njelenje) carbonatite (8° 45-54' S, 33° 12-30' E) is about 23 km by road from Mbeya. This carbonatite is a dyke structure parallel to the present rifting. It extends for about 19 km with discontinuities, and the width varies from 6-30 m. The average thickness is 50 m. The P_2O_5 content is highly variable and varies between 3.0 and 10.0 wt.-%. Due to its high silica content, the dyke is resistant but whenever susceptible it often alters into limonitic material which contains up to 18 wt.-% P_2O_5.
- The Mbalizi carbonatite (8° 55' S, 33° 21' 30" E) is 10 km by road west of Mbeya. This carbonatite is covered by a thick volcanic cover, so the exact structure could not be measured but is estimated to be oval with an area of 1.2 x 0.4 km. The P_2O_5 content is 6-8 wt.-%. There also are enrichments of phosphates in irregular, up to 0.5 m thick limonite weathering crusts grading up to 30 wt.-% P_2O_5. The best material for agronomic applications is soft apatite-phlogopite rock occurring at the western and northwestern margin of the Mbalizi carbonatite. While the P_2O_5 content is 7-20 wt.-% the resources have been calculated to be only a few thousand tons.
- Musensi Hill forms a prominent hill some 42 km west of Mbeya. Most of the hill is made up of volcanic rocks which are intruded by a carbonatite. All analyses of rocks and soils remained under 1 wt.-% P_2O_5.
- X-Mbulu intrusions. This carbonatite occurrence is in the Mbozi District where the deposit forms two hills rising nearly 300 m above the surrounding plain. No economic evaluation is given in the literature.
- Ngualla carbonatite. The Ngualla Hill complex (7° 42' S, 32° 50' E) is situated in northern Chunya District approximately 48 km east of Lake Rukwa. The distance from Mbeya is 212 km by road. The carbonatite is a ring like structure about 3 km in diameter, surrounded by a 1 km wide fenite zone. There are two types of phosphate mineralization. The first is a primary magnetite-apatite mineralization occurring in 15-20 m wide and several hundred metre long veins. Zones exist within the extensive N-S striking vein system that contain 15-35 wt.-% P_2O_5. Further on, there are thick blankets of residual and transported fertile soils containing 12-20 wt.-% P_2O_5. During a semi-detailed exploration campaign more than 1.5 million tons of residual soils with an average grade of 12.3 wt.-% P_2O_5 were delineated.
- Nachendezwaya carbonatite. This carbonatite is situated in the Ileje District of the Mbeya Region only about 600 m from the Songwe River, i.e. the border to Malawi. The carbonatite is a dyke 25-90 m thick, about

Figure 45: Carbonatites in Tanzania (from STRAATEN van 1995).

900 m long, and up to 400 m wide. The P_2O_5 content varies from 2.1 up to 6.1 wt.-% with vermiculite and nepheline syenite as important economic accessory minerals. The Nb_2O_5 content is very low at 0.03 wt.-%. The calculated tonnage of P_2O_5 resources is 43.5 kt at $>$5 wt.-% which is too little to be of economic interest. However, the Nachendezwaya carbonatite forms a large resource of liming material with estimated resources of 5.1 million tons of carbonates.

- Oldonyo Dili is situated in the Mbulu District about 20 km east of Oldeani. This is a carbonatite complex with an area of 1 km x

0.6 km. The principal economic minerals are pyrochlore, magnetite and apatite. Some rocks have been found to be made up of 82 wt.-% apatite. However, in general the analysed P_2O_5 contents range from 1.0 to 3.0 wt.-%. The innermost ring of the structure is said to be highly radioactive.

- Sangu-Ikola carbonatite complex. This complex is located in the Mpanda District about 70 km SW of Mpanda town. However, it cannot be accessed easily by road but only by boat from Kigoma. The complex consists of three bodies which are elliptical in structure: the Ikamba carbonatite measures 18 km x 1.5 km, the Ikola carbonatite measures 3 km x 1 km, and the Middle carbonatite measures 1 km x 0.2 km. The apatite content varies from 16-35 wt.-% with residual soils discovered containing more than 10 wt.-% P_2O_5.
- The Zizi carbonatite is situated in the Morogoro District south of Kisaki in the Selous Game Reserve. Access is very difficult. This apatite-bearing carbonatite is a lenticular dyke 1.15 km long and 20 m thick on average. The apatite is very visible and forms rounded columnar crystals. The average apatite content of the rock is 10 wt.-%. The P_2O_5 content varies from 3.1 to 11.3 wt.-% with 6.9 wt.-% on ave-

Table 34: Chemical composition (XRF-analyses, data in wt.-% or ppm) of apatite-rich carbonatites from Tanzania (from Chesworth et al. 1988).

	Songwe Scarp carbonatite	Panda Hill carbonatite	Ngualla carbonatite	Zizi carbonatite
	Weathered Zone	Soil-Kunja zone	Soil	Carbonatite
P_2O_5	17.75	11.54	24.06	11.33
SiO_2	24.82	35.70	0.92	0.43
TiO_2	1.59	1.20	1.37	0.00
Al_2O_3	5.97	3.64	0.13	0.09
Fe_2O_3	14.52	24.81	39.40	2.86
MgO	0.16	0.91	0.94	13.13
CaO	25.46	15.98	31.03	37.20
MnO	0.36	0.26	0.35	0.36
Na_2O	0.76	0.21	0.24	0.07
K_2O	5.48	0.21	0.09	0.03
LOI	3.11	5.55	1.47	34.47
total	*99.98*	*100.01*	*100.00*	*99.97*
Ba	505 ppm	n.d.	n.d.	172 ppm
Ce	1,200 ppm	7,600 ppm	n.d.	159 ppm
La	120 ppm	5,200 ppm	n.d.	110 ppm
Nb	395 ppm	1,720 ppm	n.d.	4 ppm
Nd	435 ppm	3,730 ppm	n.d.	68 ppm
Rb	74 ppm	21 ppm	n.d.	10 ppm
Sr	4,610 ppm	2,220 ppm	n.d.	2,860 ppm
Y	1,243 ppm	44 ppm	n.d.	9 ppm
Zr	989 ppm	1,160 ppm	n.d.	128 ppm

The main requirements for deposits of phosphate ores are given in table 35 next page:

Table 35: Main requirements for deposits of phosphate ores.

	Grade	Resources
Marine-sedimentary origin - Phosphorite	>20 wt.-% P_2O_5	>100 million tons
Magmatic origin - Apatite	>4-17 wt.-% P_2O_5	>5 million tons
Guano	27-30 wt.-% P_2O_5	>500,000 tons

rage. A different campaign revealed a P_2O_5 content of 4.4 wt.-% on average. The P_2O_5 content of overlying soils is also highly variable and ranges from 0.5 to 7 wt.-%.

- Wigu Hill is a carbonatite body about 60 km north of the Zizi carbonatite and just north of Kisaki Village. It is built up by carbonatitic rocks of intrusive and extrusive origin, later cut by several distinct dykes. In regard to phosphates, all analytical results were disappointing (<1 wt.-% P_2O_5), however most authors report high rare earths concentrations (see Rare Earths).
- Maji ya Weta is also in the Morogoro District about 10 km south of the Wigu Hill carbonatite. Like Wigu Hill, Maji ya Weta is not a single carbonatite body or plug. It is made up of a great number of narrow carbonatite dykes, each rarely exceeding 0.5 m in width. Analyses of soil and rock samples show generally low values of <3 wt.-% P_2O_5.

REQUIREMENTS AND EVALUATION

For direct use as fertilizer, i.e. without any other beneficiation besides grinding, phosphate ores should contain >15 wt.-% P_2O_5 (>33 wt.-% BPL). 55 wt.-% of the phosphate content must be dissolvable in 2 %-conc. formic or citric acid. 80-90 wt.-% of the crude phosphate ore has to be ground to <0.1 mm.

For industrial uses, phosphate rocks, i.e. phosphate ore concentrates, need to contain >28 wt.-% P_2O_5, <11 wt.-% $CaCO_3$, <5 wt.-% SiO_2, <3 wt.-% F, <2.5 wt.-% R_2O_3, <0.25 wt.-% MgO, <0.10 wt.-% Cl, <1 wt.-% organic substance, <20 ppm Cd, as well as extremely low values of Pb, Hg, U, Cr, As, Se, and V. Phosphate rocks also should be fine-ground and dry.

Potential investors in phosphates in Tanzania should know that Minjingu phosphate rock has been tested as a direct fertilizer by numerous scientists, on various soils and in various countries always proving to be of the highest value. In general, the relative agronomic effectiveness (RAE) of mainlining phosphate rock in comparison to imported phosphate fertilizers ranges from 65-85 %. The RAE of the Minjingu phosphate is 75 % and 91 % for the long and short rainy period respectively. Other tests show it to be nearly as effective as commercial triple superphosphate. However, farmers using the product for direct application complained about the product's dustiness. Thereupon, other tests showed that fine soft Minjingu ore mixed with urea and granulated, pelletized or compacted gives a product that handles well and contains not only phosphorus but also nitrogen.
Companies interested in investing in Minjingu phosphate will also benefit from additional phosphate resources, some of which has already been identified near some of the other inselbergs in the Minjingu area.

With respect to magmatic deposits of phosphate ore in Tanzania, only Ngualla, Sangu-Ikola, Zizi, and above all Panda Hill carbonatites show any realistic economic potential. Because only Panda Hill carbonatite has a favourable infrastructure and because deposits of phosphate- and pyrochlore-rich soil have already been verified in the Panda Hill area mining these occurrences might also prove worthwhile.

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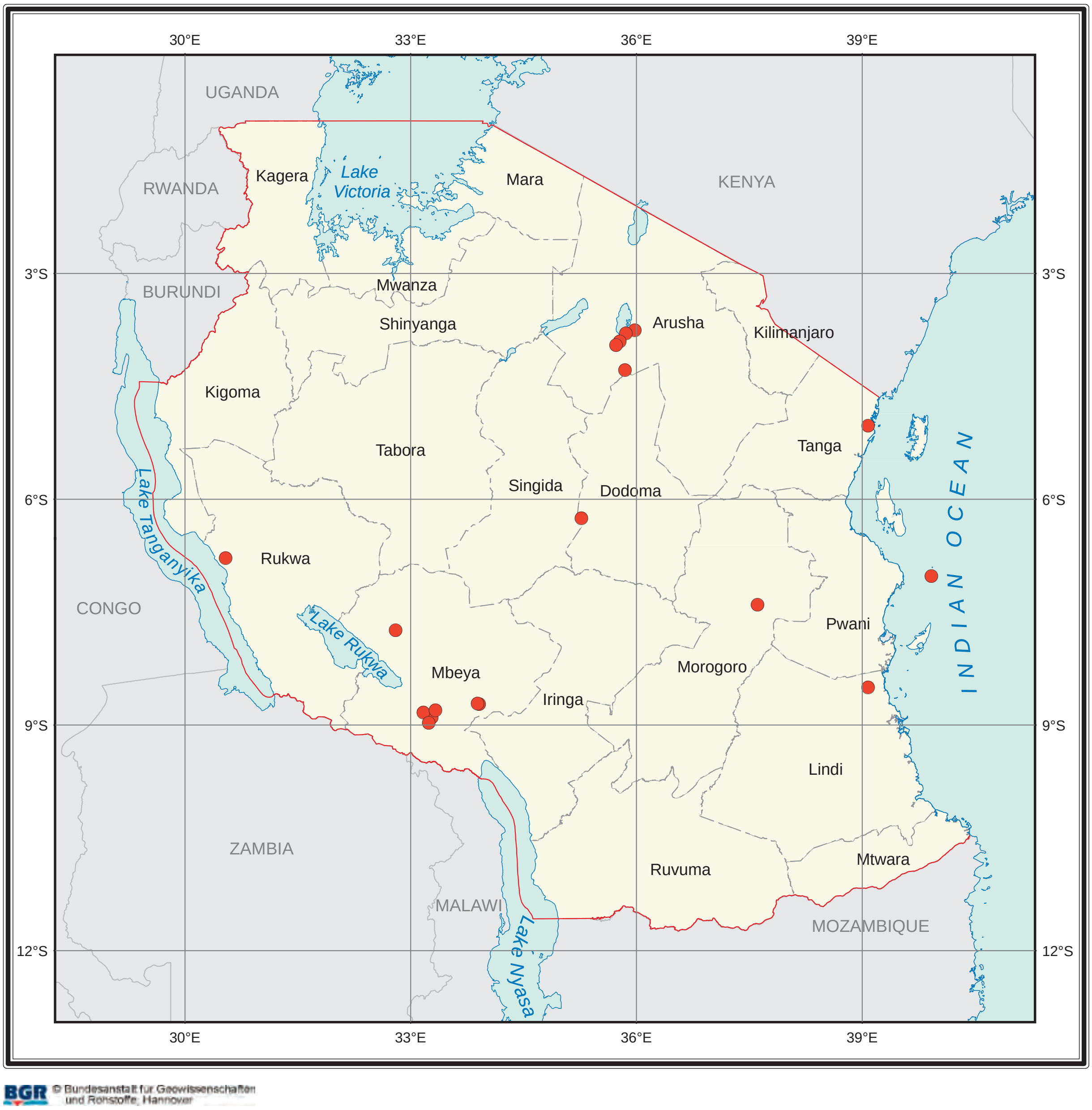
Occurrences of Phosphate Ores in Tanzania



Scale 1 : 10,000,000

0 100 200 300 400 500 km

Legend

● Phosphate

PUMICE AND RELATED VOLCANIC ROCKS

GENERAL INFORMATION AND USES

Pumice is a highly porous volcanic glass which floats on water. The grain size of the particles thrown out by volcanoes diminishes with distance from the eruption centre, as does the thickness of the pumice deposits. Pumice deposits often include rock fragments from the wall of the magma chamber, and the pumice lapilli (2-64 mm diameter) and bombs (>64 mm diameter) can also contain varying quantities of quartz, feldspar, hornblende, olivine etc. Pumicite forms fine-grained deposits of pumice with particle sizes <2 mm (ash). Highly porous dark pumice of basaltic composition is also known as scoria. If pumice has a vitreous character and hardens hydraulically in the presence of $Ca(OH)_2$, it is called pozzolana.

Because of its good thermal and acoustic insulation properties, its fire and moisture resistance, and its low unit weight, pumice is mainly used as an aggregate for the production of lightweight concrete solid blocks. Other minor but sometimes valuable end uses of pumice are as an abrasive and polishing material, as an absorbent, as a filler, as a filter additive, and for landscaping. Pumicite is used as a flux in ceramic masses, and as a potash source in glass recipes and plant fertilisers. Pozzolana is used for the production of pozzolanic cement.

Tuffs are consolidated volcanic extrusive products of various grain sizes. They are used as fluxes in various industries and in numerous building applications.

Other solidified volcanic rocks can be used for the production of crushed rocks, as dimension stones (see Stones, Dimension), as fluxes (phonolite, rhyolite), as soil improvers (phonolite), or finely ground in water treatment (ignimbrite).

RELEVANT OCCURRENCES IN TANZANIA

In Tanzania **pumice** deposits of economic importance are found at three locations:

- The most north-westernly most deposit is near Lengijave Village, west of Mount Meru, just 20 km north of Arusha and close to the main road from Arusha to Nairobi. Here pumice is being mined by small-scale miners in several pits and adits. The pumice was deposited by Mount Meru in historical time and covers an area of some 10 km^2. Its thickness varies between 1.5 and 2 m. Locally, the thickness can reach up to 5 m although the pumice layer is then rather impure. Overburden is up to 8 m of tuff. After mining, the pumice is stock-piled where it gets sorted naturally by strong-blowing winds removing all the fine ash. The pumice is sold to local customers and businesses in Arusha, who use it to manufacture lightweight concrete blocks. It is said that this pumice was tested by Tanga Cement Company Ltd. for its pozzolanic applications and was found quite suitable. A new bulk sample taken by a field team of GST, STAMICO, and BGR geologists in 2006 (3° 11.855' S, 36° 36.838' E) also gave very good results, except for contents of alkali oxides and C_{Org}, which are too high (see next page).

Apparent density:	2.642 g/cm^3
Bulk density:	0.498 g/cm^3 (low = positive)
Bulk density of size >3.55 mm:	0.262 g/cm^3 (very low = positive)
Bulk density of size <3.55 mm:	0.598 g/cm^3 (low = positive)

Table 36: Grains size distribution of bulk pumice sample from west of Mount Meru (BGR analysis).

Grain size (mm)	Wt.-%	Limits / Ranges for applications
>6.3	24.2	
3.55 – 6.3	18.4	
2.0 – 3.55	16.1	
1.2 – 2.0	13.6	
0.63 – 1.12	8.9	Σ 10-40 wt.-% for use as lightweight aggregate, as high as possible for use in pozzolanic cement
0.355 – 0.63	6.6	
0.20 – 0.355	3.1	
0.112 – 0.20	3.2	
0.063 – 0.112	2.5	
<0.063	3.4	<2-5 wt.% for use as lightweight aggregate

Table 37: Selected chemistry of bulk rock analysis by XRF of pumice sample from west Mount Meru (BGR analysis).

Chemistry	Wt.-% / ppm	Limits / Ranges for applications
SiO_2	50.71	≥50-75 wt.-% for pozzolanic use
TiO_2	1.27	
Al_2O_3	18.37	≥10-25 wt.-% for pozzolanic use
Fe_2O_3 total	6.18	<10 wt.-% for "stone-washing" < 1 wt.-% for "acid-washing"
CaO	3.62	≤15 wt.-% for pozzolanic use
MgO	1.21	
MnO	0.17	
Na_2O	8.24	≤10 wt.-% for pozzolanic use
K_2O	4.50	
(Cl)	0.11	≤0.1 wt.-% for pozzolanic use <0.04 wt.-% for beneficiated lightweight aggregate
(SO_3)	0.04	≤1.0 wt.-% for pozzolanic use or use as lightweight concrete
P_2O_5	0.29	
LOI	4.61	≤12 wt.-% for pozzolanic use
total	*99.32*	
C_{org}	0.11	<0.1 wt.-% for lightweight aggregate
Ba	1,568 ppm	
Ce	154 ppm	
La	120 ppm	
Sr	1,456 ppm	
Th	27 ppm	Σ<500 ppm for any commodity
U	8 ppm	
Zr	460 ppm	

Figure 46: Stockpiles of pumice west of Mount Meru.

Figure 47: Entrance into adit showing thickness of pumice layer below overburden of tuff west of Mount Meru.

- The most north-easternly deposit is at Holili (3° 21.685' S, 37° 38.861' E) at the border crossing to Kenya. Here pumice from Mount Kilimanjaro covers an area of some 1 km² and reaches a thickness of up to 12 m. Thickness of overburden only is 0.5 – 1.5 m. At greater depths the pumice is solidified into pumice rock, which is mined by small-scale miners for use as building blocks. Tanga Cement Company Ltd. was the first to prove the pumice to be pozzolana and started using it in large amounts in 2004. According to official production statistics, some 153 kt of pozzolana were mined in 2004 and 163 kt in 2005. No analyses are known, but the pozzolana from Holili has already been shown to meet all the requirements of a major customer.
- The southwestern area of pumice occurrences is between Tukuyu and Mbeya. Deposits are thickest on the slopes of the Rungwe and Ngozi volcanoes, which were the sources of the erupted material. According to old reports, this material was tested and also produced good-quality pozzolanic concretes.
Between Uyole Village and Rungwe volcano, close to Nzenga Village, layers of pumice are cut on the slopes of obvious old cinder cones. The areal extent and usability of these pumice layers were explored in 1999 by a local company, kindly making their exploration data available for this publication.
This exploration campaign in a reconnaissance area of 84.6 km² revealed a total of 4.4 km² of mineable pumice deposits in four separate areas between 0.4 and 1.9 km² in size, and with total reserves of 3.424 million tons of pumice. Pumice layers were only included in the reserve calculation if they had a minimum thickness of 1.0 m. In the explored areas, the average pumice and

Figure 48: Mining of pozzolana by Tanga Cement Company Ltd. at Holili.

Table 38: Grain size distribution of bulk pumice sample from Nzenga Village, Rungwe area (BGR analysis).

Grain size (mm)	Wt.-%	Limits / Ranges for applications
>20.0	13.8	
11.2 – 20.0	16.0	
6.3 – 11.2	20.6	
3.55 – 6.3	19.7	
2.00 – 3.55	15.7	
1.12 – 2.00	9.2	Σ 10-40 wt.-% for use as lightweight aggregate, as high as possible for use in pozzolanic cement
0.63 – 1.12	3.0	
0.355 – 0.63	0.9	
0.20 – 0.355	0.5	
0.112 – 0.20	0.3	
0.063 – 0.112	0.2	
<0.063	0.0	<2-5 wt.-% for use as lightweight aggregate

overburden thicknesses are 1.6 to 3.2 m and 1.2 to 1.8 m respectively. Parameters analyzed were chemical composition, bulk density (0.278 g/cm³), grain size distribution and basic geotechnical parameters for possible use as road material.
Due to the limited demand, the pumice is currently not being mined. A bulk sample taken by a field team of GST, STAMICO, and BGR geologists in 2005 (8° 57.142' S, 33° 32.290' E) gave excellent results, even better than for pumice from west Mount Meru (see below).

Mineralogy (by XRD): No crystalline minerals of any kind detectable.

Apparent density: 0.499 g/cm³
Bulk density: 0.377 g/cm³ (very low = positive)

- A totally different but very interesting deposit of volcanic material has been reported from Lashaine (3° 22' 10'' S, 36° 25' 30"

Table 39: Selected chemistry of bulk rock analysis by XRF of pumice sample from Nzenga Village in Rungwe area (BGR analysis).

Chemistry	Wt.-% / ppm	Limits / Ranges for applications
SiO_2	57.82	≥50-75 wt.-% for pozzolanic use
TiO_2	0.56	
Fe_2O_3 total	4.29	<10 wt.-% for "stone-washing" <1 wt.-% for "acid-washing"
Al_2O_3	16.03	≥10-25 wt.-% for pozzolanic use
CaO	0.67	≤15 wt.-% for pozzolanic use
MgO	0.36	
MnO	0.35	
Na_2O	6.21	≤10 wt.-% for pozzolanic use
K_2O	4.69	
(Cl)	0.05	≤0.1 wt.-% for pozzolanic use <0.04 wt.-% for beneficiated lightweight aggregate
(SO_3)	0.09	≤1.0 wt.-% for pozzolanic use or use as light-weight concrete
P_2O_5	0.05	
LOI	8.32	≤12 wt.-% for pozzolanic use
total	*99.52*	
C_{org}	0.097	<0.1 wt.-% for lightweight aggregate
Ba	76 ppm	
Ce	351 ppm	
La	242 ppm	
Sr	552 ppm	
Th	60 ppm	Σ<500 ppm for any commodity
U	14 ppm	
Zr	879 ppm	

Figure 49: Satellite image of the West Mount Meru pumice deposit west of Mount Meru and the Lashaine olivine deposit south of Monduli Mountains. Arusha town in lower left of image (Photo courtesy of Google Earth).

E), some 8 km south of Monduli, which is 40 km west of Arusha. Lashaine is a small volcanic hill rising some 200 m above the surrounding peneplain. The crater is markedly asymmetrical and 450 – 550 m across. There were at least two main phases of volcanic eruption, with volcanic bombs mainly deposited around the eastern side of the crater. Winnowing by wind produced a predominance of progressively finer material towards the west. The bombs consist of fresh peridotite, consisting mainly of clear green **forsterite** (olivine mineral), some of which is of gem-quality, and lesser amounts of enstatite, chrome diopside, pyrope garnet, and ilmenite. Bombs constitute between 1 and 2 vol.-% only of the total volume of the rock in the area of highest concentration. In contrast to the coarser material, the tuffs in the western part mainly consist of crystals of olivine from <1 mm to >1 cm in size. The small crystals have a thin dull-brown or dull-green opaque coating of serpentinous but refractory material. The analysis of olivine from bombs and tuffs revealed a ratio of forsterite to fayalite of >90 %. Tests by dry-screening gave a concentration of

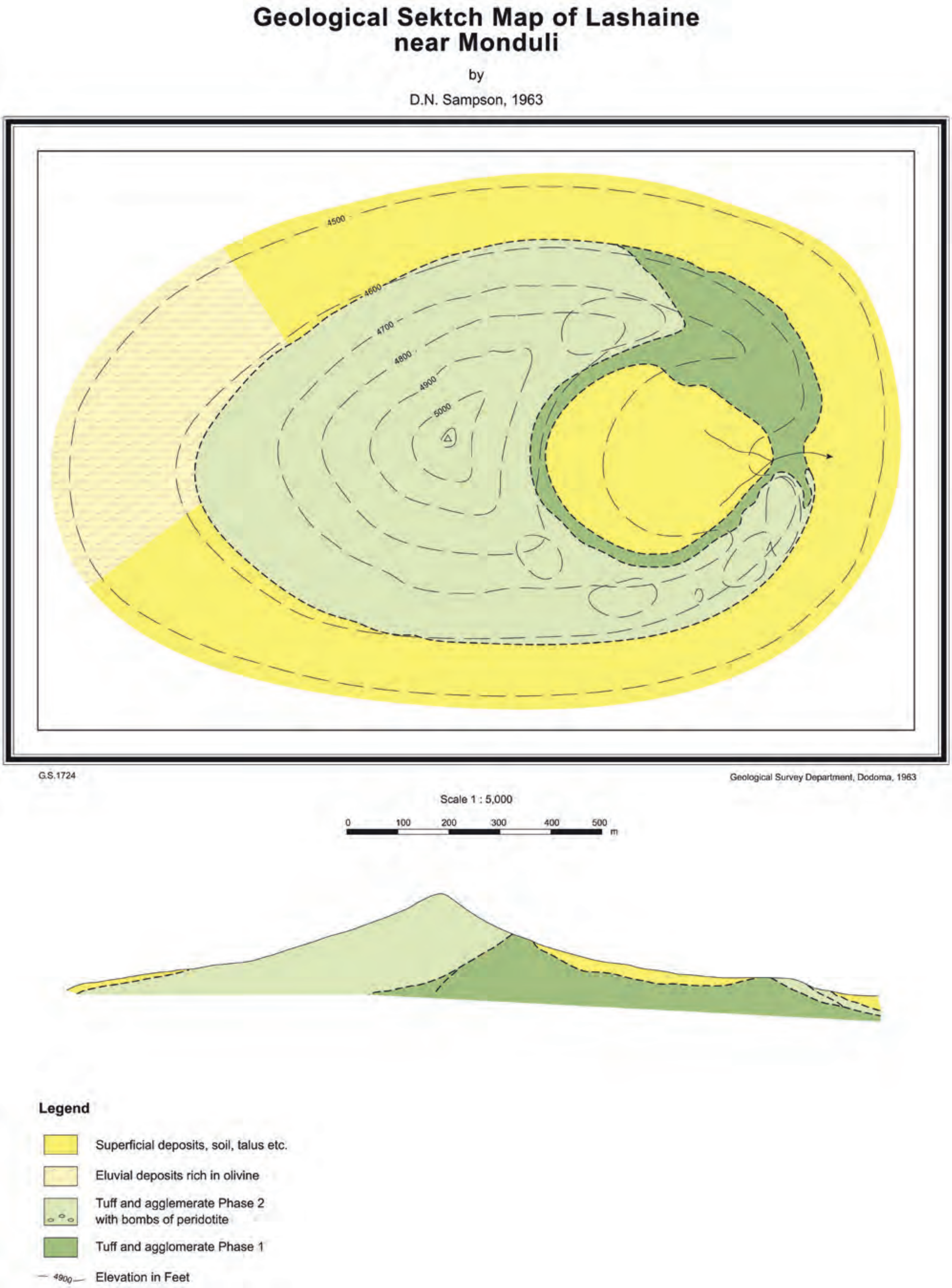


Figure 50: Geological sketch map of Lashaine Hill and olivine deposit near Monduli (Sampson 1963)

Table 40: Chemical composition (data in wt.-%) of olivine from Lashaine (after Sampson 1963)

Chemistry	Olivine selected from peridotite bombs	Olivine selected from tuff, western slopes	Limits / Ranges for applications
SiO_2	42.1	41.29	41.5-42.5 wt.-% for refractory and foundry sand 42-43 wt.-% as flux
Fe_2O_3	0.67	0.62	6.5-7.0 wt.-% for refractory and foundry sand 6.8-7.3 wt.-% as flux
FeO	6.0	6.89	
Al_2O_3	0.16	-	0.4-0.5 wt.-% for refractory and foundry sand 0.5-0.8 wt.-% as flux
CaO	n.d.	n.d.	<1.5 wt.-% for refractory sand 0.05-0.1 wt.-% as flux and foundry sand
MgO	51.9	51.85	49-51 wt.-% for refractory and foundry sand >48-50 wt.-% as flux
Na_2O+K_2O	n.d.	n.d.	<0.02 wt.-% as flux
P	n.d.	n.d.	<0.05 wt.-% as flux
LOI	n.d.	n.d.	0.8-1.3 wt.-% for refractory and foundry sand 0.3-<0.7 wt.-% as flux
total	*100.83*	*100.65*	

80 – 85 wt.-% olivine in the size fraction >1 mm. Resources have not been calculated but are estimated to be >500 kt of forsterite. Olivine is used as a flux and as a foundry sand in the steel industry, as a refractory material, as a blasting agent and as a fertilizer when finely ground.

RELEVANT OCCURRENCES IN TANZANIA

Because raw pumice only very rarely fulfils the specifications of the manufacturers for pumice construction material, grading is usually unavoidable. For the production of lightweight concrete blocks, pumice should contain the lowest possible amounts of clay and silt (<2 wt.-%), lithic components (<2 vol.-%) and organic materials (<0.1 wt.-%). The bulk density should be between <400 - 1,000 g/l and the grain size used between 1 and 32 mm. For use as pozzolana, however, fine material (<1 mm) is preferred. For many other applications, coarse pumice is wanted (>30 mm diameter). Sulphates and all soluble salts are not wanted for any applications. The thickness of any deposit of interest always should be >2 m.

In olivine deposits, the raw material should contain >40 wt.-% MgO. After beneficiation in the mine, the commodity must contain >85 % forsterite. Reserves should be >10 million tons.

Because most of the pumice deposits in Tanzania seem to be suitable for the production of pozzolanic cement, potential investors should first talk to cement companies in Wazo Hill, Mbeya and Kenya to identify their interests. Similar to the pumice from north of Arusha, pumice from all areas can also be used for the production of lightweight concrete. Coarse pumice (>30 mm) should be handpicked for more significant applications. In tourist areas, pumice might be sold to hotels for landscaping. Potential investors in the Lashaine olivine deposit should keep in mind that reserves are limited and the quality is not suitable for all applications. However, this material might produce a good fertilizer or blasting agent, which might be marketed together with other natural abrasives (see Abrasives, Natural) from Tanzania.

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Occurrences of Pumice and Related Volcanic Rocks in Tanzania

Scale 1 : 10,000,000

0 100 200 300 400 500 km

Legend

- Pozzolana
- Pumice

RARE EARTHS

GENERAL INFORMATION AND USES

The rare earth elements (REE) comprise the element yttrium (Z = 39), and a group of 15 elements, called the lanthanides (Z = 57 to 71). Due to their geochemical similarities thorium and scandium, are also included under the term rare earths. REE occur in significant amounts in many accessory minerals either as oxides, phosphates or carbonates, often formed by hydrothermal fluids.
In modern technologies, REE play an important role due to their special optical, biochemical, electronic, magnetic and other physicochemical properties. Roughly 35 % of REE produced worldwide are used as catalysts, mainly in the refining of crude oil. About 30 % of the REE are used in the glass and ceramics industry as glass-polishing compounds, decolourising agents, UV absorbers and anti-browning agents, glass and ceramic colouring agents, additives to structural ceramics and in optical lenses and glasses. Another 30 % are used in metallurgy as alloying agents to desulphurise steel, as a modularising agent in ductile iron, as lighter flints and as alloying agents to improve the properties of alloys and superalloys. A rapidly expanding application is in batteries as mischmetal which is a mixture of REE. Also REE-alloys forming permanent magnets are being increasingly used in industrial, military and aerospace applications, or as less costly permanent magnets used in automobile starting and accessory motors, medical magnetic-resonance-imaging devices, industrial motors, compact disc players, computer disc drives, personal stereos, and camera motors.

RELEVANT OCCURRENCES IN TANZANIA

In Tanzania, rare earth minerals occur in pegmatites, and most importantly in carbonatites. Known deposits are presented in Table 42, whereas reported analyses are given in Table 43.

In all studies, the carbonatite dykes in the 600 m high **Wigu Hill** in the Morogoro District are regarded as the most promising deposit. Wigu Hill is very remote and about 7 km NW of Kisaki, i.e. some 10 km north of the Selous Game Reserve.

The carbonatites or carbonatite dykes of Wigu Hill are known as a source of the REE-bearing minerals bastnaesite, monazite and florencite.

Figure 51: Southern flank of Wigu Hill as seen from Kisaki.

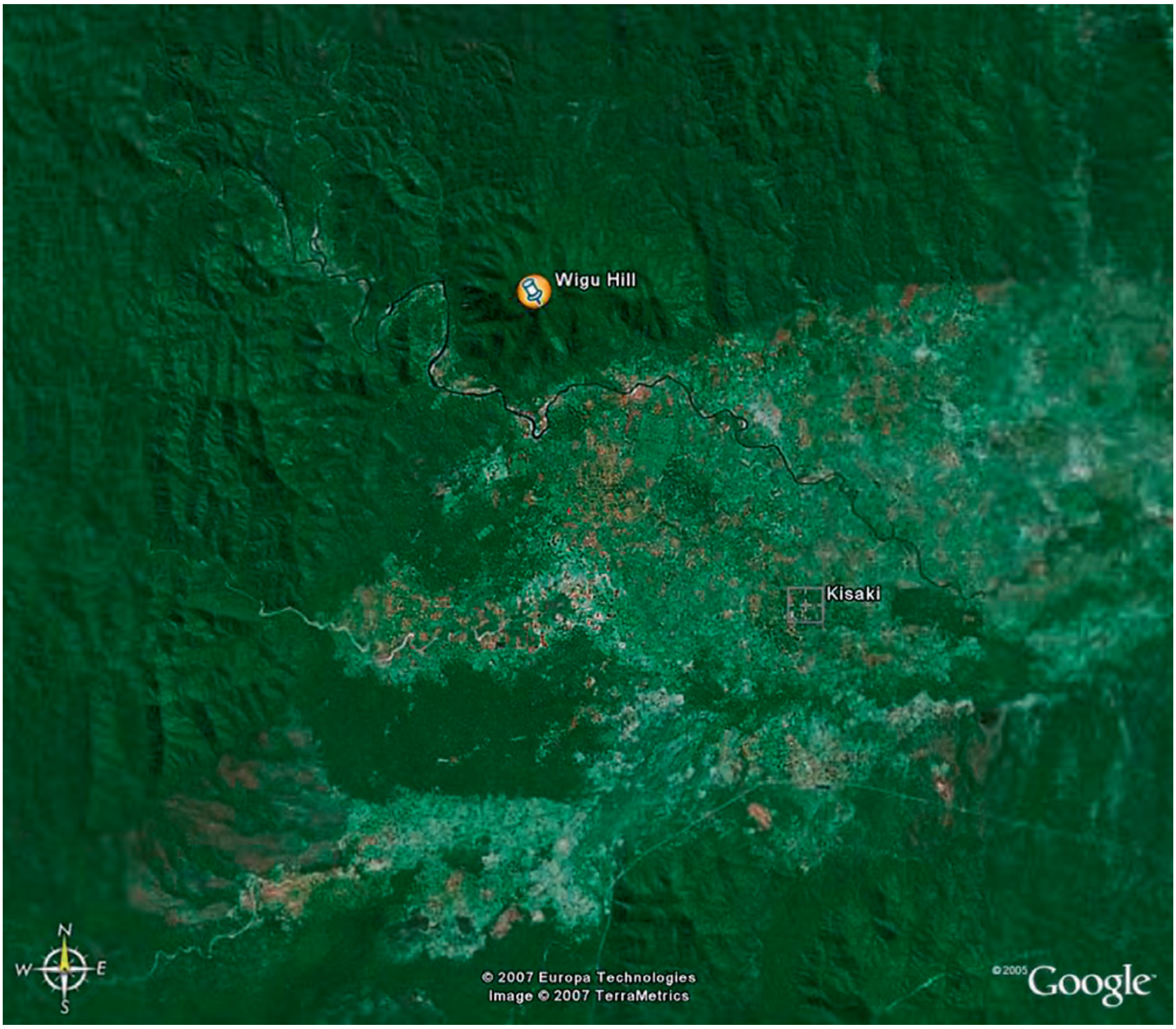

Figure 52: Satellite image of Wigu Hill about 7 km NW of Kisaki, Morogoro District (Photo courtesy of Google Earth).

The highest concentrations of REE are reported from the top of Wigu Hill. The carbonatite dykes of Wigu Hill are 0.5 to 4 m wide and cross-cut fenetised gneisses and granulites. Veins locally carrying up to 20 wt.-% RE-oxides mainly consist of Ce-oxides and La-oxides. Several distinct carbonatite dykes were reported by a Tanzanian-Chinese geological field team, and by MARIANO in 1973.

According to these sources, there are two different types of carbonatite magmas, which can also be distinguished by colour: sovite, and on the western flank of the hill rauhaugite. In sovite, fine grained brownish hexagonal prisms as pseudomorphs of bastnaesite and barite (barite-celestite) can be observed. They have a mineralogical composition of 58 vol.-% quartz, 29 vol.-% bastnaesite, and 13 vol.-% barite. In medium to coarse grained rauhaugite, greenish prismatic hexagonal monazite, parasite, strontianite, and barite pseudomorphs appear together with quartz. The mineralogical composition is reported as 35 vol.-% strontianite, 26 vol.-% parasite, 17 vol.-% quartz, 11 vol.-% barite and 10 vol.-% monazite. The total REE content of this green rauhaugite was analysed as 22 wt.-%. Finally, pinkish hexagonal prisms composed of florencite and barite can be found. All analytical results vary

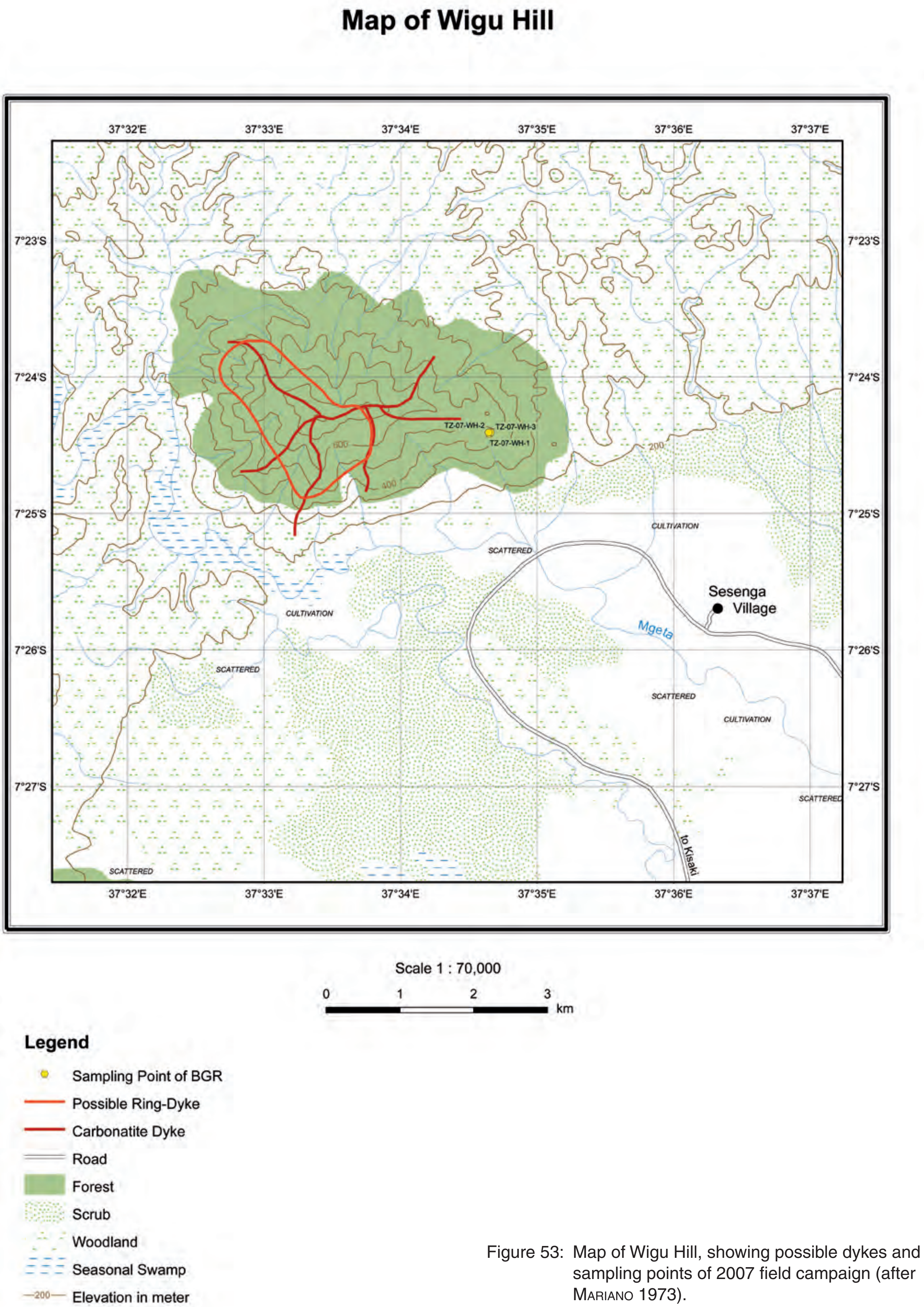

Figure 53: Map of Wigu Hill, showing possible dykes and sampling points of 2007 field campaign (after Mariano 1973).

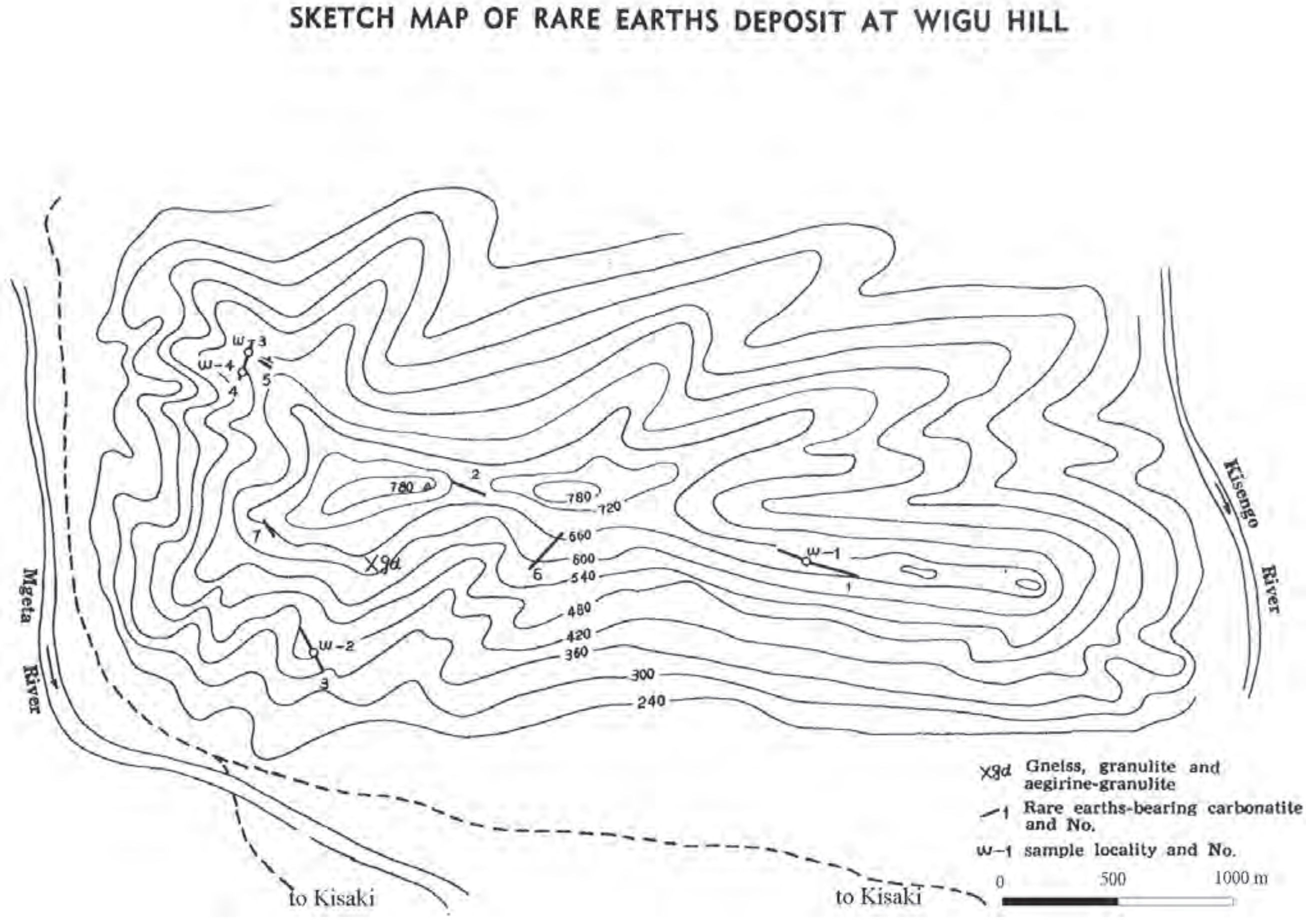

Figure 54: Sketch map of Wigu Hill showing REE-bearing carbonatite dykes (Geological Investigation Team of the People's Republic of China 1973).

dramatically, possibly due to unsystematic sampling, and to the fact that the REE minerals are hosted in 0.5 to 4 m wide and up to several hundred metre long carbonatite dykes which might reflect varying hydrothermal fluids.

In 2007, a team of Tanzanian and German experts from STAMICO, GST, and BGR tried to relocate and sample those highly enriched dykes. Access was gained with the help of villagers from nearby Sesenga Village. Because the slopes of Wigu Hill are very steep and are covered by tall grass, and because the top of the hill is densely wooded, orientation, even by GPS, is very difficult. However, during this campaign at least two carbonatite dykes could be found containing quite big negative crystals of yet unknown minerals. However, the REE content of all samples taken was rather low (see Table 41). Only one sample shows high REE and Sr concentrations, but is also enriched in thorium. Areas of high concentrations of REE, therefore, seem to be rather small and restricted to structural faults which forced the transport of hydrothermal fluids.

In the Mbeya District, several carbonatites with elevated REE values are known. The **Sengeri carbonatite** with high Mg and/or P-enrichment shows enrichments particularly in lanthanum up to 9,100 ppm. The **Ngualla carbonatite** also shows some REE potential (see Table 42). The **Panda Hill** carbonatite complex, which is known for its reserves of pyrochlore, also shows some elevated values of LREE.

Table 41: Bulk composition of samples taken by STAMICO-GST-BGR field team at Wigu Hill in 2007. Data are shown as wt.-% of oxides or as mg/kg for minor and trace elements.

ID	TZ-07-WH-1		TZ-07-WH-2		TZ-07-WH-3	
no of samples	*n=1*		*n=1*		*n=1*	
analytical method [1]	XRF	ICP-MS	XRF	ICP-MS	XRF	ICP-MS
SiO_2	9.45		71.35		0.78	
TiO_2	0.01		0.69		0.01	
Al_2O_3	0.15		3.81		<0.05	
$Fe_2O_3^{tot}$	5.74		1.37		1.42	
MnO	1.34	1.22	0.12	0.12	0.58	0.55
MgO	10.88		0.48		18.98	
CaO	22.53		1.96		31.45	
SrO	4.62	4.16	1.72	1.84	0.46	0.38
BaO [2]	2.62	2.26	7.13	5.92	0.02	0.02
Na_2O	<0.01		0.01		0.01	
K_2O	<0.005		0.11		<0.005	
P_2O_5	2.67		2.12		2.50	
SO_3 [3]	1.64		4.02		0.01	
Cl [3]	0.003		0.015		0.004	
F [3]	0.61		<0.05		0.21	
LOI	32.42		4.96		43.27	
Σ	*94.68* [4]		*99.90*		*99.75*	
Y	171	127	20	16	24	19
La	18,979	16,100	316	303	134	112
Ce	21,801	19,429	503	488	289	249
Pr		1,488		52		28
Nd	4,552	3,903	193	175	132	107
Sm	260	301	<16	18.4	21	16.0
Eu		65.1		7.0		4.3
Gd		158		9.9		11.3
Tb		16.6		1.1		11.3
Dy		44		3.3		5.6
Ho		7.1		0.6		1.0
Er		5.5		1.5		2.1
Tm		1.1		0.16		0.21
Yb		6.1		0.95		1.1
Lu		1.0		0.14		0.16
ΣREE incl. Y	45,763	41,652	1,048	1,077	600	568
Nb	15	52	149	146	1172	400
Ta	<6		<5		<5	
Pb		113		97		138
Th		481		21		49
U		6.7		1.0		0.1

Notes: [1] Parties interested in analytical methods used should contact BGR directly, [2] Samples enriched in REE show high Ba amounts. Those high Ba amounts cause easy precipitation while preparing ICP-MS solutions, which will lead to low REE concentrations, [3] remaining amount after annealing at 1000 °C, [4] Including REO the oxides will be 99.66 wt.-% in total.

Figure 55: Sampling of carbonatite dyke, several hundred metres in length, in the southeastern part of Wigu Hill.

The **Lihogosa Swamp** is about 10 km NW of Njombe. From here phosphates enriched in aluminium and REE were described as minerals in lateritic bauxite which formed as weathering products of an epidote-apatite rich granite. Whole rock analyses indicate enrichment of up to 10 times light REE in the laterite compared to the fresh granite below. This laterite therefore bears similarities to Chinese laterites which are also enriched in REE. However, the extractability of these REE and hence, the economic value of this occurrence, still needs to be determined.

EVALUATION

Potential investors in rare earths deposits in Tanzania should by all means focus on Wigu Hill carbonatite. Obviously only Wigu Hill has a chance to compete with the REE flooding the world market from China. Possibly one of only three major REE deposits outside China, Wigu Hill should be explored in detail in due time. Because REE beneficiation and refining is very difficult, and therefore very expensive, investors might also consider mining the carbonatite dykes at Wigu Hill and transporting the crude ore to Kisaki railway station for export via Dar es Salaam harbour.

Table 42: Important rare earth element occurrences in Tanzania (after Orris & Grauch 2002).

Deposit	Latitude	Longitude	REE Mineralogy	Other Ore or Important Minerals	Host Rock(s)	Comments / Resources
Mbeya Region						
Nakonde	10° 03' S	34° 31' E	Apatite	Magnetite, Ba-enriched and Sr-enriched	Carbonatite	Mg-carbonatite contains 1500 ppm La+Ce+Nd
Panda Hill	9° 00' S	33° 14' E	Bastnaesite, Monazite, RE-Carbonates	Apatite, Pyrochlore, Pyrite, Magnetite, Fluorite, Celestite, Barite, Ilmenite, Rutile, Sphene	Carbonatite in fenitised gneiss and granulite	Nb reserve, P resource (480 Mt@0.33 Nb_2O_5, 3.5 wt.-% P_2O_5)
Sengeri	8° 57' S	33° 11' E		Apatite, Fluorite, Pyrite, Barite, Pyrite	Mg-carbonatite dykes and breccias	
Ngualla	7° 42' S	32° 50' E	Parasite, Monazite, Apatite, Barite, Pyrite, Sulphides	Magnetite, Biotite, Muscovite, Fluorite, Diamond	Sovite	P resource, REO ~5 wt.-%
Iringa Region						
Lihogosa Swamp	9° 13' S	34° 47' E	Apatite, Goyazite, Florencite, Rau-haugite	Epidote, Monazite, Goethite/Hematite, Zircon, Crandallite, Wavellite, Millisite	Lateritized epidote-apatite granite	6 to 12 times P and REE-enrichment compared to fresh granite
Morogoro Region						
Wigu Hill	7° 26' S	37° 34' E	Bastnaesite, Monazite, Ce-Goyazite	Nb-rich, Fluorite, Strontianite, Barite, Celestite, Pyrite, Spinel	Weathered dolomitic carbonatite (rauhaugite), hydrothermal solutions rich in REE, Sr, F, Ba, and silica	$\geq$7 carbonatite dykes emplaced in granulite terrain. 5-20 wt.-% REO

Table 43: Analyses (data in mg/kg) of important rare earth element occurrences in Tanzania (various authors and campaigns).

Location	Panda Hill					Sengeri				Ngualla				
Rock type	Kunja Zone not denoted			Dolomite		High Mg-Content		Biotite-Apatite?	Fe-Carbo-natite	not denoted			WD pit	
ID	Residual adit IV	328	conc.	PH/05b	PH/02	EP500	VS417		VSNg-83	VS 384A	VSNg 82	*VS 385*	top 80 cm	5 m
reference	Chesworth et al. (1988)			Ohde & Mataragio (1999)		Chesworth et al (1988)								
no of samples	*n=1*	*n=1*	*n=1*	*n=1*	*n=1*	*n=1*	*n=1*	*n=1*	*n=1*	*n=1*	*n=1*	*n=1*	*n=1*	*n=1*
Y	44	61	23			30	14	31	39,269	16	58	33	25	18
La	5,200	2,190	1,320	1,846	1,180	200	9,100	1,511	2,370	-	-	13,700	1,270	12,670
Ce	7,600	3,790	2,950	5,290	2,990	4,260	470	4,575	3,400	3,940	2,500	20,100	18,100	21,500
Pr	-	-	-	-	-	-	-	-	-	1,670	1,180	-	-	-
Nd	3,730	1,540	1,050	725	1,750	2,310	475	382	1,350	1,590	1,470	9,700	9,620	10,800
Sm	-	-	-	41.8	161.0	-	-	-	-	-	-	-	-	-
Eu	-	-	-	12.9	47.0	-	-	-	-	-	-	-	-	-
Gd	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tb	-	-	-	3.49	19.80	-	-	-	-	-	-	-	-	-
Dy	-	-	-	LLD	2.3	-	-	-	-	-	-	-	-	-
Ho	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Er	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tm	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Yb	-	-	-	5.79	34.6	-	-	-	-	-	-	-	-	-
Lu	-	-	-	LLD	1.7	-	-	-	-	-	-	-	-	-
Th	-	-	-	59.2	36.2	-	-	-	-	-	-	-	-	-
ΣLREE	*16,530*	*7,520*	*5,320*	*7,903*	*6,081*	*6,770*	*10,045*	*6,468*	*7,120*	*7,200*	*5,150*	*43,500*	*2,8990*	*44,970*
ΣHREE +Th,Y	*16,574*	*7,581*	*5,343*	*81*	*142*	*30*	*14*	*31*	*39,269*	*16*	*58*	*33*	*25*	*18*
ΣR EE incl. Y	*16,574*	*7,581*	*5,343*	*7,925*	*6,186*	*6,770*	*10,045*	*6,468*	*7,120*	*7,200*	*5,150*	*43,500*	*28,990*	*44,970*
Method	XRF	XRF	XRF	INAA	INAA	XRF	XRF	XRF	XRF	XRF	XRF	XRF	XRF	XRF

Table 43: Analyses (data in mg/kg) of important rare earth element occurrences in Tanzania (various authors and campaigns). Continuation.

Location	Lihogosa Swamp			Wigu Hill						Ufipa
Rock type	Lateritic Bauxite			Dolomite-Bastnaesite-Carbonatite						Apatite-Pegmatite
ID	A7/214	A7/215		3			283	326	327	
reference	Murakyahwa *(1991)*			McKie *(1962)*	Mariano *(1973)*	Sampson & Wright *(1964)*	Chesworth et al (1988)			Harris *(1961)*
no of samples	*n=1*	*n=1*	*n=10*	*n=1*	*n=3*	*n=2*	*n=1*	*n=1*	*n=1*	*n=1*
Y	762	1,267	634		635	350	39	7	10	
La	2,633	6,002	2,278	465,591	24,394	5,000	5,470	30,800	40,800	
Ce	3,321	3,710	2,173	464,057	26,406		7,760	37,400	47,500	75,319
Pr				51,468	10,028					
Nd	2,928	6,751	2,462	129,585	7,232		2,090	9,890	12,500	
Sm				16,119	3,131					
Eu				1,158						
Gd					1,118					
Tb										
Dy				6,771	425					
Ho				5,728						
Er				2,859						
Tm										
Yb				2,847						
Lu										
Th				2,138						
ΣLREE	*8,882*	*16,463*	*6,913*	*1,126,820*	*71,191*	*5,000*	*15,320*	*78,090*	*100,800*	*75,319*
ΣHREE +Th,Y	*762*	*1,267*	*634*	*21,501*	*2,178*	*350*	*39*	*7*	*10*	*0*
ΣREE incl. Y	*9,644*	*17,730*	*7,547*	*1,146,183*	*73,375*	*5,350*	*15,359*	*78,097*	*100,810*	*75,319*
Method	unspecified	unspecified	unspecified	unspecified	unspecified	unspecified	XRF	XRF	XRF	unspecified

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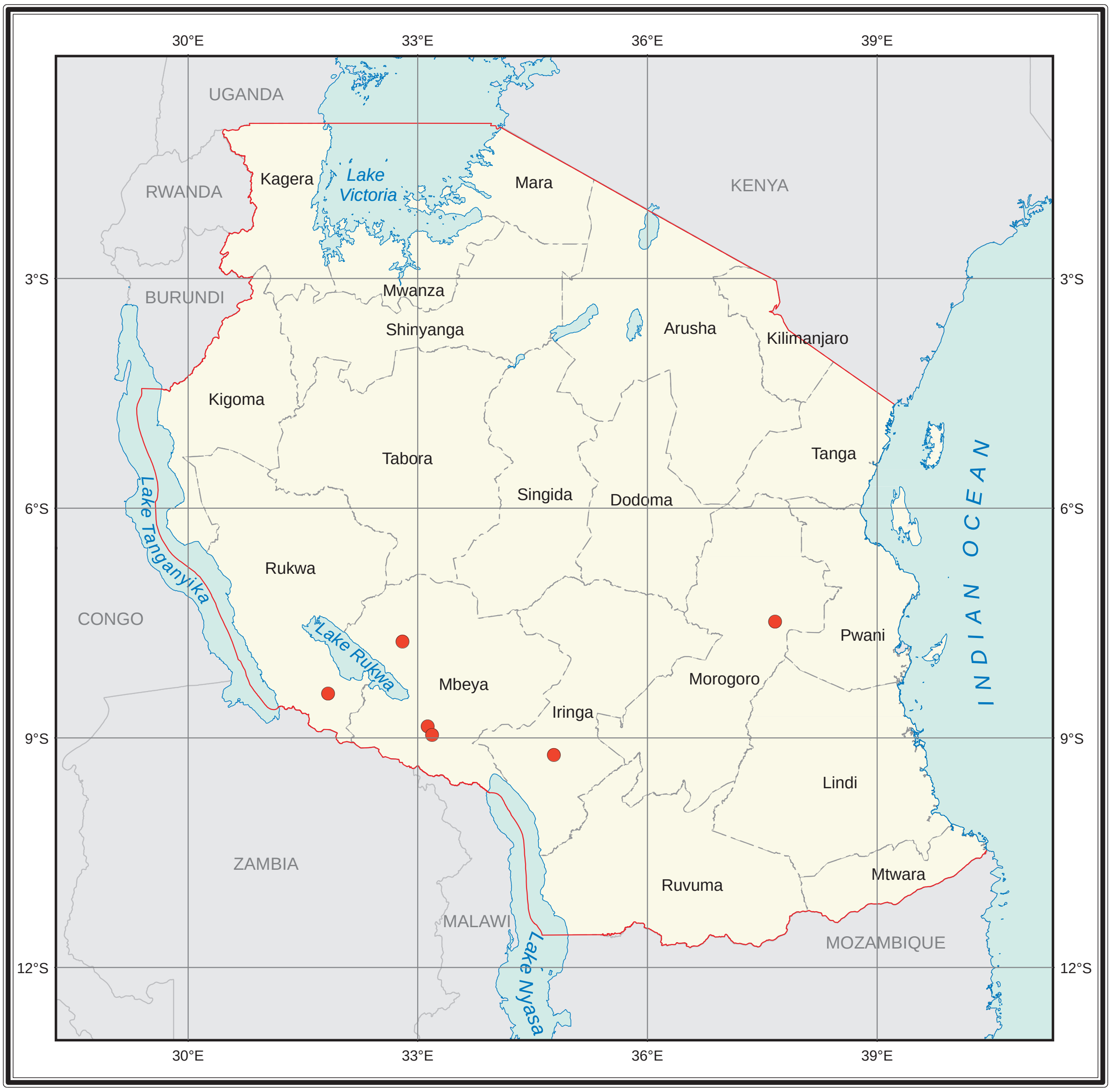
Occurrences of Rare Earths in Tanzania



Scale 1 : 10,000,000

0 100 200 300 400 500 km

Legend

● Rare Earths

ROCK QUARTZ

GENERAL INFORMATION AND USES

Although quartz is a highly ubiquitous mineral, rock quartz is a highly sought after and in some cases very valuable commodity. While rock crystal, vein quartz, and pegmatitic quartz can be differentiated by origin, common applications are that they are all used for the production of quartz and optical glasses, piezo-electric quartz and silicon.

RELEVANT OCCURRENCES IN TANZANIA

Only finds worth mentioning in the geological literature on Tanzania are of **rock crystals**, but not of pure vein quartz or pegmatitic quartz. Rock crystals of small sizes were first reported from gravels and surface detrital deposits near Mbirira north of Kasulu in Kigoma District. This occurrence was never investigated, so no details are known. The same can be said about a large quartz crystal which was apparently found in a lake in the Munguli area near Lake Selya some 15 km from Kondoa Boma. One find of marketable grade rock crystal was made in the Rubeho area of the Kilosa District in 1944. Here, 11 km NW of Taragwe Mountain, a small eluvial pocket delivered a bag of 58 well-formed and transparent crystals weighing 26 kg. In 1954 another occurrence was found in the same area, at Idibo, 11 km from Chmatui. 50 kg of quartz crystals were taken out of the ground, having been found in pockets and irregular small veins in rotted basic rock.

Figure 56: Large crystal of pegmatitic quartz covered by mica tailings at the abandoned Tchenzema mica mine.

When building the railway way line from Dar es Salaam to Zambia, 13.7 kg of rock crystals were collected about 6 km east of Uchindili station (571.3 railway-km from Dar es Salaam). The weight of the biggest crystal was 6.2 kg. By the road side, a network quartz vein belt occurs in the weathered granitic rocks and is about 70 m long and 6 m wide.
Another occurrence of rock crystals was discovered at Lugama 858.5 railway-km from Dar es Salaam). Here, in a quarry on the southern side of the railway a network quartz vein occurs in the weathered gneisses with a length of over 40 m and width of 3-4 m. In the quartz vein, a few geodes with semi-transparent quartz crystals can be found.

Large crystals of **pegmatitic quartz** of presumably high to exceptionally high quality were found by experts from a joint GST-STAMICO-BGR team in tailings of the abandoned Tchenzema mica mine (7° 07.088' S, 37° 34.814' E) at an elevation of 1,518 m a.s.l. in the Uluguru Mountains (see Mica). The weights of several crystals exceeded 50 kg each. While reserves may easily exceed several tons of high quality rock quartz at this site, access to most of the old mica mines in the Uluguru Mountains is only possible on foot after a strenuous walk.

REQUIREMENTS AND EVALUATION

For industrial use, all rock quartz resources have to be exceptionally clean. For the production of quartz glass, impurities must be below 150-200 ppm, with the sum of Cu, Co, Cr, Mn, Ni and V <5 ppm! Piezo-electric quartz must be chemically pure and may not have any inclusions, cracks or twinning. Rock crystals should weigh >125 g. For the production of electronic grade silicon, impurities are only allowed in the ppb range. However, other varieties of silicon are much easier to produce. Because these requirements are very difficult to comply with, even small deposits of rock quartz, say half a ton, may be worth marketing.

Although Tanzania does not have the best geology for occurrences of rock crystals, potential investors might get lucky . Gemstone brokers and dealers might be approached for large amounts of quartz crystals offered on local markets. Also, it has been said that pegmatitic quartz from Tanzania is not of good enough quality. This opinion already has been contradicted at at least one abandoned Tchemzema mica mine. Quartz veins have never been looked for in Tanzania as resources of quartz. Here, discussions with local geologists may lead to interesting finds. Summing up, the great interest worldwide in even small resources of exceptionally clean rock quartz offers a chance even for the low-budget but assiduous investor to find a comfortable niche market.

RELEVANT LITERATURE

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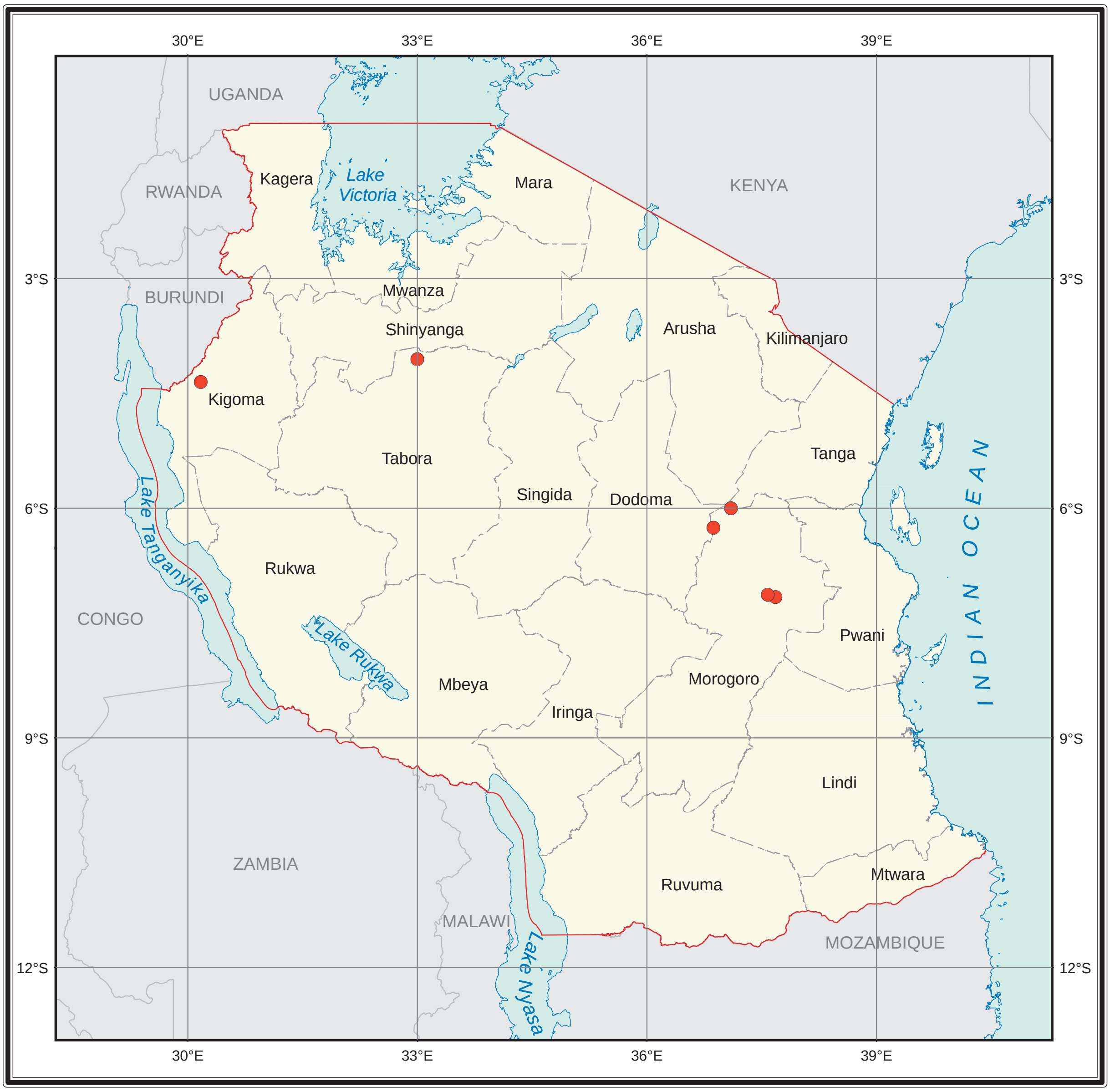
Occurrences of Rock Quartz in Tanzania



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Scale 1 : 10,000,000

0 100 200 300 400 500 km

Legend

● Rock Quartz

SALT, SODIUM CHLORIDE

GENERAL INFORMATION AND USES

Common salt, which is sodium chloride, NaCl, is essential for human and animal life. It is used for food flavouring and conservation, for the production of animal feed, for preserving skins, and for the production of caustic soda and chlorine in the chemical industry. It also finds numerous other applications in other industries. In Tanzania every year about 110 kt of common salt is consumed by humans, about 10 kt are used for food processing, and another 10 kt is consumed by livestock.

RELEVANT OCCURRENCES IN TANZANIA

In Tanzania, common salt is produced in solar salt works along the coast and from brines in the interior of the country. Currently there are 108 licensed salt producers.

The largest individual production of salt in Tanzania still comes from the works of Nyanza Salt Mines in **Uvinza**, Kigoma District. The source of the salt is a saline spring which was first exploited in 1904 during the time of German administration. About thirty springs or seepages of varying degrees of activity and salinity are known in the Uvinza area, but

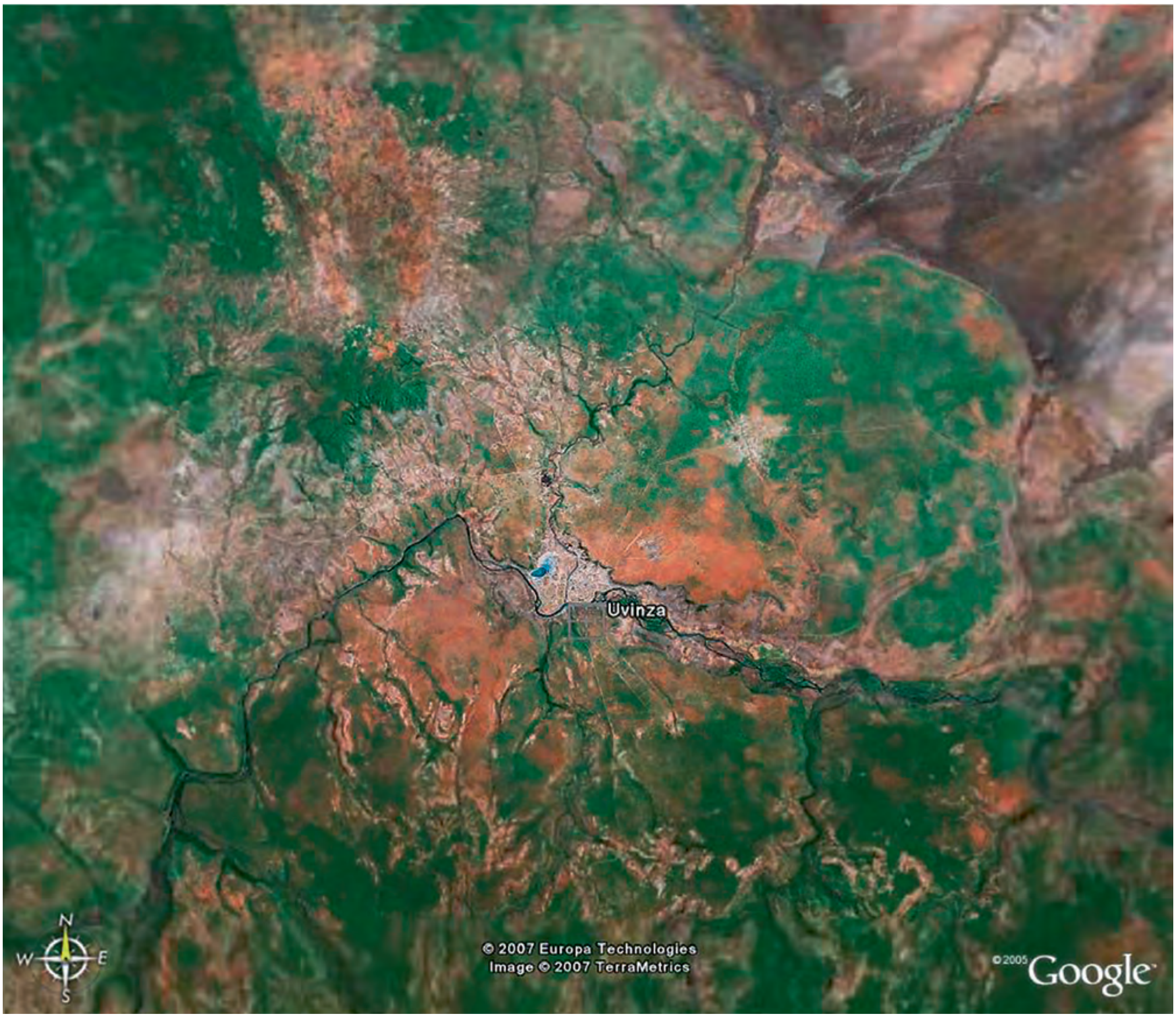


Figure 57: Satellite image of Uvinza, Kigoma District (Photo courtesy of Google Earth).

only five of these can be considered as major springs. The main points of emergence of brine are along the valley of the Ruchugi River for about 8 km upstream of Uvinza, and on both sides of the Malagarasi River valley for about 3 km upstream and 3 km downstream of Uvinza.

The brine concentration varies considerably in the different springs, though the composition is remarkably constant. NaCl makes up from 90.7 to 93.6 wt.-% of the dissolved solids, and KCl from 2.14 to 2.93 wt.-%; the remainder is made up of sulphates and chlorides of calcium and magnesium (see Salts, Potassium and Magnesium). The absolute composition of dissolved solids is given in the old literature as: 16.67 wt.-% NaCl, 0.511 wt.-% KCl, 0.408 wt.-% $MgCl_2$, 0.115 wt.-% $CaCl_2$, 0.014 wt.-% $CaCO_3$, and 0.357 wt.-% $CaSO_4$ (total: 18.33 wt.-%). The Nyanza spring has been artificially deepened to form a well about 10 m deep. Brine flows into the well from a pair of sub-parallel, steeply dipping fissures. The brine obtained from the Nyanza Spring by pumping it to capacity contains about 15 to 19 vol.-% total dissolved solids and thus provides a very suitable raw material for the production of sodium chloride by evaporation. A good quality salt is obtained by pre-concentrating of the brine in solar pans followed by evaporation in salinas and crystallization in solar pans again. About 34 kt of salt are produced at Uvinza each year, with about 75 % exported to neigh-

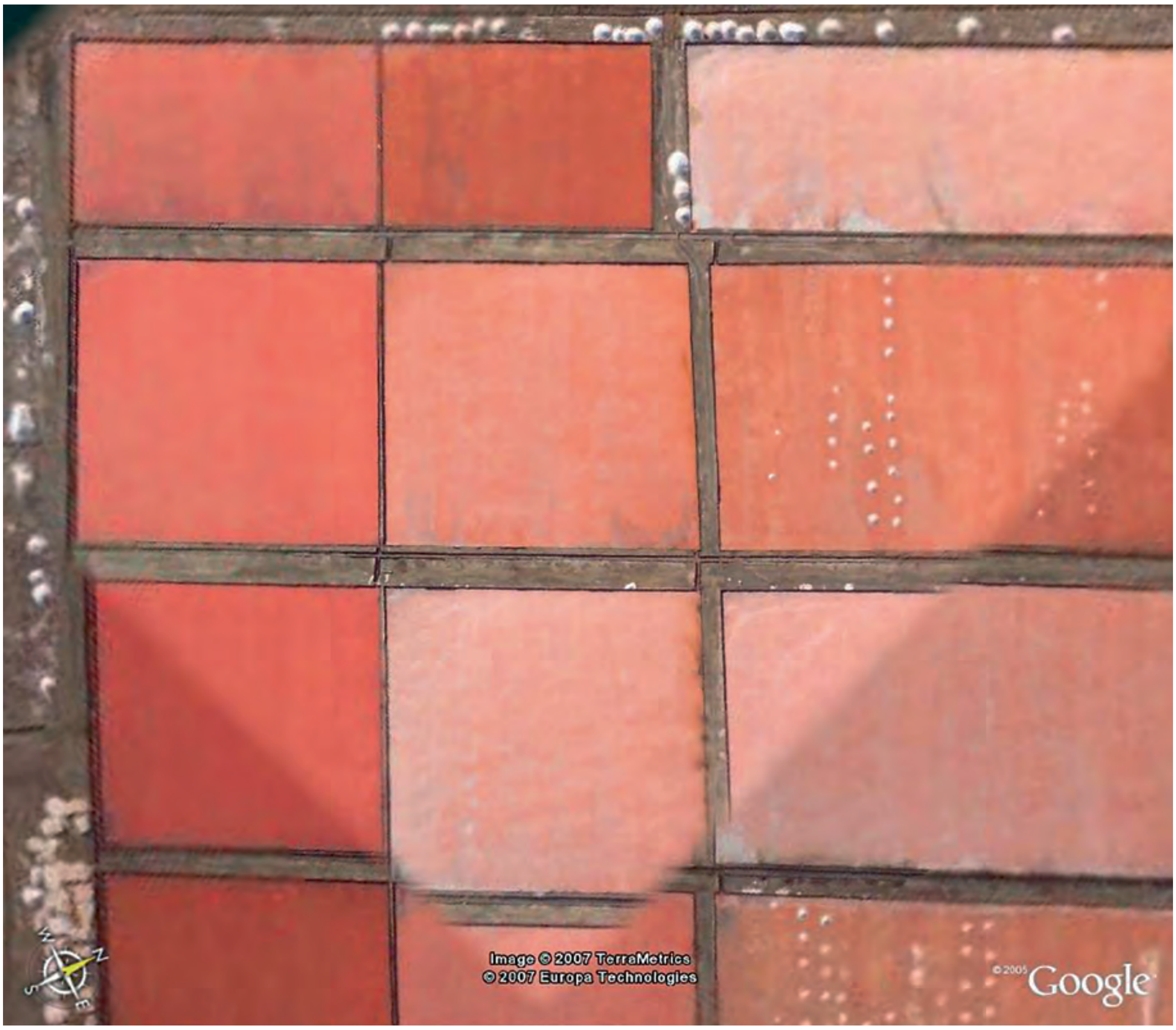


Figure 58: Satellite image of concentration pans being harvested in solar salt works at Saadani, Bagamoyo District (Photo courtesy of Google Earth).

Figure 59: Satellite image of salt works south of Mtwara (Photo courtesy of Google Earth).

bouring countries like DRC, Rwanda, Burundi, and Zambia.

There also are several small cooperatives which produce salt by boiling brines using fire wood. A recent survey puts the number of their members at about 5,000 in 23 salt producing districts. Though white in colour and not needing to be crushed this salt is inferior in quality as there is no process control.

A number of poor families produce salt by scooping saline soil ("steppe salt"), leaching it with brine from pits dug in the soil, and boiling the resulting solution. Both the quantity and the quality of the salt that they produce is meagre. An analysis of typical salt produced this way is given in the literature as: 66.5 wt.-% NaCl, 15.3 wt.-% KCl, 3.7 wt.-% $MgCl_2$, 2.7 wt.-% sulphates of potassium and calcium. The residual 11.8 wt.-% will be insolubles and moisture. The extensive use of valuable firewood for production of such a low-quality commodity is highly disputable.

At **Ivuna** at Lake Rukwa in the Mbeya District salt has been produced in salt-pans since ancient times. The pans are fed by three

Figure 60: Concentrating pans ready for harvesting of salt in solar works near Mtwara.

groups of springs, two of which produce hot, slightly saline water, which discharge into the middle of a steep-sided depression about 500 x 250 m in area and about 4.5 m below the general level of the surrounding flat sandy plain. The brine from the springs has a temperature of about 60 °C and a total solute content of 0.36 to 0.42 vol.-%. Salt is obtained during the dry season by solar evaporation of the weak brine which accumulates in the depression. The salt produced in this way is impure and contains up to about 20 wt.-% sodium sulphate and 5 wt.-% potassium chloride. However, it finds a ready market in the Mbeya area where transport costs make salt from Uvinza and the coast very expensive.

Most of the salt being produced and consumed in Tanzania comes from **solar salt works** along the coast. The centres of solar salt works are in Tanga District, Bagamoyo District, Kisarawe District, Lindi District and in Mtwara District. These solar salt works, most of which were established several decades ago, profit from favourable weather conditions, a copious supply of sea brine (density of 3 - 3.5 °Bé = degree Baumé = vol.-% common salt solution) and clayey soil. Quite often they were established in lagoons, or behind natural barriers of barrier islands or dunes offering protection against flooding by exceptional tides or storms. At least one works is sited on a tidal creek, the water of which can even have a density twice that of water from the open sea. The clayey soil is needed for the erection of shallow concentrating pans, just a few decimetres deep. These are flooded at high tide, supplemented in some cases by pumping. The density of the water in the ponds is gradually increased until crystallisation of the salt. Harvesting takes about 20 to 45 days and takes place at a concentration of about 25 °Bé. Production is restricted to the dry season. Some of the production is iodised (100 ppm) by hand spray.

The final product should contain >97 wt.-% NaCl. However, the lack of cladding in the noncompacted concentrating pans means that the salt produced in this way is relatively impure containing too many impurities (see table 44). Also concentration and harvesting does not follow scientifically proven, i.e. optimum procedures. Therefore, the salt from Tanzania can unfortunately still not compete with salt produced in industrialized countries or even in neighbouring Kenya.

Table 44: Chemical bulk rock analysis (data in wt.-%) of salt produced in solar salt works in the Mtwara District. BGR analysis by ICP-OES.

	Saline Joineè	Saline P.
Cl^-	57.0	57.4
Na^+	35.8	37.0
Mg^{2+}	0.48	0.25
Ca^{2+}	0.17	0.10
K^+	0.16	0.11
Sr^{2+}	0.01	0.01
SO_4^{2-}	1.15	0.59
Br^-	0.04	0.02
NO_3^-	0.03	0.02
HCO^{3-}	0.03	0.02
BO_3^{3-}	0.02	0.01
SiO_2	0.01	0.01
Sum water insoluble	5.1	4.5
total	*100.00*	*100.02*

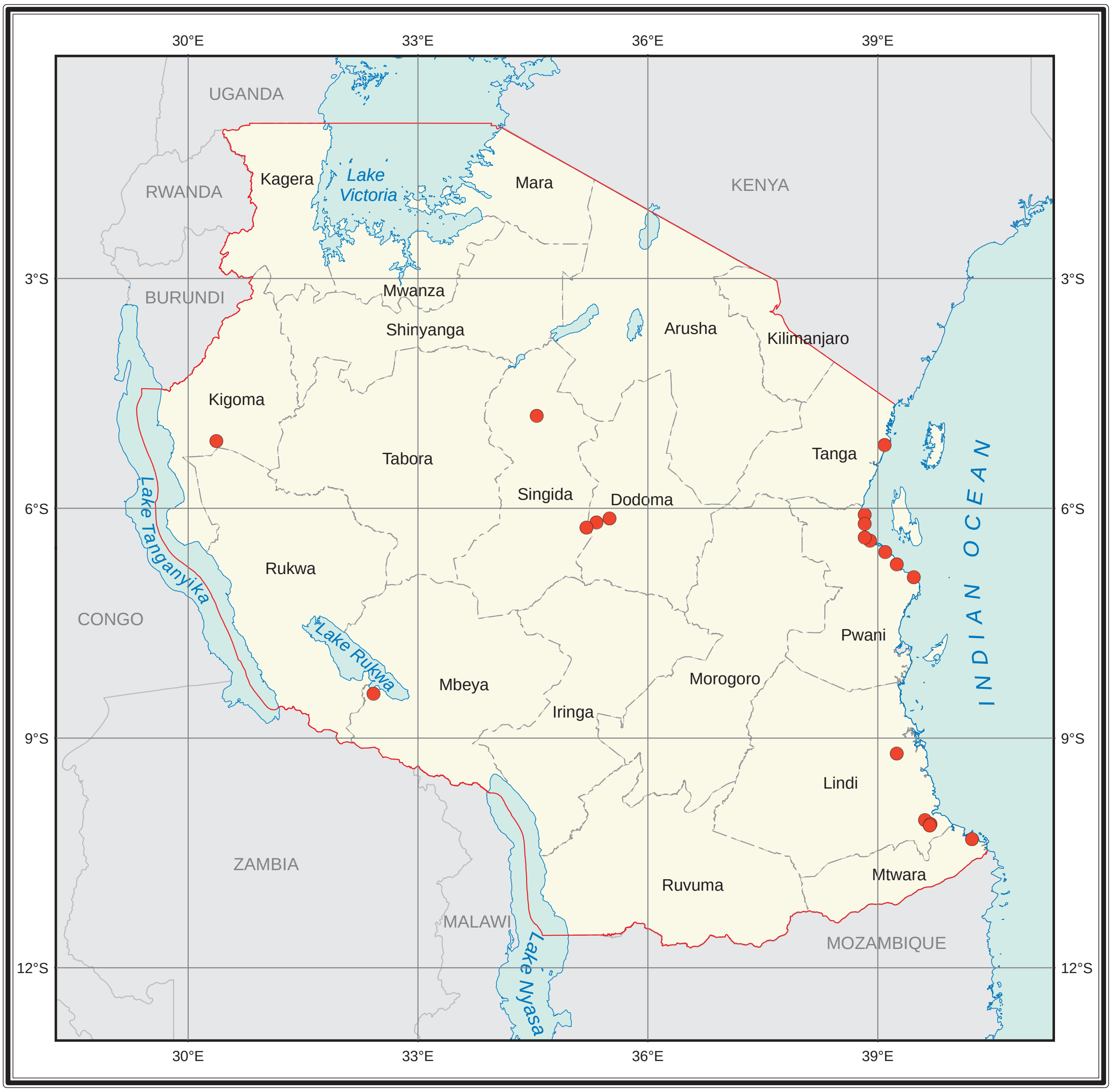
Importantly horizons of almost pure rock salt, several hundred metres in total thickness and most probably with nearly unlimited resources, have been found in several deep drill holes in the Kilwa District (see Gypsum). The overburden is between 70 to 200 m.

REQUIREMENTS AND EVALUATION

The basic chemical requirements of raw unpurified salt for for industrial use are: >95.5 wt.-% NaCl, <2.5 wt.-% moisture, <0.1 wt.-% Ca, Mg, K, <0.5 wt.-% insolubles. For human consumption (table salt) the basic chemical requirements are: >97.5 wt.-% NaCl, <2 wt.-% Ca, Mg, <16 ppm Fe, <4 ppm heavy metals (e.g. Pb), <1 ppm As. Iodized salt should contain 60 – 100 ppm J.
Typical chemical compositions of table salt are: 99.3-99.5 wt.-% NaCl, 0.05-0.08 wt.-% moisture, 0.3-0.6 wt.-% Na_2SO_4, 0.04-0.06 wt.-% insolubles, 0.03-0.05 wt.-% Ca, 0.008-0.015 wt.-% Mg.

Potential investors in common salt production in Tanzania should focus on the many well-established marine salt works along the coast. Cladding the existing evaporation pans and implementing small changes in harvesting procedures can drastically improve the quality of marine salt produced in this way. By doing so, high-quality table salt could also be produced in Tanzania which can easily compete with imported salt from Kenya or the USA.

Occurrences of Salt (Sodium Chloride) in Tanzania



BGR © Bundesanstalt für Geowissenschaften und Rohstoffe, Hannover

Scale 1 : 10,000,000

0 100 200 300 400 500 km

Legend

● Sodium Chloride

SALTS, SODIUM OTHER THAN SODIUM CHLORIDE

GENERAL INFORMATION AND USES

Other economically important salts of sodium other than sodium chloride are

- Sodium carbonate or soda, also called natron ($Na_2CO_3 \times 10\ H_2O$),
- Trona ($Na_2HCO_3CO_3$),
- Nahcolite ($NaHCO_3$),
- Sodium sulphate or thenardite (Na_2SO_4),
- Mirabilite or glauber's salt ($Na_2SO_4 \times 10\ H_2O$),
- Sodium nitrate or salpetre ($NaNO_3$),
- Sodium phosphate (Na_3PO_4)

All sodium carbonates are very important raw minerals for the chemical industry. They are also used as fluxes in the production of glass and enamel, as well as soap and detergents. Other applications can be found in industries such as paper, pulp, textiles, steel, energy and food production. Sodium sulphates are mainly used in the production of paper and pulp, detergents, and glass. Saltpetre is an important fertilizer, and sodium phosphate, is mainly used in the production of soap and detergent.

Figure 61: Satellite image of Lake Natron showing white salt crust covering much of its surface (Photo courtesy of Google Earth).

RELEVANT OCCURRENCES IN TANZANIA

Because sodium salts are very typical for saline lakes in general, they are also quite typical and well-known in the brines and salt crusts of the salt lakes of the Eastern Rift Valley of Tanzania. In fact, Lake Natron was even named after the mineral natron which is the dominante mineral in its salt crusts.

Lake Natron is in the Loliondo District, Arusha Region and can be reached only by plane or by several hours drive on very rough roads or tracks. The lake is about 57 km in maximum length and 24 km in maximum width. The size of the lake is quite variable (570 – 1,040 km^2) with some of it drying up during dry season. About 120 km^2 of the lake area is covered by a crust of mixed salts up to 1.5 m thick. This salt crust is created by evaporation of moisture from underlying saline water, i.e. brine, which is also enriched in various salts. The brine in turn originates from a number of hot springs constantly delivering soda brine to the lake. Due to this fact, mining of the salt could be really sustainable as the deposit is constantly being replenished. The brine in the lake is pink to light brown in colour which is due to the pink heliophilic bacteria contained in the brine as organic matter. The average chemical composition of the salt crust and the brine is given in table 45. The average thickness of the crust is said to be 0.43 m and of the underling brine only 0.35 m. The maximum water level is 1 – 2 m in the south where a permanent water body exists. The thickness of the salt crust especially differs to Lake Magadi in Kenya where the salt crust being mined since 1919 is up to 30 m thick.

In co-operation with STAMICO, the Lake Natron soda deposit has been explored in detail by companies from Japan (1978), and France (1992/93). In 1993, investment costs were estimated at 125 million US-$ including the costs for building roads, and the construction of facilities on site and in Tanga. The costs of the road infrastructure for a road from Lake Natron to Mto wa Mbu (118 km) were estimated at 12.5 million US-$ (i.e. 10 % of the total cost of the project) alone. Other major problems with the deposit are its high fluoride content because fluoride is regarded as a contaminant, and difficult mining due to the thinness of the crust and the brine

Table 45: Average chemical composition (data in wt.-%) of brine and salt crust from Lake Natron (various authors and campaigns).

Constituent	Brine	Crust	
Na_2CO_3	19.3	-	-
$NaHCO_3$	1.3	-	-
Na_2CO_3 x $NaHCO_3$ x $2H_2O$	-	60.3	60.90
Na_2CO_3 x H_2O	-	30.7	27.33
NaCl	11.2	5.45	6.23
Na_2SO_4	0.69	2.80	3.36
NaF	0.25	1.37	1.25
SiO_2	0.10	0.19	-
Fe_2O_3	0.005	0.0237	trace
$CaCO_3$	n.d.	0.14	0.19
P_2O_5	0.07	0.03	-
Acid insol.	n.d.	0.15	0.44
B	0.011	0.06	-
K	0.41	0.0014	-
Li	n.d.	n.d.	-
Br	0.034	0.015	trace
I	0.002	0.002	-
Ba	n.d.	n.d.	-
Mn	n.d.	0.004	-
Cr	0.0000007	0.00002	-
Zn	0.000004	0.0031	-
Ti	0.00017	0.0046	-
V	0.000003	0.0016	-
COD (Chemical Oxygen Demand)	0.05	0.10	-

Table 46: Estimated resources of various sodium salts (data in million tons) in Lake Natron (various authors and campaigns).

	Crust	Brine	Total
Na_2CO_3	109 – 166	27 – 32.5	136 – 198
NaCl	11.5 – 18.7	15.0 – 19.5	31.0 – 33.7
Na_2SO_4	4.5 – 6.0	0.9 – 1.2	5.4 – 7.2
NaF	2.2 – 2.8	0.3 – 0.4	2.5 – 3.2

Table 48: Composition (data in wt.-%) of brines from pools along the Sibiti River (after Orr & Grantham 1931).

	Pool 1		Pool 2
NaCl	51.2	59.2	62.9
Na_2CO_3	36.8	24.8	26.3
Na_2SO_4	9.1	7.0	6.2
$NaHCO_3$	1.5	5.0	4.5
Na_3PO_4	1.2	0.5	n.d.
KCl		n.d.	trace
Mg / Ca		0.0	0.0
Acid insol.		0.0	0.0
Total salinity (g/l)	423.5	424.8	415.5

Table 47: Composition (data in wt.-%) of upper cm of salt crust of various regions in Lake Eyasi (after Orr & Grantham 1931).

	SE region			NE Centre			NW region				NE
NaCl	75.5	46.3	15.8	18.9	35.4	15.3	13.1	52.0	41.0	56.2	44.5
Na_2CO_3	8.6	33.1	32.5	25.0	24.8	27.0	43.8	18.6	22.9	16.1	17.5
Na_2SO_4	2.3	6.6	10.5	trace	5.5	4.5	7.8	5.5	8.1	8.8	7.0
$NaHCO_3$	6.4	6.7	25.7				25.7	15.4	17.1	10.7	10.7
Na_3PO_4							0.0	0.0	0.0	trace	0.0
KCl							0.0	trace	0.0	0.0	0.0
Mg / Ca							0.0	0.0	trace	trace	0.0
Acid insol.	0.6		1.3				4.4	0.7	0.0	0.0	9.9
Moisture	3.4		11.1				12.1	6.4	8.5	6.1	7.6

Lake Eyasi is also quite remote and about 80 km in length and 15 km in width. It is more or less dried up during most of the year. In the middle of the lake, there is a crust of clay and silt cemented by salts a few cm thick. Below this layer there are other strata of fine sediments intercalated with sediments cemented by salts. The chemical composition of the salt is highly variable as shown in table 47.

Realistic resources of salt from Lake Eyasi have never been calculated because only the top salt layer was analysed some 70 years ago and the lake has never been explored or sampled since. Regrettably, there are also no reports to date on the thickness and composition of the brine in this lake. Commercial mining of salt from Lake Eyasi will run into problems anyway because of the need to separate the salt from the muddy intercalated sediments.
The composition of the brines flowing into Lake Eyasi via Sibiti River are given in table 48.

Lake Manyara is about 41 km in length and 15 km in maximum width. The average water depth is about 3 m. Lake Manyara is protected as a National Park. The total resources of Na_2CO_3, $NaHCO_3$, KCl, and $MgCl_2$ have been estimated as 70 million tons with no other details available in the literature.

Lake Balangida lies about 80 km NE of Singida and has a relatively good road infrastructure. It covers an area of about 33 km², about half of which is covered by a salt crust about 0.075 to 0.1 m thick. The composition of this salt is given in table 49. In contrast to Lake Natron, but similar to all other saline lakes in

Table 49: Chemical composition (data in wt.-%) of crust of Lake Manyara, and crust and water of Lake Balangida (after Teale & Oates1946).

	Lake Singida	Lake Balangida Lelu	Lake Manyara		Lake Balangida	
	Salt crust					Water
			North end	South end		
NaCl	91.72	72.52	59.5	8.1	40.8	14.4
Na_2CO_3	-	1.19	13.1	26.8	21.7	9.4
$NaHCO_3$	-	14.89	-	2.9	6.4	-
Na_2SO_4	0.68	9.82	22.7	59.4	23.8	4.1
K_2SO_4	-	2.81	-	-	-	0.4
KCl	-	-	-	n.d.	2.7	-
Na_3PO_4	n.d.	n.d.	n.d.	n.d.	0.3	n.d.
Acid insol.	0.66	n.d.	n.d.	n.d.	0.5	n.d.
Moisture	3.90	n.d.	n.d.	n.d.	4.2	n.d.

Figure 62: Satellite image of Lake Eyasi (Photo courtesy of Google Earth).

the Central Rift Valley the salt is a result of the continued high evaporation of surface waters in an undrained basin, itself the consequent of the absence of rainfall during several consecutive months of the year.
The resources of Lake Balangida (assuming a salt thickness of just 2.5 cm) were calculated at 200 kt NaCl, 120 kt Na_2SO_4, 110 kt Na_2CO_3, 32 kt $NaHCO_3$, 14 kt KCl, and 1.6 kt Na_3PO_4.

Lake Balangida Lelu is 50 km SW of Lake Balangida and covers an area of about 47 km^2. Its salt crust is rich in common salt, nahcolite, and thenardite. Nothing is known about the thickness of the crust or the salt resources in total. However, the extent of the salt crust is said to vary considerably each year.

Other lakes of the rift zone are said to be relatively poor in sodium salts other than sodium chloride, e.g. Lake Babati is poor in any salts and the salt in Lake Singida contains no natron, and only about 0.7 wt.-% Na_2SO_4. However, in general, hardly anything is known about the chemical composition of the waters and salt crusts of the other lakes in Tanzania besides Lake Natron.

Bahi Swamp covers an area of 125 – 140 km^2 and lies in the central part of Tanzania about

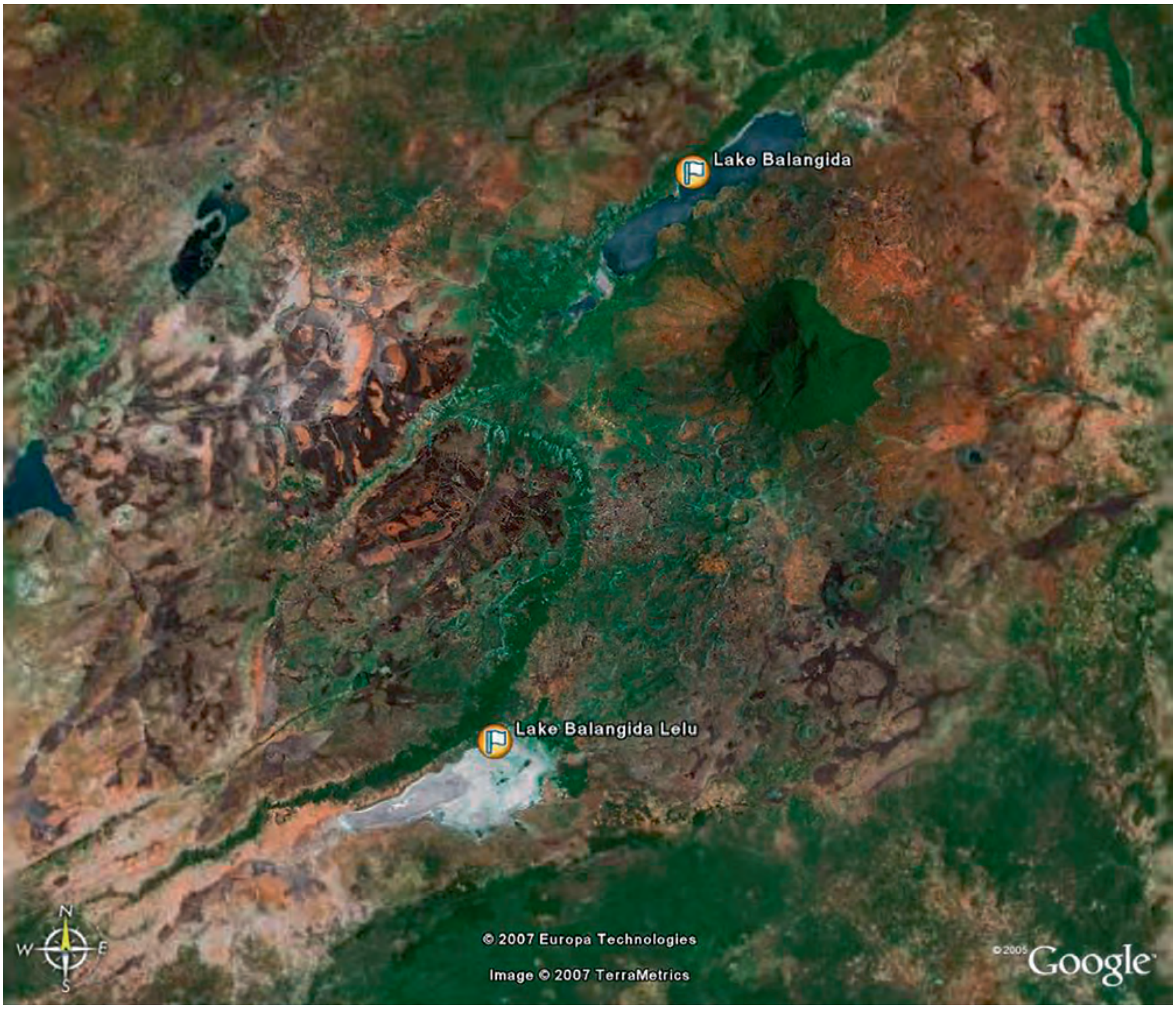


Figure 63: Satellite image of eastern shoulder of Central Rift Valley showing Lake Balangida and Lake Balangida Lelu (Photo courtesy of Google Earth).

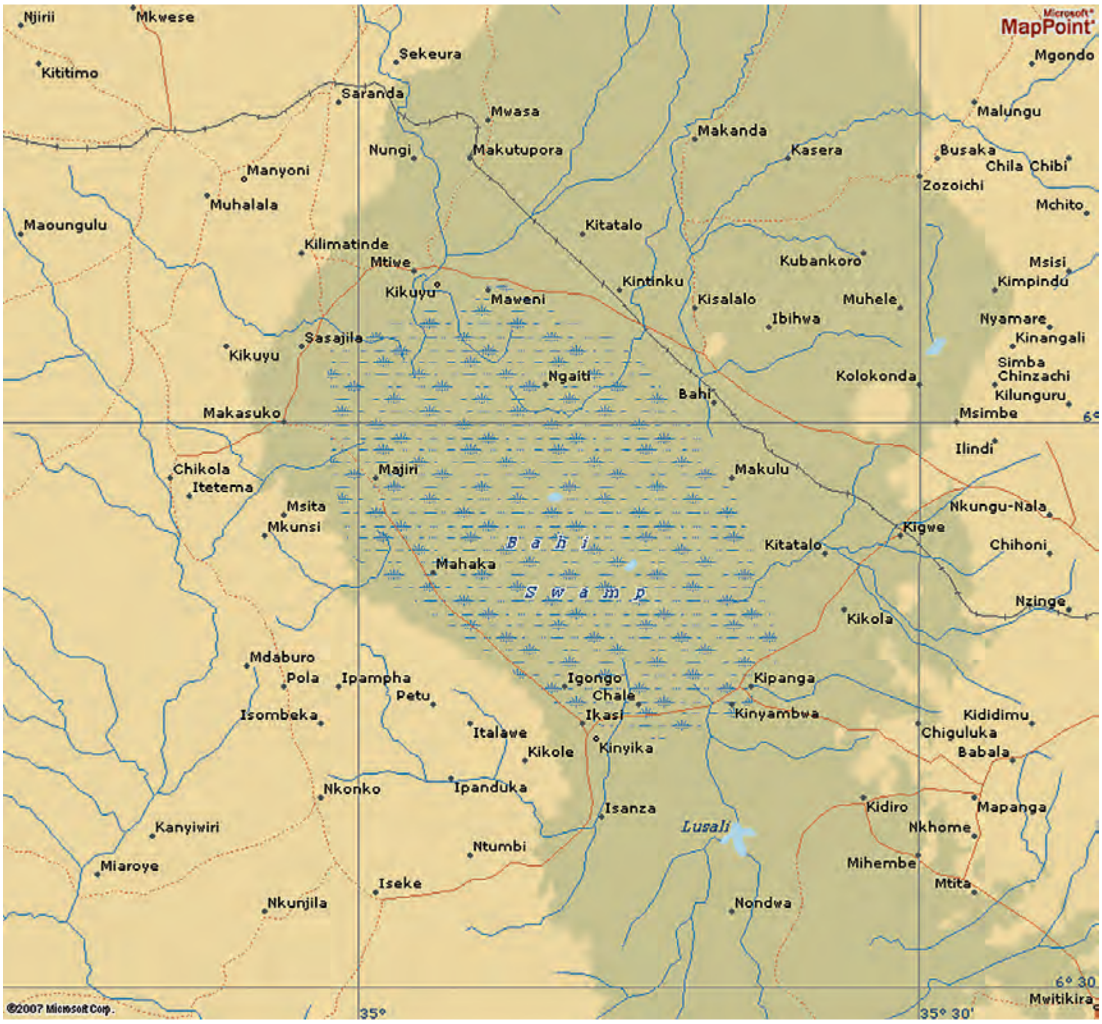


Figure 64: Map of Bahi Swamp.

50 km to the west of Dodoma. In the middle of the swamp there is a large playa lake which falls dry every few years. The swamp is underlain by layers of clays and sandy clays about 110 m thick. Some of the clay layers have been found to be radioactive due to their content of uranium-bearing minerals. At Ikasi to the south of the swamp, brines were found underneath the sediment strata and in shallower wells (1 – 3 m from surface). All the brines showed a highly variable chemical composition containing from 3 to 12 vol.-% total solutes and various salts of sodium, magnesium, and calcium. The annual volume of brines available at Ikasi was calculated as 365,000 m^3, not including any replenishment. Replenishment involves the leaching of surface sediments, and brine of magmatic origin presumably underlying the swamp.

Two other small occurrences of sodium salts other than sodium chloride have been reported:

The Shambarai soda deposit is 12 km from the Lucy Sisal Estates which are about 20 km to the SE of Arusha. Here, several shallow ponds up to 15 cm deep can be found covered with patches or thin layers of sodium salts. They are formed by the evaporation of water in ponds, which has dissolved the sodium from the underlying volcanic rocks and soils. The dominant mineral is trona, followed by other sodium carbonates and about 2 % sodium sulphate.

A small occurrence of rather pure mirabilite was reported in Ruaha Valley, about 5.5 km south of the Dodoma-Iringa road. No data are known.

REQUIREMENTS AND EVALUATION

The requirements for deposits of sodium salts other than sodium chloride are met in most Tanzanian deposits because reserves should be > 1 million tons of mineable salts. However, the industrial beneficiation of these minerals first requires the removal of sodium chloride by complex fractional crystallization. The final products also have to be very clean with >99 % purity required.

Potential investors should be aware that both Lake Natron and Lake Balangida Lela are major breeding grounds for flamingos in East Africa, and Lake Natron is the only regular breeding site for the lesser flamingo in Africa. Although currently both have no protection status, especially as Lake Natron is very remote, they are well known to bird lovers everywhere in the world. This means that any attempt to establish a mine will activate numerous international wildlife organizations and will finally most probably cause the mining companies to

Figure 65: Satellite image of Ikasi Village and Bahi Swamp at the end of the rainy season (Photo courtesy of Google Earth).

withdraw from following up on such a sensitive mining project. In addition to this ecological problem, there are also other problems which have already been mentioned. Especially the mining of thin salt crusts poses major technological questions because the commercial scale production of soda ash requires high investment costs and is therefore not suitable for small-scale mining. Due to these and other problems, investors should not focus on salt crusts or lakes of high ecological importance, but on brines.
According to current knowledge - which is quite limited - Lake Eyasi, Lake Balangida and Bahi Swamp seem to be attractive exploration targets for brine production only. Here, the composition and volume of the brine available have to be explored first with expenditure on boreholes and qualified analyses.

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Occurrences of Sodium Salts other than Sodium Chloride in Tanzania

Scale 1 : 10,000,000

0 100 200 300 400 500 km

Legend

● Sodium Salts other than Sodium Chloride

SALTS, POTASSIUM AND MAGNESIUM

GENERAL INFORMATION AND USES

Salts, other than sodium, occurring naturally in Tanzania are potassium chloride or sylvite (KCl), potassium nitrate or nitre (KNO_3), magnesium chloride, and magnesium sulphate. While all potassium minerals and magnesium sulphate are very important for fertilizer production most magnesium chloride is used for the production of magnesium metal.

RELEVANT OCCURRENCES IN TANZANIA

The only known sources of potassium salts in Tanzania are natural brines from certain saline springs, saline lakes, and minor occurrences of potassium nitrate.
Especially brines from the Western Rift System have been found to be enriched in potassium chloride. Salt produced at Ivuna, near Lake Rukwa, contains about 5 wt.-% KCl. The salt crust from Lake Balangida (see Salts, Sodium other than Sodium Chloride) was analysed and contains up to 2.7 wt.-% KCl. Also the bitterns from salt production at Nyanza Salt Mines, Uvinza, (see Salts, Sodium Chloride) are relatively rich in potassium chloride (0.51 wt.-% in raw salt) and magnesium chloride (0.41 wt.-% in raw salt). KCl is reported to make up 2.14 – 2.93 wt.-% of the salt bitterns.

The natural occurrences of potassium nitrate in Tanzania are all of very small extent. Three of the known occurrences are in the Kibaya area of the Arusha District, at Sikonge in the Tabora District, and about 100 km SE of Nzega. These deposits are the result of the action of rock rabbit urine on the potassium silicates in granitic rocks. At Nyabusalo on the western bank of Ugalla River in the Kigoma District, at Likonje in the Kigoma District, and at Kalama in the Mpande District potassium nitrate deposits have been formed by the accumulation of bat excrement in caves. The concentration of potassium nitrate in cave soil at Nyabusalo was calculated as about 5 vol.-%.
Salt produced from pans by locals close to the Lupa goldfields was reported to contain 15.3 wt.-% KCl and 3.7 wt.-% $MgCl_2$.

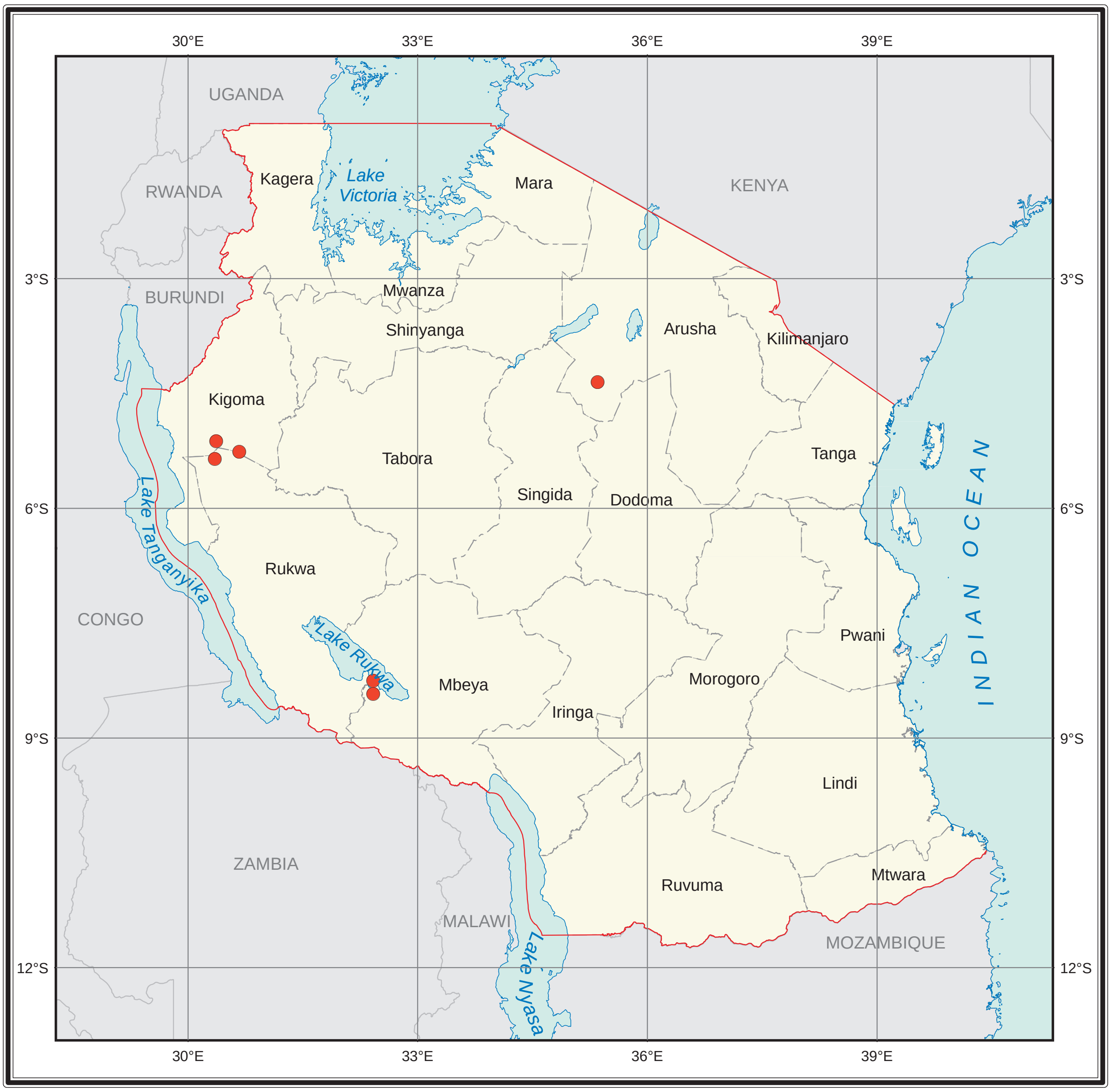
Lake Singida contains about 0.86 Wt.-% $MgCl_2$. A small occurrence of epsomite ($MgSO_4 \times 7H_2O$) was reported from the Pangani falls at Rufidji. Magnesium sulphate (up to 6.5 %) and magnesium chloride (up to 4 %) were detected in sodium chloride-rich brines of wells near Ikasi in the Manyoni District (see Salts, Sodium other than Sodium Chloride).

REQUIREMENTS AND EVALUATION

Although any potassium occurrence would be of interest to the Tanzanian economy as a potential source for fertilizer production, the beneficiation of purified potassium chloride from brines is rather difficult, i.e. expensive, and resources in Tanzania are quite small. For the economical production of muriate of potash (KCl-product), the minimum concentration of KCl in brines is 1.6 wt.-%. Total reserves of sylvite should be >5 million tons.
The occurrences of potassium nitrate are so small that they can only be used by locals for the production of gunpowder.

Although natural resources of potassium and magnesium salts are limited in Tanzania, interested investors should note that all the solar salt works along the coast (see Salt, Sodium Chloride) throw away mother liquors, containing large quantities of magnesium and potassium salts.

Occurrences of Potassium and Magnesium Salts in Tanzania



Scale 1 : 10,000,000

0 100 200 300 400 500 km

Legend

● Potassium Salts

SILICA SAND

GENERAL INFORMATION AND USES

Silica sand, also called quartz or glass sand, is the basic raw material for the production of glass. It is also used extensively as a refractory material, in ceramics, as a filler, in filtration, and in the production of building materials, like mortar and lime-silica bricks. In contrast to rock quartz, it is not being used for the production of silicon, where coarser and much purer material is preferred. It should also not be used as a blasting agent, because silica dust causes silicosis. Silica sand is not produced anywhere from normal beach sands or as a by-product from the heavy mineral mining of beach sands, because it is too expensive to separate the impurities contained in normal beach sand.

RELEVANT OCCURRENCES IN TANZANIA

In Tanzania, two occurrences of good-quality silica sand are known.

- The first and superior quality occurrence is in a strip from 30 km north to 15 km south of Bukoba on the shores of Lake Victoria, where large quantities of clean, rounded to subangular, sorted sands derived from Bukoban sandstones occur. These sands are mostly quartz grains, but a few sporadic grains of anatase (TiO_2) or ilmenite ($FeTiO_3$) have been observed. Some sand grains are stained superficially due to oxides of iron and manganese. Between 82 and 99 % of the sand is in the 150-500 µm size range. The total tonnage of suitable sand in seven separate stretches explored is estimated at about 1 to 2 million tons. The biggest single deposit is at Kashenye. Here the thickness of the sand is >5m of which only the upper 1.5 m are above the water-table. Resources are estimated at about 600 kt.

Table 50: Chemical analyses (statistical mean and ranges of data in wt.-%) of Bukoban sands at Lake Victoria (Kashenye deposit) (from Kimambo 1986, ed.).

	Silica sand (n=6)	
	Mean	Range
SiO_2	99.66	99.52 – 99.74
TiO_2	0.015	trace – 0.024
Al_2O_3	0.05	0.05 – 0.06
Fe_2O_3	0.028	0.011 – 0.048
Cr_2O_3	absent	absent (n=1)
CaO	0.02	0.02
MgO	0.01	0.01
Na_2O	0.01	0.01
K_2O	0.03	0.03
LOI	0.17	0.12 – 0.26
total	*99.993*	

Figure 66: Satellite image of Bukoba at western shore of Lake Victoria (Photo courtesy of Google Earth).

- The clean silica sand, which can be obtained when mining the Pugu Hills kaolin deposit (see Kaolin) was also found to be very suitable for the production of (amber, green, and sheet) glass, and also for refractory purposes. 85 % of this sand is in the 150-500 µm size range. Chemical analyses of beneficiation tests performed on Pugu Hills sand samples are given below.

Table 51: Chemical analyses (data in wt.-%) of Pugu Hills silica sand samples after beneficiation tests (from Kimambo 1986, ed.) and of commercial coarse silica sand produced by Pugu Kaolin Mines Ltd. (from Salim 1992).

	Silica sand after simple washing with agitation and scrubbing								Coarse silica sand
	Once-agitated						Twice-agitated		
sample-#	#1	#2	#3E	#4	#5	#6	#3C/D	#7	Pugu Kaolin Mines Ltd.
SiO_2	97.86	98.52	96.77	97.93	94.85	97.16	99.10	98.94	98.10
Al_2O_3	1.14	0.72	1.97	1.16	3.00	1.41	0.26	0.44	0.18
Fe_2O_3	0.19	0.18	0.22	0.19	0.62	0.35	0.11	0.12	0.09
TiO_2	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.04
CaO	0.02	0.02	0.10	0.02	0.12	0.22	trace	0.09	0.21
MgO	0.00	0.00	0.06	0.00	0.09	0.11	0.17	0.02	n.d.
Na_2O	0.01	trace	0.07	trace	0.03	0.02	0.01	0.01	0.02
K_2O	0.03	0.02	0.14	0.02	0.06	0.04	0.01	0.01	0.02
LOI	0.75	0.54	0.27	0.68	1.25	0.68	0.27	0.38	0.32
total	100.00	100.00	99.60	100.00	100.02	99.99	99.94	100.01	98.98

Table 52: Grain size distribution (data in wt.-%) of commercial coarse and fine silica sands produced by Pugu Kaolin Mines Ltd. (from Salim 1992).

Screen size	Pugu Kaolin Mines Ltd.	
µm	Coarse silica sand	Fine silica sand
>1,700	0.51	
1,000-1,700	1.37	
850-1,000	5.04	
710-850	20.75	
425-710	15.64	
355-425	18.12	
250-355	29.09	
180-255	7.17	
125-180	1.53	
90-125	0.67	
63-90	0.06	
<63	0.2	
>63		2
45-60		18
25-45		33
10-25		34
5-10		5
2-5		2
<5		6

REQUIREMENTS AND EVALUATION

To be called a silica sand, raw sand has to contain >98 wt.-% SiO_2. Because there are numerous applications for silica sand, there are also numerous requirements. In general the grain size distribution of the raw sand should be fairly constant with hardly any fines and heavy minerals. For colourless bottle glass production especially the concentrations of heavy metals (contained in heavy minerals) have to be very low with Fe_2O_3 <0.03 wt.-%, TiO_2 <0.03 wt.-%, Cr_2O_3 <0.001 ppm, and ZrO_2 <0.01 wt.-%. In general, all grain size distributions can be corrected by sieving, and all heavy mineral impurities can be taken out by separation, flotation and attrition. However, as this might be very expensive raw sand deposits of naturally good quality are definitely preferred.

Deposits should contain at least 1 million tons of mineable sand. At full production reserves must last for >20 years. For typical quality silica sand the distance from the deposit to point of sale may not exceed 200 km. The ratio of overburden to sand should be <1.3 to 1:4 with overburden not thicker than 5-10 m.

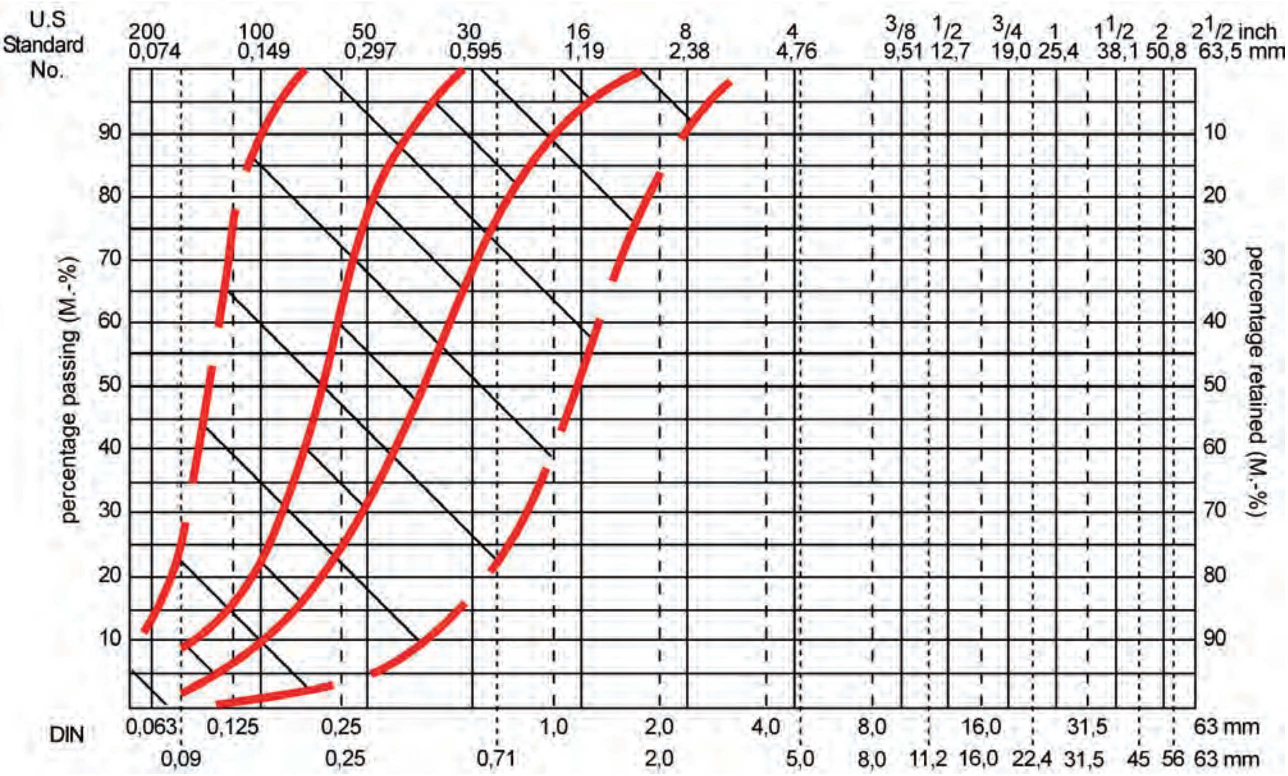


Figure 67: Grain size distribution of typical sand for the manufacture of lime-silica bricks. The tight-hatched zone is considered to be particularly favourable, the open-hatched zone is considered usable.

Potential investors in silica sands in Tanzania must define their main interest first. For the production of colourless bottle glass, only the Bukoban sands at Lake Victoria will be suitable. However, reserves are limited and mining will be difficult. The costs for an environmental impact study necessary for all major mining operations in Tanzania will be high for this location due to the sensitivity of the lake-shore area.

For nearly all other applications silica sand, which can easily be produced from any Pugu Hills mining operation will be just perfect. Investors could make even more money when using this silica sand not only for the production of green and amber bottle glass or sheet glass but much more for the production of mortar and lime-silica bricks. Dar es Salaam with its building industry, is very close, and bricks can also be transported by railway to distant markets. Silica sand from the Pugu Hills fulfils the highest requirements for the production of top-quality lime-silica bricks, except that in general finer silica sand is preferred (5-10 wt.-% <90 µm, majority in the 60-125 µm size range). Therefore, final production tests in a running lime-silica factory are highly recommended.

Occurrences of Silica Sand in Tanzania

Scale 1 : 10,000,000

0 100 200 300 400 500 km

Legend

● Silica Sand

STONES, DIMENSION

GENERAL INFORMATION AND USES

Dimension stones are hard, non-slatey natural stones either mechanically and/or manually worked into more or less regular geometrical shapes with specific dimensions. If they have more or less irregular decorative shapes and are for artistic purposes they are called ornamental stones (see Stones, Ornamental). The uses of dimension stone today are dominated by facade slabs, gravestones, window sills, stair treads, floor tiles, and wall tiles. Waste from light marble is processed in various ways including into terrazzo slabs (frequently mixed with dark rocks) as well as used for improving plasters.

RELEVANT OCCURRENCES IN TANZANIA

While dimension stone deposits in Tanzania may be numerous, only a few have been mentioned in the literature. Others have been visited by a field team of STAMICO, GST, and BGR geologists during field trips in 2005, 2006, and 2007.
One reports describes the Tanga **limestone**, which is a very sound, pale grey to beige, often oolitic limestone that crops out in large, homogenous blocks and lends itself very well to cutting and polishing. This limestone is already used in Tanga for the production of facade slabs and looks very nice.

Greenish stromatolitic limestone occurs SE of Kakonko north of Uvinza, close to the Brundi border. While only small polished slabs have been produced, GST classifies this material as very attractive, and it might even be worth transporting to Dar es Salaam harbour.

Travertine intercalated with **onyx** is being mined in the Songwe valley in Mbeya Region (8° 53.556' S, 33° 12.675' E). It was and still is being deposited by waters from hot springs, which are abundant in this area. The travertine occurs as vertical beds deposited about former

Figure 68: Facade of house in Tanga clad with slabs of Tanga limestone.

Figure 69: Extraction of travertine/onyx blocks at Songwe River.

elongated vents, or as horizontally bedded limestone deposited in the thermal lakes in the immediate neighbourhood of the springs. Average thickness and area of distribution of the vertically banded travertine is estimated to be 6 m, covering 9,000 m^2, while average thickness of the horizontally bedded travertine, which is very often intercalated with beautiful layers of onyx, is much higher, and is also covers larger areas. Blocks are being extracted for ornamental stone and dimension stone use. The trade names of travertine from Songwe are: Pearl White Premium, Smoked Onyx, African Sunrise, African Leopard, and Onyx Waves.

8 km west of Igawa, some 115 km east of Mbeya and 65 km west of Makambako, to both sides of the main road, fine crystalline, white, greenish and pinkish dolomitic crystalline limestones of very good quality are exposed. This occurrence is called Kihumbi Hills in literature and trends N-S for some 16 km. The average width exposed is 1 km. In one of the licence areas granted at the north side of the road a **marble** quarry was opened up in 2004 to mine the dimension stones (8^0 47.262' S, 34^0 18.408' E). Money for opening up this site was originally invested by an Italian company, with the most beautiful and biggest blocks of marble (minimum sizes 1.5 x 1.5 x 1.0 m) designated for export to Italy, while smaller blocks were to be used for the production of floor tiles in Mbeya. While quarrying continues the extraction of blocks is meanwhile limited to mostly white and greenish marble due to extensive problems with fractures in the areas of pink marble at least at this site.

Figure 70: Typical freshly quarried block of white and greenish marble in the Igawa quarry.

Figure 71: Beautiful marble block from Igawa showing green and pink striated layering.

East of Igawa there is another occurrence of **marble** (8° 50' S, 34° 25' E), called the Mbarali deposit. Here the pink and white very hard crystalline limestone forms a more or less continuous band which can be followed over a distance of 11 km. The thickness varies widely from 2 to 20 m with an average thickness of 10 m. Unlike Igawa the MgO content is very low, and impurities of red garnet, diopside, amphiboles and green epidote are common. It is likely that blocks of beautiful colours could also be extracted from this deposit.

Greenish and white marble is also being extracted at Lufilyo in the Rungwe District, but no details are known.

In southern Mtwara Region the western slope of the Makonde Plateau is built up by coarse to medium crystalline, mostly snow-white marbles. In the Nagaga-Namaleche area this **marble** is being mined by artisanal miners for the production of aggregates. Here some of the the marble contains silvery shiny fine flakes of graphite (10° 54.490' S, 39° 8.245' E). In other outcrops it is coloured bluish by apatite (10° 53.598' S, 39° 10.517' E) or greenish by diopside. After cutting and polishing at BGR, optical results were quite favourable, with only phlogopite leading to some instability of the rock. Evaluation of possible spottiness of the rock will only be possible after cutting and polishing of larger blocks from various locations. However, the deposit seems to contain some highly valuable marble with a strong possibility of extracting large blocks suitable for export, with a number of varieties, and nearly unlimited reserves. Mtwara international harbour can be reached via 160 km of unpaved roads.

Figure 72: Polished marble with tiny flakes of shiny graphite from the the Nagaga area.

In the southern Mtwara Region light to dark grey **marble** also occurs at Malapa Hill, between Chikundi and Ndanda (also known as the Chikundi-Pachani deposit, 10° 30.830' S, 38° 59.018' E). The marble being mined by small-scale miners at this site is then transported to nearby Ndanda mission, where altars, sculptures (also see Stones, Ornamental), tombstones, and pews have been produced for decades.

East of the main Uluguru Mountain range from north of Mbuyuni and Kibangile to the south, outcrops of mostly white **marble** are very obvious along the road leading from Morogoro to Kisaki. Here a quarry has been opened up by a Tanzanian company with Italian investors

Figure 73: Production of pews and altars from marble from Malapa Hill at the Ndanda mission.

(6° 58.090' S, 37° 48.422' E). Because fracturing at this site is no problem, blocks of any size will be quarried and exported mainly to Arabian and South-East Asian customers. The trade name is "Pearl Jam". While the marble at the quarrying site is creamy white, very coarse crystalline and dolomitic, it also quite often contains impurities so it will not fetch a high price.
Blue marble in the same area has been reported from Dabwala on the east of Magari Hill. Pink marble is said to occur near Gogo Hill, a little further north and near Mzuhe on the Msonge River.
Others deposits of white crystalline **marble** were checked at Seven Sisters (2° 47.570' S, 36° 56.967' E) in the Arusha Region, at Lobolorsoit (4° 23.187' S, 37° 28.796' E) in the Arusha Region, and at Lugoba (6° 33.304' S, 38°

Figure 74: Test quarrying of marble at Mbuyuni.

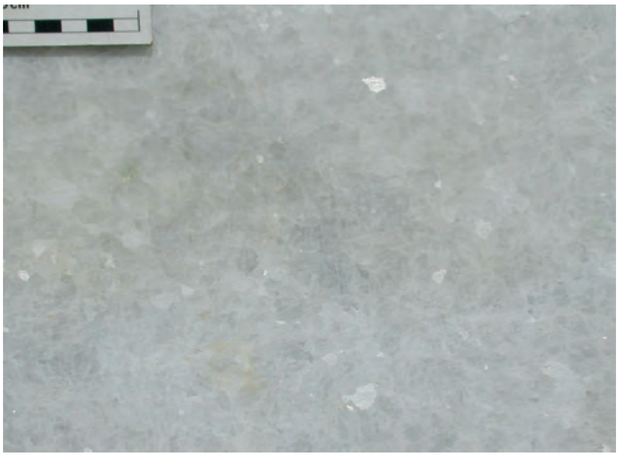


Figure 75: “Pearl Jam” marble from Mbuyuni.

Figure 76: Piece of beautiful blue marble sent to GST lapidary.

17.140’ E) in the Pwani Region. The first two deposits have a very bad infrastructure, while the latter contains a very coarse white marble, which upon cutting and polishing shows unwanted tremolite inclusions.
Of course there are many more occurrences, e.g. at Shambarai, Arusha Region, at Mahenge, Morogoro Region or at Handeni, Tanga Region, of beautiful white crystalline marble in Tanzania which warrant prospecting. A full list of marble occurrences in Tanzania has been given by Wright (1938).

Of high relevance is the observation of **blue marble** in Ndanda mission where it is used for carving of sculptures. This marble is said to come from an as yet undescribed mining site in Nachingwea District, southern Lindi Region. The same origin has been mentioned for blue marble sent to the GST lapidary in Dodoma. Meanwhile a prospecting license for blue marble has been granted at Mwangazi, SE of Liwale, in Liwale District, Lindi Region. Here also pink and white marble is very common. Blue marble is also said to occur at Kiangara in the Liwale District. In addition to Mwangazi there might be a second deposit of blue marble: any occurrence of blue marble will surely attract a lot of investors, as there are just two known blue marble deposits outside Tanzania!

Figure 77: Sculpture of blue marble produced in the Ndanda mission.

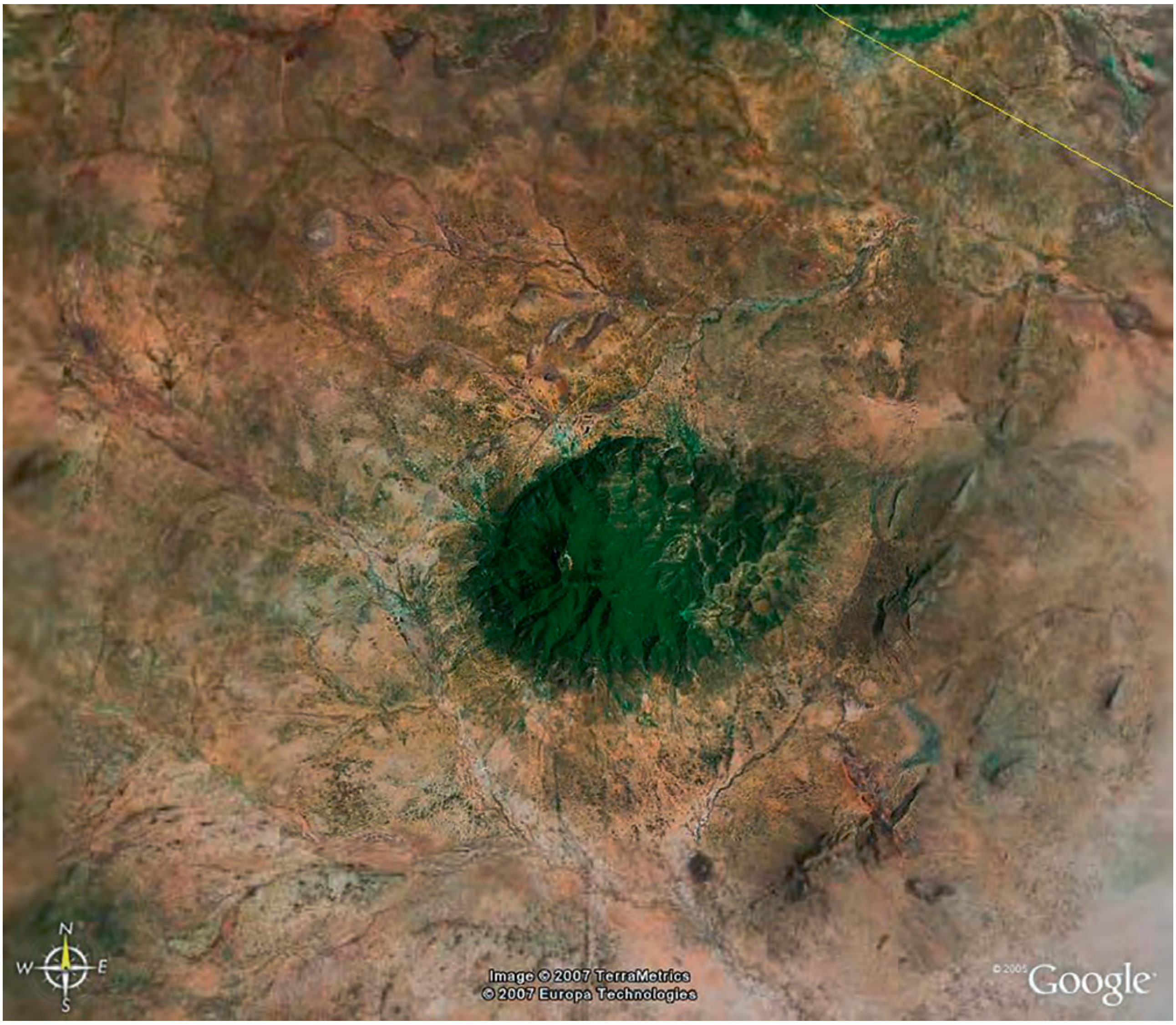


Figure 78: Satellite image of Longido Mountain in the centre of the image, and border to Kenya as yellow line in upper right (Photo courtesy of Google Earth).

Longido Mountain, on the main road, and just half way between Arusha and Nairobi, seems to have high potential for opening up a quarry for mining **granite** - both for the production of high quality aggregates and dimension stones. The top of Longido Mountain towers 2.690 m a.s.l., i.e. more than 1 km above the surrounding Masai steppe. Geologically the mountain is a batholith made up of porphyroblastic granites, intruded by numerous pegmatites and amphibolitic xenoliths. Around the main batholith, gneisses bearing hornblende, garnet, and diopside are developed. Just east of Longido Village, there already exists a quarry (2^0 43.349' S, 36^0 41.890' E), where a variety of magmatic rocks can be studied. It should be mentioned that the steep slopes of Longido Mountain do not have any weathering crusts and that the mountain resembles the famous inselbergs in Brazil which are the main source of dimension stones in that country.

Pinkish red **granite** has been described from Igombe, Misha, and Kakola areas in the Tabora Region. A specimen of quite beautiful, strong porphyroblastic granite from the Tabora Region

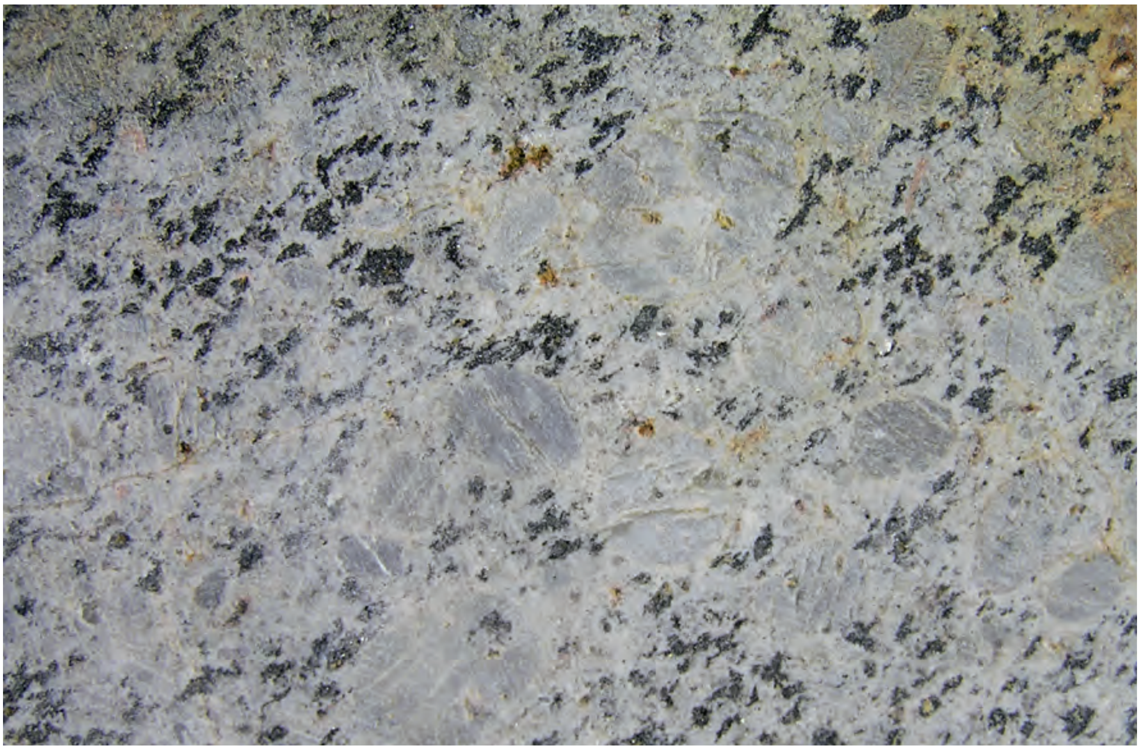


Figure 79: Polished alkali granite (boulder) from western slope of the Longido Mountain.

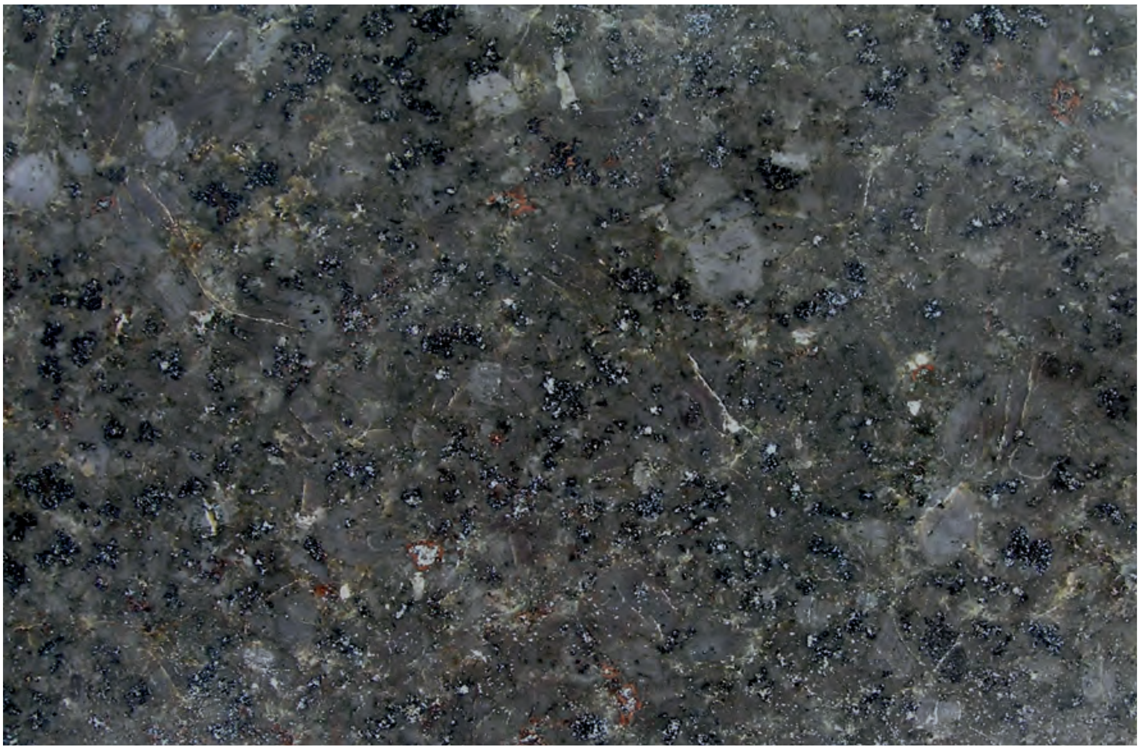


Figure 80: Polished alkali tonalite (boulder) from western slope of the Longido Mountain.

can be inspected in the GST museum in Dodoma. However, the exact original location of this granite is not known.
In contrast, most pinkish red granites from the Mwanza Region have all been sampled, but are too expensive to transport from Mwanza to Dar es Salaam harbour for export.

At Ligangatoroli, about 97 km south of Njombe, a pinkish banded porphyroblastic gneiss is said to look quite beautiful when cut and polished. The size of this deposit is 12.5 x 1.1 km.

At Itiso (5° 38' 36"S, 36° 02' 35" E) in the Molomgola area in the Dodoma District an ultrabasic dolerite dyke was explored for potential use as "**black granite**" dimension stone. However, no mineable deposit could be delineated.
Other bodies of "black granite" are reported from Mtera (12.5 km x 1 km), Nkulabi (2,600 m x 15 m) and Chipogolo in the Dodoma Region. At Chipogolo (6° 53.779' S, 36° 02' 823' E) there is a dyke of fine-grained dolerite, about 60 m wide and stretching for a total length of about 12 km.
Especially in the Dodoma Region there are many more occurrences of "black granite". Examples are large occurrences of very tough, beautifully red-sparkled ecologite and eclogite-amphibolite, which is fine-grained and contains blackish streaks at Ilumba Hills (6° 59.729'S, 36° 14.526' E) or medium-grained in Nyarumba Mountains both close to Rudi Village. At Ilumba Hills there is also a deposit of fine-grained black green-sparkled gabbro (6° 59.432'S, 36° 14.582' E).

Figure 81: Specimen of dolerite from Chipogolo.

At Gulwe station on the Central Railway, there is a large hill made up of deep-black amphibolitic gneiss with white quartz striae (6° 26.960'S, 36° 24.824' E). None of these deposits of "black granite" have yet been checked for mineability.

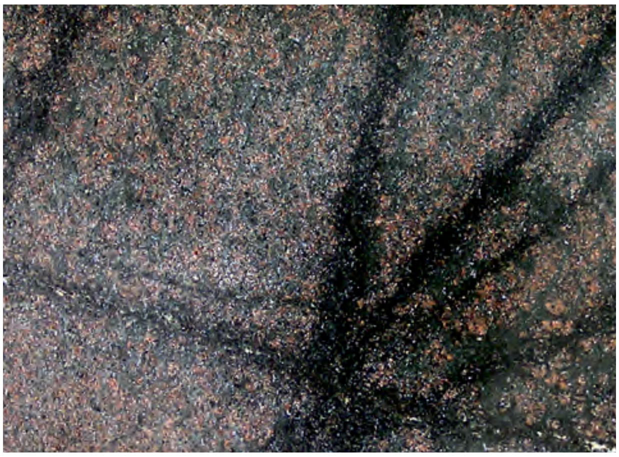


Figure 82: Polished eclogite-amphibolite from the Ilumba Hills.

At Nankwale in the Ileje District, Mbeya Region, a big deposit (12.5 km x 1.1 km) of coarse black gabbro can also be proposed for use as "black granite".

Sodalite occurs at Nankwale Hill in the southern Ileje District and at N'gambe, which is about 60 km west of Mbeya just north of Malonje Village in the Mbozi District. This

Figure 83: Polished amphibolitic gneiss from Gulwe station.

blue mineral, which in masses makes a very valuable dimension stone, occurs as primary euhedral crystals or as veins in a medium to coarse-grained nepheline syenite together with feldspar, nepheline, and mafic minerals. The N'gamba sodalite occurrence (9° 07.377'S, 32° 50.991' E) is part of the Mbozi syenite gabbro complex (see Feldspar and Nepheline Syenite). 75 km to the south as the crow flies in northernmost Malawi at Ilomba Hill in the Chitipa area, beautiful sodalite is already being temporarily mined as dimension stone. Other locations which have been mentioned regarding possible sodalite occurrences in Tanzania are Ihanda and Msangano in the Mbozi District, Kiurungi in the Iringa Region, and Likimbira Hills in the Rudewa District.

REQUIREMENTS AND EVALUATION

While there are several requirements for dimension stone deposits, the most important is the beauty of the stone and the size of the blocks which can be quarried. While beauty is subjective, the rocks should be homogenous in structure and colour. For export purposes, out of the ordinary material should be looked for because dimension stones for the mass market are already supplied in large amounts and very cheap by Indian and Chinese producers. Extractable blocks must have a minimum volume of >1.5 m^3, with lengths >1 m, widths >1 m, and thicknesses >0.4 m. Blocks for export should have a volume of 1.5 to 6 m^3, with lengths >2-3 m, widths >1-2 m, and thicknesses >0.5-1 m. Other requirements are good sawing or cleavage properties, very high weathering resistance, low water absorption, adequate frost resistance, high compressive and tensile strengths, low thermal expansion, uniform relative density, high polishing capacity, and possibly also good adhesion of protective coatings. These geotechnical requirements have to be proven by certified labs or by the customer.

Reserves should be >100 kt, or rather >30,000 m^3. In general, only very high-value rocks, like sodalite or pink marble, can be transported over long distances, i.e. across Tanzania.

Potential investors in dimension stones first have to identify a suitable deposit. In Tanzania, the main difficulties for exploration are thick weathering crusts and few outcrops. Costs for drilling, cutting, sawing and hauling equipment for a decent mining operation are about one million US-$. Later transportation of blocks will become a major issue, because e.g. a 1.5 m^3 block of marble weighs about 4 tons, and a 6 m^3 block weighs about 16 tons! If these problems can be overcome, there are good chances of making a profit in the dimension stone business because Tanzania has a booming building industry, is a huge country with a variety of (unexplored) rocks, and only has a very few dimension stone deposits currently being exploited.

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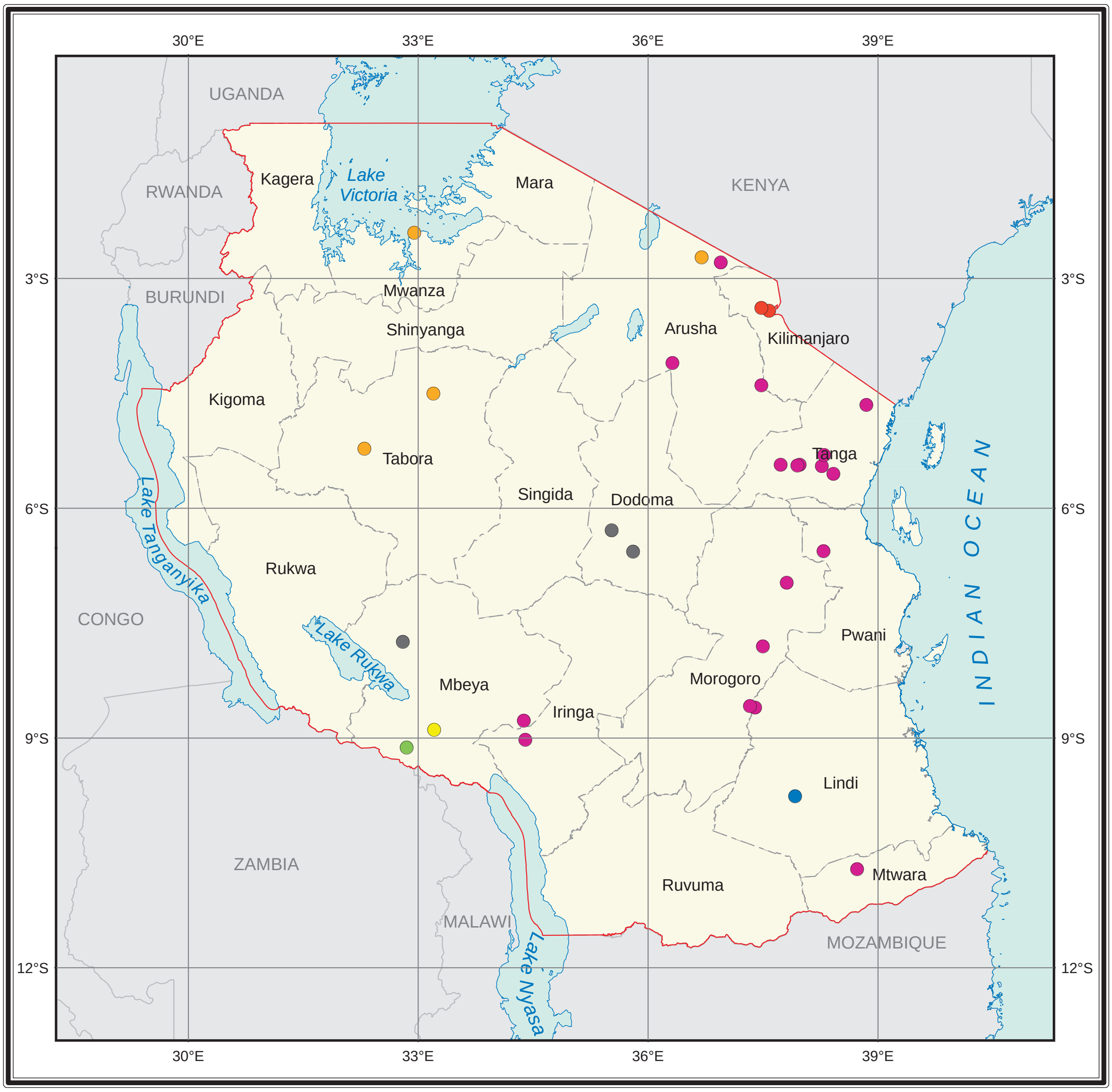
Occurrences of Dimension Stones in Tanzania



Scale 1 : 10,000,000

0 100 200 300 400 500 km

Legend

- Dimension Stones of Volcanic Origin
- Marble (white, green or pink)
- Blue Marble
- Sodalite
- Travertine
- Granite
- Black Granite

STONES, ORNAMENTAL

GENERAL INFORMATION AND USES

Ornamental stones are used for decorative purposes only. They are the raw material for the production of small articles like pipes, ash-trays, candlesticks, buttons, watchcases, semi-precious jewellery, sculptures, picture frames, boxes, urns and many other items. Ornamental stones either have excellent carving properties or show an extraordinary colour and/or texture. While most of the deposits of ornamental stones may be small in size, the value of the ornamental stones in general is high enough to allow feasible mining in most cases.

RELEVANT OCCURRENCES IN TANZANIA

Tanzania has long been known for two of its ornamental stone varieties.

The most important and most valuable one is **anyolite**. Anyolite from the Masai word "anyoli" meaning "green" is the name for a hard and tough green chromiferous zoisite rock, which quite often contains inclusions of variable sizes of violet-red ruby of mostly non-gem quality. The highest concentration of anyolite rocks is found in an area about 30 km west of Longido. While several outcrops are known from this area around Merkerstein Hill, only two mines are currently in operation. The biggest mine belongs to Thai-owned Longido Ruby Zoisite Company Ltd. (2° 37.866' S, 36° 28.623' E), which originally went into operation some 60 years ago.

In this mine, the zoisite vein is between 0.3 m to 1.2 m wide and mined by blasting in eleven adits reaching out from a central mine shaft some 200 m deep. For prospecting veins of coarse crystalline black hornblende are being looked for. Sorting of material blasted is done in daylight by differentiating three varieties: zoisite or zoisite with inclusions of rubies,

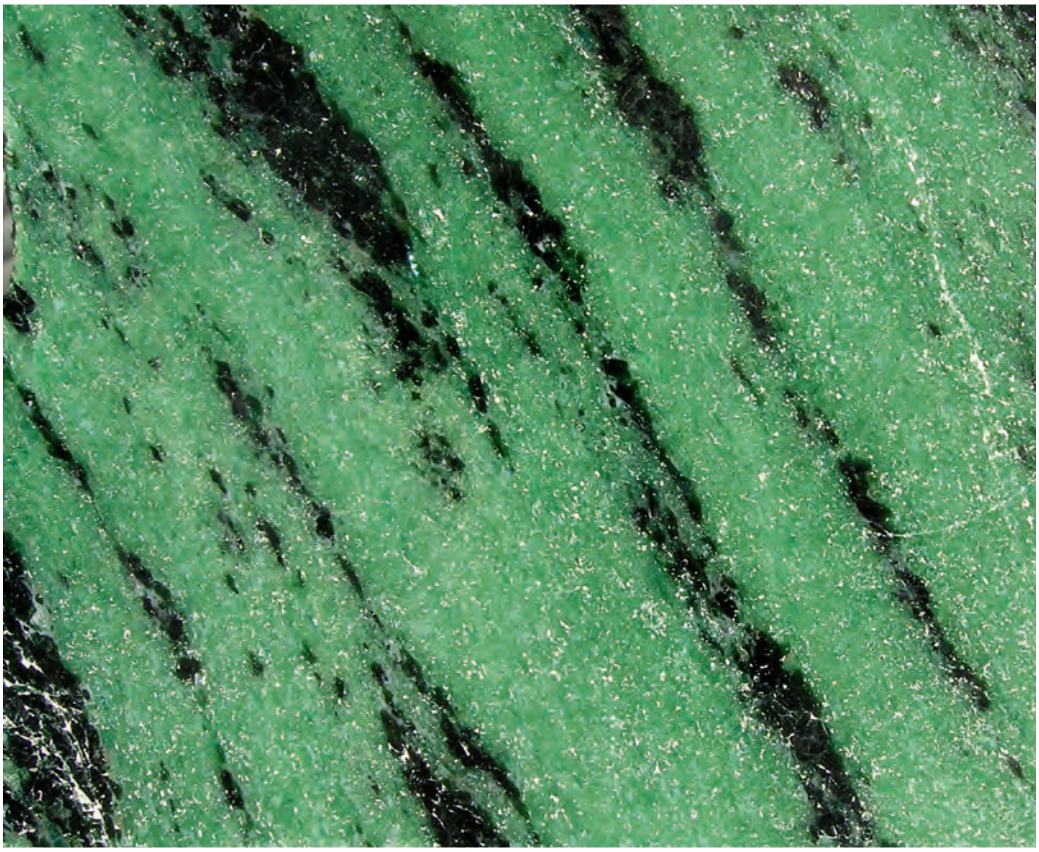


Figure 84: Polished zoisite rock with black hornblende from the Longido Ruby Zoisite Mine.

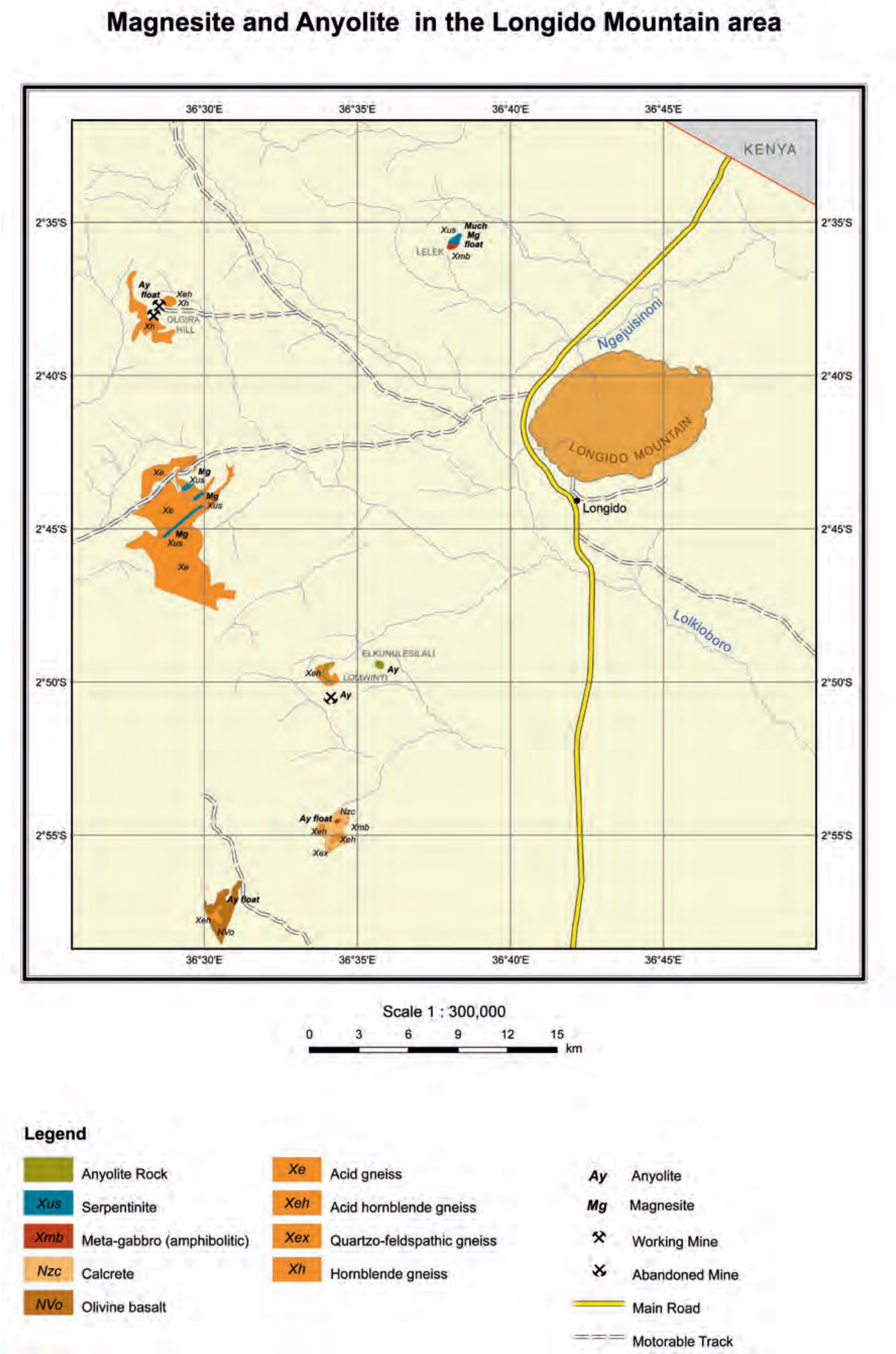


Figure 85: Sketch map of Longido Mountain area showing occurrences of anyolite and magnesite.

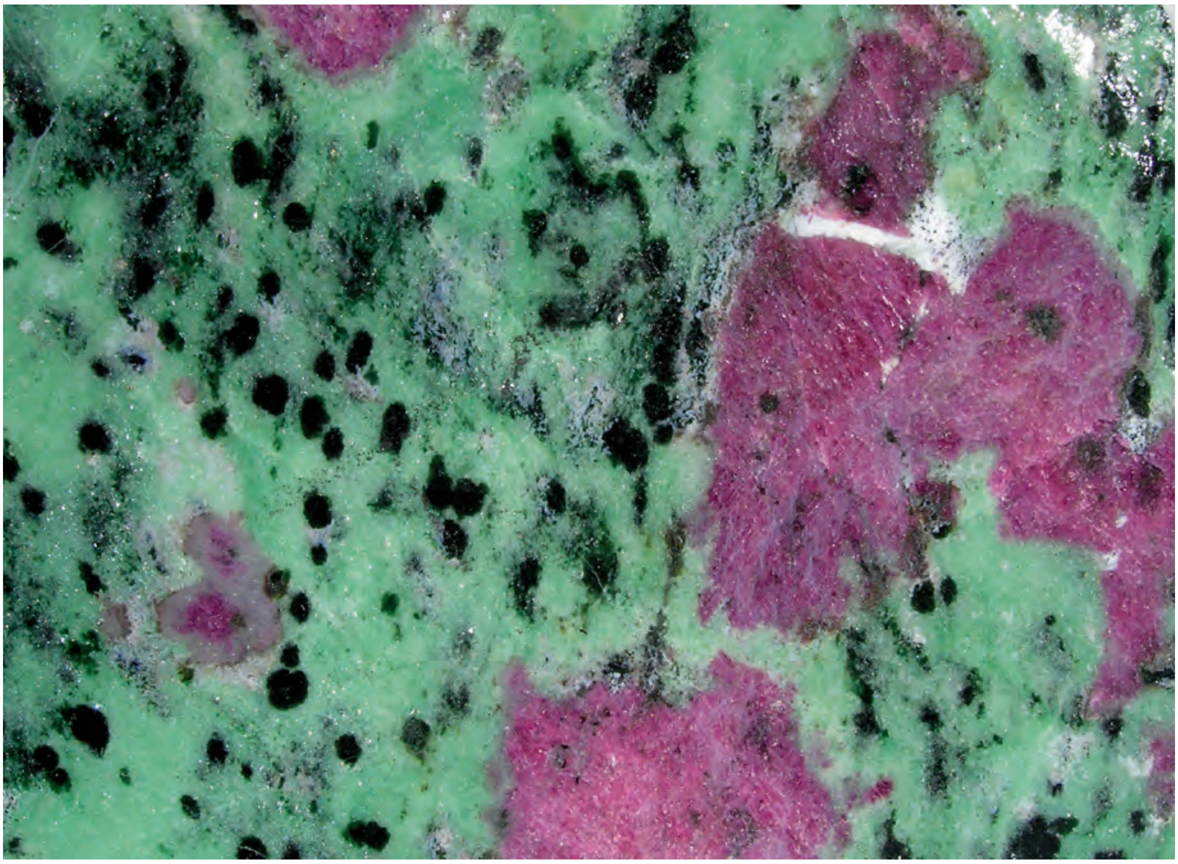


Figure 86: Polished ruby-bearing zoisite rock from the Longido Ruby Zoisite Mine.

ruby-bearing zoisite, and rubies of cabochon quality. Some 300 tons of zoisite and some 550 kg of ruby-bearing zoisite are produced every month. The mined material is transported to Arusha for final sorting and exported afterwards to customers worldwide. Because the vein is not very wide and as mining has to be done by blasting, no blocks big enough for the production of dimension stones can be extracted – at least not from this site.

Another area with outcrops of anyolite rocks is at Lossogonoi Plateau in the Masai Steppe about 75 km southwest of Moshi. Here, anyolite is found in two lenses about 60 m and 180 m long, with widhts estimated at 0.6 to 0.9 m, and 3 m respectively. The quality is said to be similar to the Longido area with much fewer but higher-quality ruby inclusions. Cracks in the anyolite are filled with white magnesite (see Magnesite).

A third area with anyolite rocks is in the Dudumera area in the Babati District, between Arusha and Singida. This occurrence was first reported in 1963 during the course of geological mapping. No prospecting data are available yet.

In addition to anyolite, **meerschaum** is the other famous ornamental stone in Tanzania. Mineralogically, meerschaum is called sepiolite, especially when it is unconsolidated. Its porosity, light weight, toughness, pleasing white to greyish-green colour and workability makes it admirably suitable for pipe and cigar holder production. However, Turkey has cornered most of the meerschaum market and interest in this ornamental stone has therefore decreased drastically. For uses of sepiolite today, the potential investor is referred to the chapter “Bentonite and Sepiolite”. Because meerschaum was of much more interest to the international mining community in previous

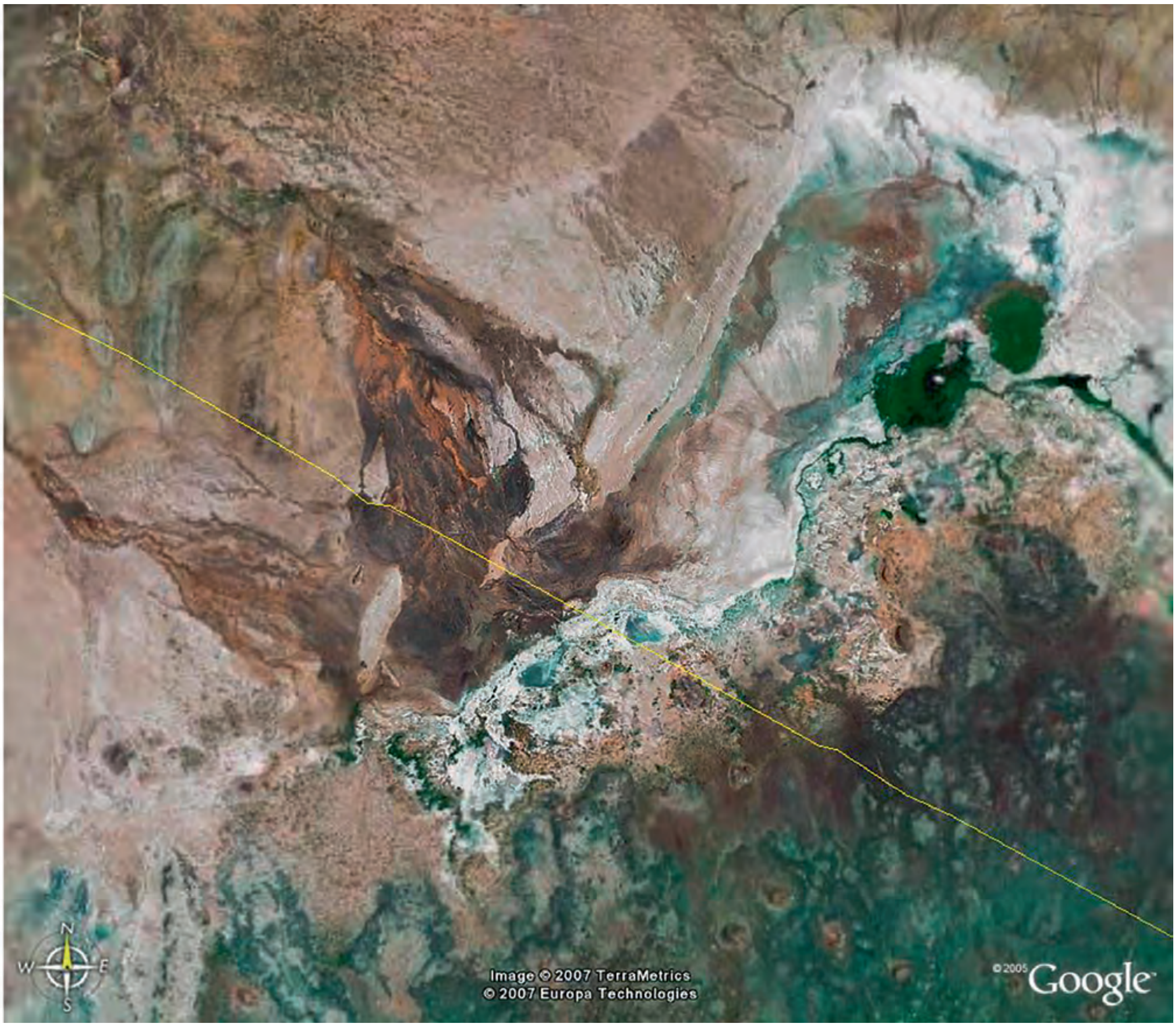


Figure 87: Satellite image of Lake Amboseli with border between Tanzania and Kenya as yellow line (Photo courtesy of Google Earth).

decades, there are many reports on the Tanzanian meerschaum deposit at Lake Amboseli. In summary, Lake Amboseli is a seasonal lake at the border to Kenya some 160 km north of Arusha. The roads leading to the former mining site at Sinya at the southern end of Lake Amboseli are very bad. Here, meerschaum and sepiolite occur in lake sediments which were mined to about 5 m depth. Meerschaum occurs as irregular masses and small veins from a fraction of a cm to 0.3 m thick. Some 500 tons of meerschaum were produced between 1954, when mining started, and 1961/62, when the mine was flooded and closed down a few years later. Estimates of the resources of meerschaum remaining in place vary widely between 300 and 6,000 tons.

Table 53: Chemical analysis (data in wt.-%) of meerschaum sample from the former Sinya mine (from Sampson 1963).

SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	H_2O -110°C	LOI	*total*
52.51	0.13	0.87	0.45	0.40	0.01	22.49	0.81	0.65	0.65	0.04	12.01	9.48	*100.50*

Table 54: Physical properties of meerschaum samples from former the Sinya mine (from Sampson 1963).

Property	No of samples	Range	Statistical mean
Bulk density (g/cm^3)	9	0.347 - 0.92	0.54
Calculated specific gravity (g/cm^3)	6	1.98 - 2.76	2.42
Absorption (%)	6	120 - 285	182
Expansion (%)	4	6.21 - 18.42	11.14
Porosity (%)	6	72.9 - 85.7	77.9

Soapstone, most of which is soft rock rich in talc, is also found in Tanzania with more than 40 known occurrences. In other African countries, soapstone is used extensively as low-price ornamental stone for the carving of animals and sculptures for sale in tourist centres.

A very special soapstone without any talc and made up of sericite and kaolin only has been mentioned from the Ukerewe Peninsula in Lake Victoria. This kind of soapstone was thought to be indigenous to the Kisii area in south-western Kenya, where it is being used for the production of sculptures and tourist items.

A list of 37 soapstone occurrences has been given by Harpum (1959). The potential investor is referred to this list, which gives the place names of soapstone deposits from all over Tanzania. All of these occurrences ought to be suitable for the production of ornamental stones of nearly all sizes.

Pure **talc**, which can be beneficiated by grinding high-grade soapstones, is an important commodity. It is used as a non-toxic, white and adsorbent filler in plastics, rubber, paper, paint, asphalt, cosmetics, ceramics, pharmaceuticals, textiles, fertilizers, and insecticides. It can also be used for the insulation of wood-burning stove fittings.

While carbonate, amphibole, and steatite soapstones can be differentiated, talc can best be beneficiated from carbonate and pure steatite soapstones. No soapstone occurrence in Tanzania has yet been proven capable of producing talc of export quality. However, ground soapstone, if of good quality and of competitive price, might find a market within Tanzania as a filler in local industries such as soap, textiles, polishes, floorings and roofings.

According to Harpum (1959), the carbonate soapstone occurrences in Tanzania are:

- Nyamuna-Bontwiga, roughly 50 km west of Kilimafeza, Musoma District
- Chipogolo with four separate deposits in the Mpwapwa District
- Kasanga, i.e. in valley of Little Kasanga River about 18 km southwest of Chunya

Pure steatite soapstone occurrences in Tanzania are:

- Ngasamo/Wamangolo, 108 km east of Mwanza, Mwanza District
- Hedaru (4° 34' S, 37° 57'E), 6.5 km from Hedaru station, south Pare area in the Same District. This deposit was mined between 1938 and 1940 and the soapstone found suitable for the production of greyish-white talc for use as a filler in the local soap industry. The talc content of the soapstone is said to be high, although no absolute figures are given. Original resources have been estimated as 300 tons.
- Itewe/Lupa, i.e. on Itewe Hill, 7.2 km south-SW of Chunya and at Chunya airfield, 5 km south of Chunya, Chunya District

Talc also was mentioned in Kiwiruka, Iringa Region which is about 45 km SW of Iringa. The talc is lump-shaped and irregularly vein-shaped. The small mineralized section is about 1 m wide and intermittently extends about 70 m.

Table 55: Chemical analyses (data in wt.-%) of soapstone samples from Kikombo (Kikaza Hill) area (from Mushi et al. 1992). Resources are estimated as 130 kt of pale bluish-grey and fairly homogenous soapstone.

	Kikombo soapstone					
	1	2	3	4	5	6
SiO_2	57.60	58.82	59.91	57.76	56.50	56.71
TiO_2	0.16	0.16	0.16	trace	trace	1.45
Al_2O_3	2.50	2.93	2.60	2.50	2.90	3.75
Fe_2O_3	6.90	5.92	5.67	5.83	7.23	4.90
MgO	25.80	24.86	23.10	22.64	28.00	23.90
CaO	trace	trace	0.18	0.18	0.18	1.07
Na_2O	0.26	0.04	0.05	0.09	0.07	0.60
K_2O	0.02	0.02	0.02	0.05	0.07	0.04
H_2O	0.05	0.14	0.07	0.07	0.06	0.11
LOI	5.80	6.24	7.60	6.56	5.08	7.45
total	*99.12*	*99.15*	*99.40*	*100.75*	*100.17*	*100.10*

Chemically pure talc has a composition of 63.35 wt.-% SiO_2, 31.90 wt.-% MgO and 4.75 wt.-% LOI (H_2O).

Industrial uses specify talc with high purity ($>$60 wt.-% SiO_2, $>$30 wt.-% MgO) and whiteness. LOI should not exceed 6 wt.-%. For use in cosmetics or soap, the heavy metal content has to be $<$40 ppm. Because most talc in Tanzania originated from the alteration of ultra-basic rocks via serpentinite to talc all occurrences have to be checked for cancerous serpentine asbestos. Reserves in place should be $>$200 kt of mineable talc.

Rhodonite, which is a rose-red coloured silicate of manganese is said to occur in northern Tanzania. Although it forms a very beautiful ornamental stone, it was only mentioned once by Kimambo (1986, ed.) with no exact location given.

Amazon stone, which is a green microcline feldspar, was found in small masses of about several kg in feldspar veins in the Handeni District. The exact location was described by Temperley (1945) as a deserted locality called Kolukonko which lies 8 km east of Luguruni Village which is 65 km SE of Handeni.

EVALUATION

Potential investors in ornamental stones in Tanzania have a wide choice. There is a good chance of establishing another anyolite mine in any of the three areas in northern Tanzania where anyolite occurrences are known. While meerschaum is not a commodity of great interest anymore, many of the soapstone deposits in Tanzania should prove valuable for establishing a local carving industry. Soapstone sculptures can be easily sold to tourists, who are familiar with soapstone items from many other countries in Africa.

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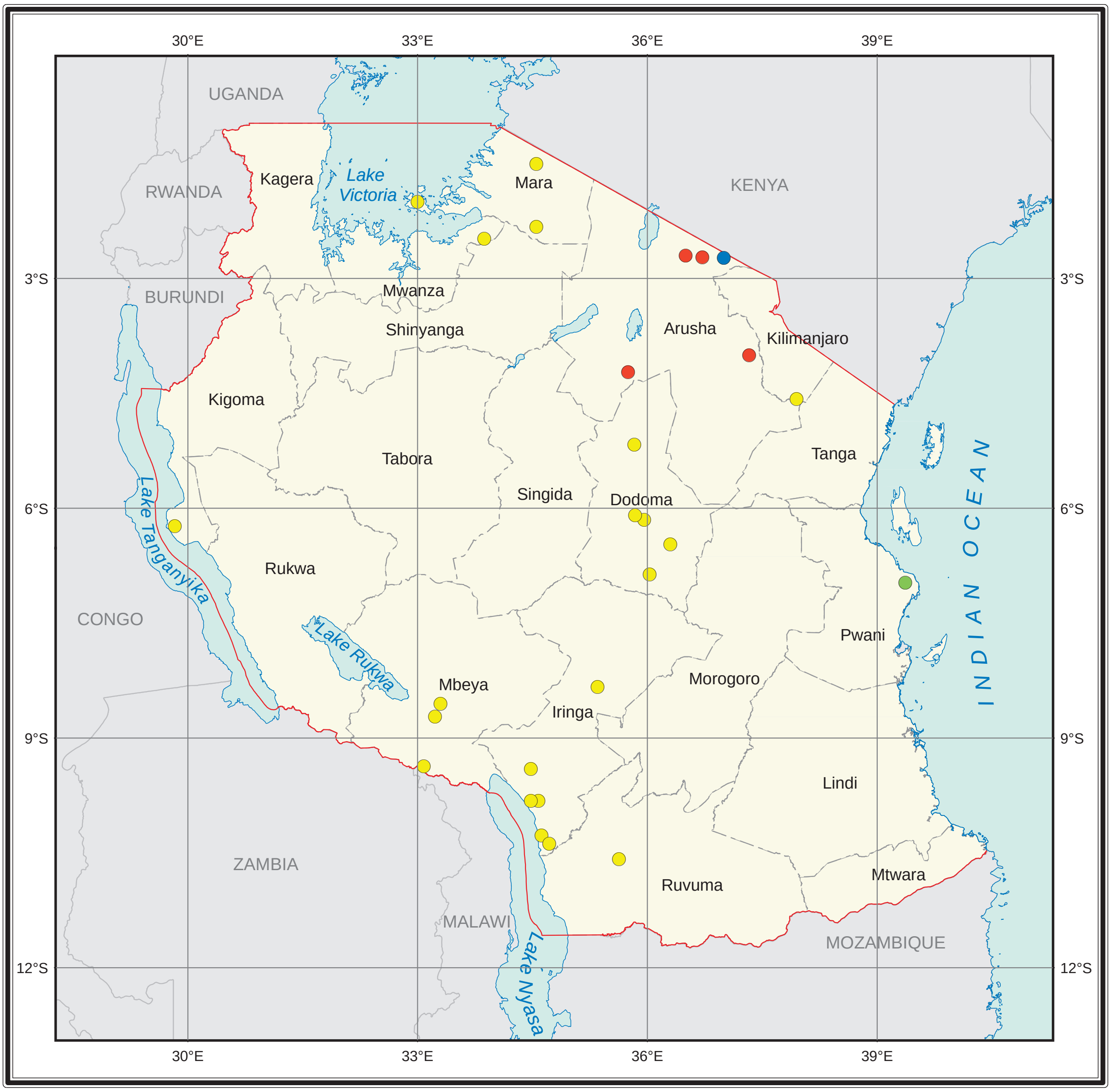
Occurrences of Ornamental Stones in Tanzania



Scale 1 : 10,000,000

0 100 200 300 400 500 km

Legend

- Anyolite
- Meerschaum
- Amazon Stone
- Talc / Soapstone

SULPHUR

GENERAL INFORMATION AND USES

Most of the **sulphur** (S) produced worldwide is used for the production of sulphuric acid and other sulphur compounds. Sulphuric acid is mainly used for the production of fertilizers, and for chemical products, as well as in mining, and in petroleum refining.

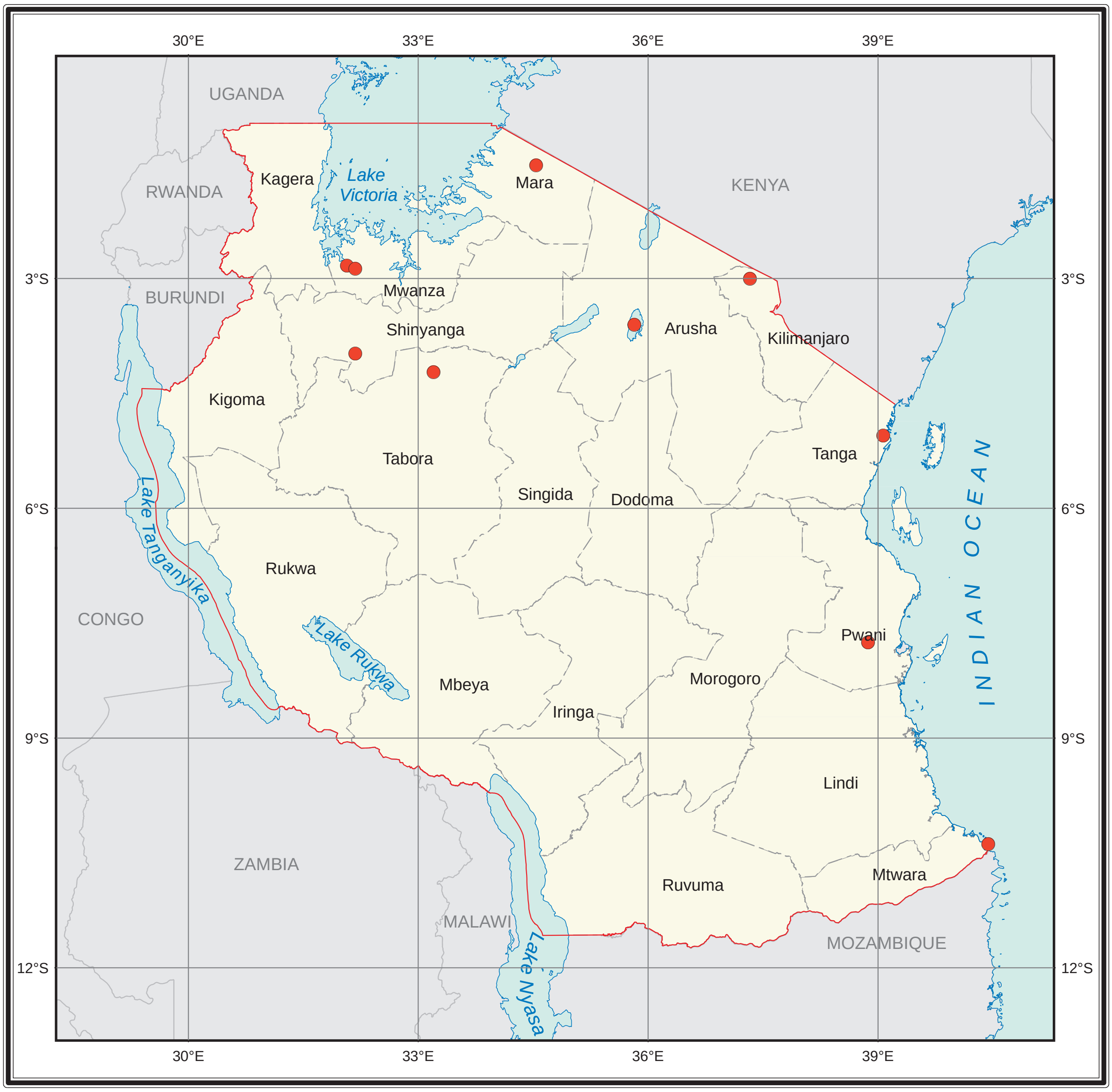
RELEVANT OCCURRENCES IN TANZANIA

In Tanzania, the only known elemental sulphur deposit of appreciable size is in the inner crater of Kibo, Mount Kilimanjaro. For a variety of reasons (altitude, inaccessibility, environmental protection) this small deposit of about 6 kt obviously does not represent a mineable occurrence.
Sandstones at Wingayongo, Utete District are impregnated with elemental sulphur, containing up to 0.2 wt.-% sulphur in places. Oil seeps and sulphur springs exist in the same area. Other sulphur springs can be found at Lake Manyara and at Tanga.
An occurrence of sand containing free sulphur has also been reported from Msimbati on the island of Ras Matunda in Mnazi Bay-Ruvuma Estuary Marine Park (see Heavy Minerals). Analyses of nine samples showed a maximum of 0.84 wt.-% S. Of course this sulphur originates from seeps from gas fields already in production in the same area.
Large amounts of sulphides are being produced in the major gold mines in the country. E.g. the ore from the Geita Mine contains about 10 wt.-% sulphides and the recovery of pyrite from the mill tailings has been considered, but was found not to be economic.

REQUIREMENTS AND EVALUATION

Any deposit of sulphur should contain reserves of more than 100 kt of mineable ore. Ore of volcanic sulphur should contain 20 wt.-% S before picking and melting. After purification the sulphur should contain >99 wt.-% S, <0.25 ppm As, and <2.0 ppm Se+Te. None of the sulphur occurrences in Tanzania meets these requirements and the chances are extremely low for any other sulphur deposit to be found. Potential investors should therefore focus on other industrial minerals.

Occurrences of Sulphur in Tanzania



Scale 1 : 10,000,000

0 100 200 300 400 500 km

Legend

● Sulphur

VERMICULITE

GENERAL INFORMATION AND USES

Vermiculite is a hydrous clay mineral which expands with the application of heat. The expansion process is called exfoliation and it is routinely accomplished in purpose-designed commercial furnaces. Exfoliated vermiculite is used for heat and noise insulation purposes in a variety of building materials. It also has applications in the chemical and packaging industries, and in metallurgy. In farming it is used as a carrier substance for fertilizers, as an additive for animal feed, and for water regulation in soil.

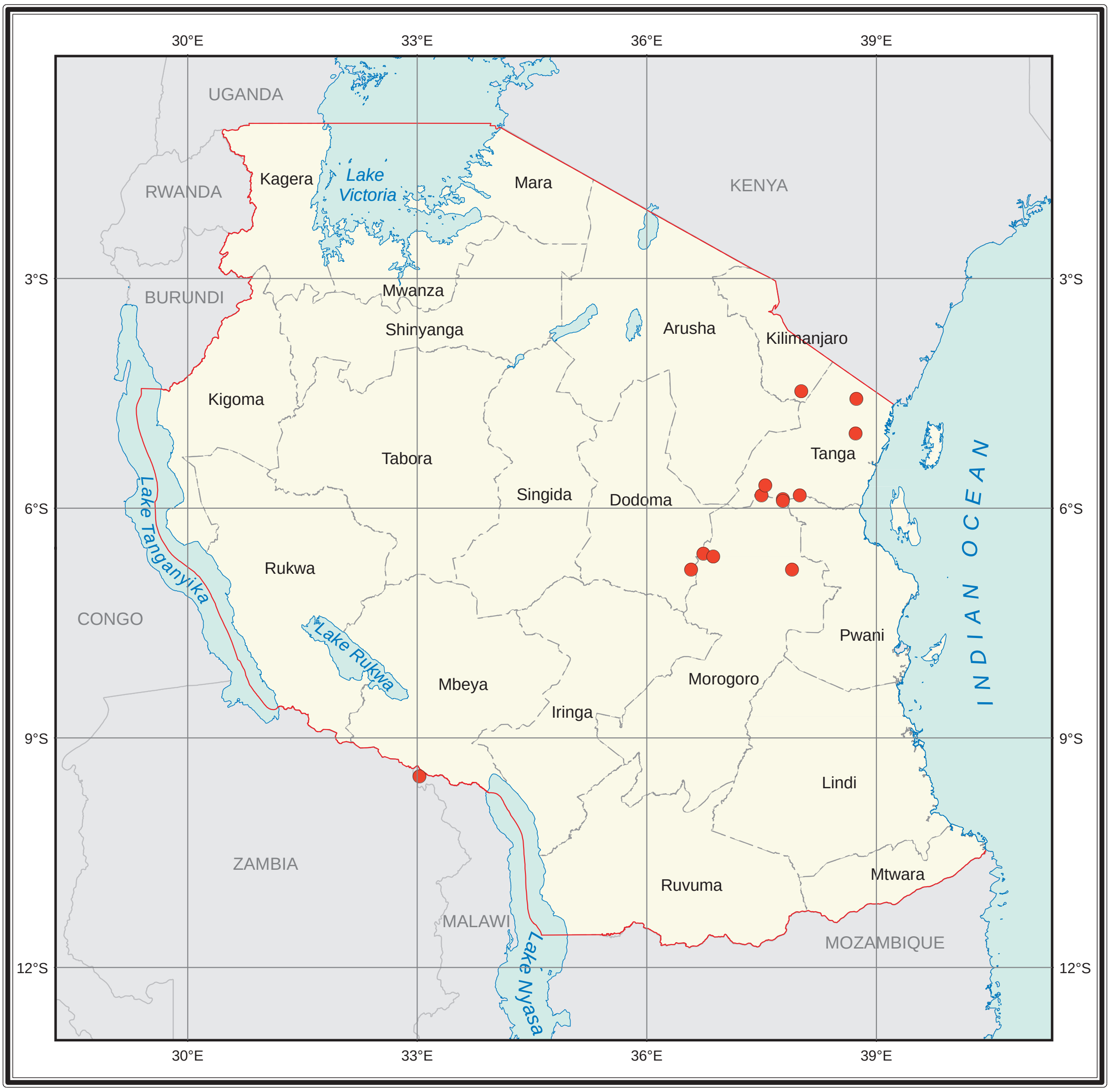
RELEVANT OCCURRENCES IN TANZANIA

Vermiculite is a common mineral in Tanzania, although no large deposits have been discovered so far. It was first found near Kwekivu, Handeni District, where it occurs as clusters of large, distorted books up to 0.15 m across in a small pegmatite which cuts across an ultrabasic rock. Much of the best vermiculite in this deposit has already been picked out for trial shipments totalling about 80 tons. Tests showed that this vermiculite is of high quality (linear expansion rate 25-31), but the deposit is small and difficult to reach. Amphibole asbestos is among the accessory minerals!
Another prospect is at Lufusi, 24 km south of Kidete on the Central Railway Line. Here, small veins and patches of vermiculite occur in an altered ultrabasic body which is cut by pegmatitic veins. The quality of the mineral is heterogeneous, some of it very poor, some of it excellent. Fair quantities are reported to be present. Two small veins of good quality vermiculite occur in a pegmatite dyke near Mjimbya on the track to Bagamoyo, 1.5 km from Mziha, Morogoro District. However, reserves are very limited at this place.
Vermiculite is also said to be a major constituent in the Nachendezwaya carbonatite dyke which is in the Ileje District about 600 m from the Songwe River which forms the border to Malawi. No details are known, however.
Vermiculite is quite common and was estimated to occur in >25 % of the mica-bearing pegmatites in the Uluguru Mountains. Size varies from fine flakes to books of between 30 and 60 cm in diameter. The expansion rate was tested to be over 12 and frequently over 15. Although several tons of vermiculite could be collected from the old mica workings, difficulties in transport have always discouraged any attempt to market it.
An experimental exfoliation plant for processing vermiculite was set up by the British in Dar es Salaam in 1957 and during the following two years, almost 200 tons of exfoliated vermiculite was produced. The raw material for this operation was mined from mica pegmatites in the Mikese area, Morogoro District. Because there was no ready market for exfoliated vermiculite at that time, the plant was shut down soon after.
Several tons of vermiculite could also be handpicked from tailings of pegmatites mined north of Kalalani Village (4° 34.64‘ S, 38° 44.35’ E) in the Umba area for rubies.

REQUIREMENTS AND EVALUATION

Vermiculite ore should contain at least 30 wt.-% vermiculite, which should come in large flakes of more than 3 mm diameter. Vermiculite flakes should best expand 15 to 20 times when exfoliated. Its bulk density must be reduced at least 6 times after heating. Deposits should contain reserves of more than 20 kt, and must always be checked for carcinogenic asbestos, which is sometimes associated with vermiculite.
Potential investors should first identify serious customers and only afterwards venture into the rather difficult vermiculite business. If only small amounts of vermiculite of good quality are needed deposits in the Lufusi, Mjimbya and Umba regions should be checked and analysed.

Occurrences of Vermiculite in Tanzania



Scale 1 : 10,000,000

0 100 200 300 400 500 km

Legend

● Vermiculite

ZEOLITES

GENERAL INFORMATION AND USES

Zeolite is the name of a group of about 50 minerals, which form by the reaction of pore water with volcanic rocks or clays. While only eight of these minerals can be found in commercial deposits, all of them have large open "channels" in their crystal structure that provide a large void space for the adsorption and exchange of cations. Due to this property zeolites are increasingly being used in aquaculture, agriculture, horticulture, the chemical industry, waste management and for domestic use. While the chemical industry prefers artificial zeolites to natural zeolites due to their more uniform structure and properties, in the agricultural field nearly all zeolites can be used as animal feed additives, as soil and compost additives, as potting media and as a medium for nitrogen capture, storage, and slow release.

RELEVANT OCCURRENCES IN TANZANIA

Erionite – which is a zeolite harmful to health when inhaled by animals and humans - has been known for quite some time to be a major constituent of weathered volcanic rocks around Lake Natron. Useful occurrences of zeolites in Tanzania have only been described more recently:

- Shingo Hill is a gentle hill in the Usangu flats north of the Chimala-Elton mountain range. It lies 3.5 km north-NE of Igurusi Village. Here, coarsely layered pebbly agglomerates at the bottom of the hill are followed by volcaniclastics which grade into fine-grained whitish zeolitized tuff-beds at the top. The zeolitic (chabasite) tuff-bed is approximately 2 to 2.5 m thick. It is harder and more compact than the underlying tuff and agglomerate horizons. Visible glass shards up to 3 cm in diameter occur in the tuff bed. The extent of the exposed zeolite bed is approximately 150 x 100 m with extensions of this or other chabazite beds found south of Shingo. Ca-chabazite is the main mineral of the zeolitized tuff with glass shards and minerals like feldspar and analcime, which is a zeolite, making up less than 30 vol.-%. The resources of zeolitic tuff have been estimated in the order of 80 to 100 kt with additional resources available in large extensions known in the surrounding areas.
- The Chamoto zeolite occurrence lies south of the Chamoto phosphate prospect (see Phosphate) with only small resources of zeolitic (chabazite) lapilli-tuffs identified.
- The Mapogoro zeolite occurrence lies in the Rukwa rift valley close to the Mbalizi-Mkwajuni all-weather-road. It is 5 km NW of Njelenje Village. Here, the zeolite mineral phillipsite was identified in lake beds together with feldspars and, in places, chabazite. Two, and in places three phillipsite layers can be traced along strike for 4 km. The thickness of each of these layers varies from 0.6 to 2.0 m. The minimum resources easily mineable by open cast mining were calculated as 84 kt. The total geological resources are at least one order of magnitude larger.

Table 56: Chemical composition (XRF-analyses, data in wt.-% of zeolitic tuff rocks from Tanzania (from Chesworth et al. 1988).

	Shingo Hill		Mapogoro	
	Chabasite		Phillipsite	
SiO_2	54.89	55.43	56.00	59.0
Al_2O_3	18.72	17.52	15.61	16.1
Fe_2O_3	2.54	2.53	3.72	3.58
MgO	1.00	0.80	0.60	1.21
CaO	2.44	4.97	0.46	0.82
MnO	0.41	0.13	0.34	0.74
Na_2O	3.58	0.39	2.50	4.49
K_2O	3.78	4.22	8.02	6.48
TiO_2	0.39	0.33	0.34	0.53
P_2O_5	0.08	0.17	0.02	0.05
LOI	12.16	13.50	12.38	6.93
total	*99.99*	*99.99*	*99.99*	*99.93*

REQUIREMENTS AND EVALUATION

For potential mining, the overburden of zeolite deposits should be low ($<$4 m) with layers of zeolite more than 20 cm thick. Deposits should contain $>$100 kt zeolites consisting of high-grade ore, i.e. grade of ore has to be $>$60-70 wt.-%.

Tanzanian zeolite deposits can almost meet these requirements. They have also been tested as a manure improver, as an underlay of turf-grass, and as a means of preventing the pollution of natural waters, especially from feed lots. While no exact data is available, the cation exchange capacity (CEC) is also said to be high. Potential investors could therefore keep in mind these deposits when looking for local material of high quality and value for soil improvement.

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Occurrences of Zeolites in Tanzania

Scale 1 : 10,000,000

0 100 200 300 400 500 km

Legend

● Zeolites

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FURTHER INFORMATION ABOUT MINERAL OPPORTUNITIES IN TANZANIA MAY BE OBTAINED FROM THESE SOURCES:

Permanent Secretary
Ministry of Energy and Minerals
754/33 Samora Avenue
P.O. Box 2000
Dar es Salaam, Tanzania
Tel +255-22-2112791
Fax +255-22-2128250
E-mail: madini@africaonline.co.tz

Commissioner of Minerals
Ministry of Energy and Minerals
754/33 Samora Avenue
P.O. Box 2000
Dar es Salaam, Tanzania
Tel +255-22-21137142
Fax +255-22-2137142
E-mail: kafumu@yahoo.com

Executive Director
Tanzania Investment Centre
Shaaban Robert Street
P.O. Box 938
Dar es Salaam, Tanzania
Tel +255-22-2116328-32
Fax +255-22-2118253
E-mail: information@tic.co.tz

Director General
State Mining Corporation
Plot no. 417/418 UN Road
P.O. Box 4958
Dar es Salaam, Tanzania
Tel +255-22-2150029
Fax +255-22-2150243
E-mail: stamico@bol.co.tz

Chief Executive
Geological Survey of Tanzania
P.O. Box 903
Dodoma, Tanzania
Tel +255-26-2322401
Fax +255-26-2323020
E-mail: madini-do@gst.go.tz

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