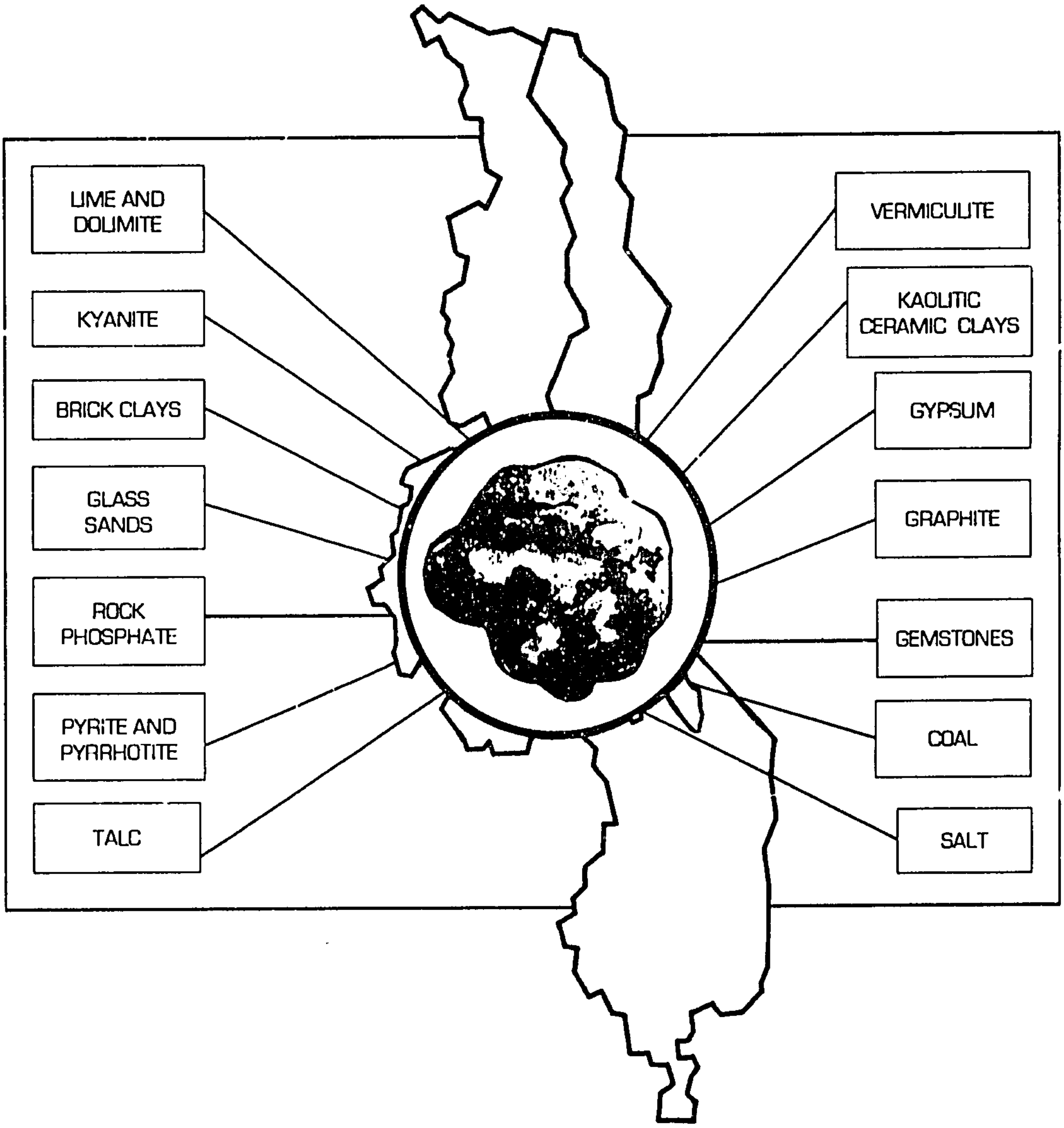
PROMOTING SMALL AND MEDIUM SCALE MANUFACTURING OF PRODUCTS FROM THE MINERALS AND ROCKS OF MALAWI

MALAWI U.S.A.I.D
RURAL ENTERPRISES AND AGROBUSINESS DEVELOPMENT PROJECTS
(R.E.A.D.I.) PROJECT



MINERALS AND ROCKS OF MALAWI

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RURAL ENTERPRISE
AND
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THE MINERALS AND ROCKS OF MALAWI

July, 1990

FOREWORD

The purpose of preparing this document is to increase the awareness of informal, small and medium scale entrepreneurs of products which can be produced from the minerals and rocks found in Malawi. The document reviews the opportunities and potential for private sector development and transformation of these mineral and rock resources into export and domestically consumed product.

For further information users of this promotional document are encouraged to contact the Ministry of Trade, Industry and Tourism, Ministry of Forestry and Natural Resources, The Department of Mines, The Associated Chamber of Commerce in Malawi or their local DEMATT, SEDOM or INDEFUND offices for further information on individual mining and rock opportunities.

Donald E. Henry
PROJECT COORDINATOR

ACKNOWLEDGEMENTS

The book was prepared by a group of consultants in close collaboration with officials of the Government of Malawi and Small and Medium Enterprise (SME) support institutions in Malawi. The team of consultants was composed of:

Mr. James Chatupa *(Team Leader)*
Mr. Frank Giarrizzo *(Editor, Production Manager)*
Mr. Richard Mwale *(Artist)*

The government ministries and departments are credited for providing the geological statistics and national survey data used in this document. The SME support institutions are credited for providing local information on markets for mineral and mining products. Our special acknowledgement go to Ministry of Forestry and Natural Resources Department of Mines and Geological Surveys for the use of their extensive library. Mr. Y.P Phiri from the Department of Mines is credited for preparing the background papers on the legal framework of the mineral sector.

We would also like to express our appreciation to the Ministry of Trade Industry and Tourism who provided valuable comments on the draft report. There are many others who provided time and effort to this document. We make special mention of John Spiropolus, Augustine Bobe, and the READI Project staff.

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SUMMARY AND RECOMMENDATIONS

1. This study describes the full range of inventories of "industrial mineral" resources found in Malawi which can be exploited in the immediate future by small-to medium-scale Malawian entrepreneurs. These resources include: limestone and dolomite; vermiculite; gypsum; glass sands; kaolinitic ceramic clays; graphite; gemstones and ornamental stones; salt; pyrite/pyrrhotite; talc; rock phosphates; brickclays and kyanite. Coal, although an energy resource, is included since there is potential for utilizing coal as a source of energy in the mining sector. In that way it may be possible to reduce the current high level of deforestation going on in Malawi.

2. All mining in Malawi, whether small-scale or capital intensive, is regulated by law. Malawi laws and regulations are sympathetic to the promotion of small-scale enterprises and provisions have been made to tolerate most mining as long as environmentally sound practices are used.

3. Malawi presently imports over K15 million of raw materials and products made from most of the mineral resources listed above. Therefore, there is great potential for promoting import substitution enterprises in the mining sector. The most promising ventures would be in locally mining, processing and producing finished commodities from the following mineral resources:

    3.1 **High potential for exploitation**

    - Limestone and dolomite
    - Kaolinitic ceramic clays and glass sands
    - Brickclays
    - Gypsum
    - Rock phosphates

    3.2 **Medium to low potential for exploitation**

    - Vermiculite
    - Graphite and talc
    - Pyrite/pyrrhotite
    - Salt
    - Kyanite

4. There is a steady demand for vermiculite, graphite and to some extent kyanite on the world market. Vermiculite has the highest potential for success on the competitive world market, followed by "flake graphite." Hence, exploitation of these resources could be promoted in terms of a capital intensive operation, or several small scale enterprises. Gemstones are best mined by small scale miners but

marketing of gemstones requires use of sophisticated marketing techniques. Malawi based marketing agencies urgently need to be created.

Both vermiculite and graphite occur as small discrete bodies, but in substantial aggregate reserves. Exploitation of such resources could lend itself to separate small-scale operations under the umbrella of some form of cooperative organization.

5. There is a great need to develop mineral resources for the agricultural sector where there is a great potential for increased demand. In the category of agro-minerals the important minerals are limestone and dolomite, gypsum, rock phosphates, talc, pyrite and pyrrhotite, and the kaolinitic clays. This is a new product area which will require aggressive market promotion.

6. Most of the industrial minerals resources are located in fairly accessible areas. There are also adequate land and water supplies to start small to medium scale enterprises. The main constraints will be in the following areas:

   6.1 Most Industrial minerals resources have low in-situ value, hence it may not be economically feasible to transport them over long distances. Consequently, projects may only be viable if the materials can be processed or marketed close to the deposit site. Only resources with high value added are really worth transporting over great distances, to the market place.

   6.2 The availability of electricity close to a deposit would be the most favorable factor in the viability of a prospect. Where electricity is not available there would be a lower potential for development of a viable new enterprise.

SMALL SCALE MINING IN MALAWI

1. GENERAL

1.1 PURPOSE

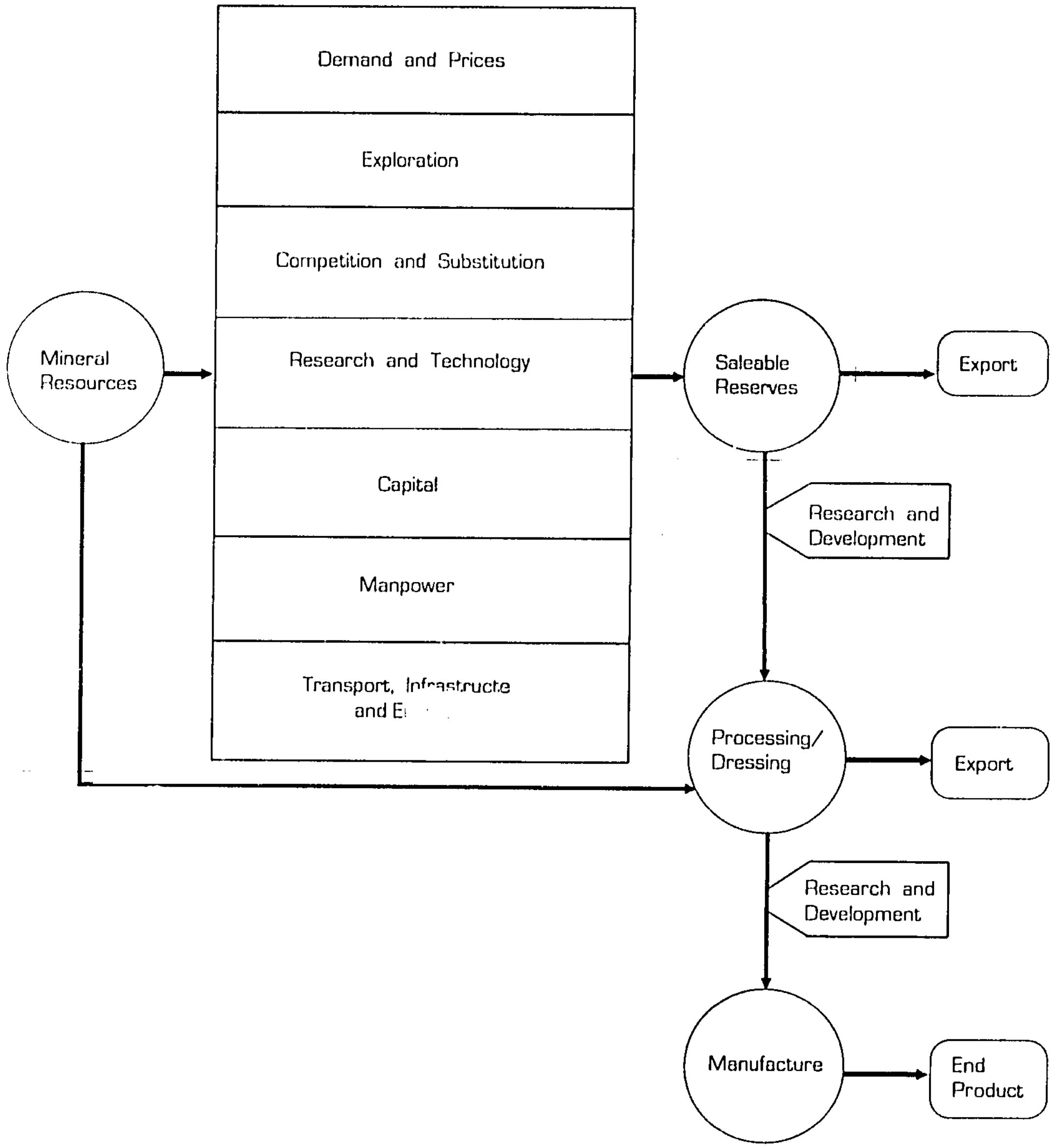
This study was commissioned by the Rural Enterprises and Agro-business Development Institute (READI Project)/U.S.A.I.D Malawi as part of their programme to assist Malawian entrepreneurs in starting up businesses in the small-to medium-scale mining sector. The READI programme involves providing guidance, training, and assistance to select entrepreneurs in preparing and identifying potential investment capital sources.

This study has therefore been restricted to describing inventories of mineral resources in the "industrial minerals and rocks" group, suitable for exploitation on a small scale, using relatively simple technologies, and with nominal initial financial investments ranging from as low as MK1,000 to as high as MK500,000. The report emphasizes the exploitation of these mineral resources to meet current and future local demand level. The purpose of this report is to help:

- identify mineral deposits which can be mined by small-to medium-scale (Malawian) entrepreneurs, (including limestone, vermiculite, kaolinitic clays, gypsum, glass sands, coal, gemstone, and graphite deposits).
- indicate the quality and quantity of all the resources identified,
- identify appropriate technologies for mining and processing each mineral where such technical information is available, especially those minerals that the Geological Survey Department has tested,
- identify possible uses of such minerals in Malawi by
- various industries and their potential for export,
- identify existing and additional infrastructure (including land, workshops, storage sheds, electricity, waste, waste disposal facilities, transport) needed to mine and process the minerals.

In promoting small-scale, import substitution industries, it is essential to note that most of these ventures will have the greatest chance of success in urban and peri-urban environments, close to the manufacturing industries. Although industrial minerals have high intrinsic values, they often have low in-place value; they are bulky and hence expensive to transport over long distances. So any decision to exploit industrial mineral resources must be based on a full analysis of markets, a deliberate choice of the resources to be exploited, selection of appropriate technologies and suitable transport arrangements. Factors that relate to the success of mining projects are given in Fig. 1.

Figure 1. Factors Affecting Development of Mineral Resources



GSN 1097C Geological Survey Dept. Malawi 1982 K.A.T.

It is assumed that labor for small scale mining is available throughout the country, as there are many Malawians with mining experience, gained while working in mines in neighbouring countries. This is best illustrated by the high skill levels demonstrated by workers who were surveyed at the Kaziwiziwi and Mchenga Coal Mines in 1985 and early 1988.

Legislation that is sympathetic to the small scale miner and processor is in place. The Mines and Minerals Act, Cap. 61:01 lists three categories of licenses:

— Mineral Permits;
— Non-exclusive Prospecting Licenses and Mining Claims;
— Mineral Rights, comprising:

under mineral rights are three sub-categories of licenses:

— Reconnaissance Licenses;
— Exclusive Prospecting Licenses; and
— Mining Licenses.

The first two categories of licenses are the most suitable choices for Malawian entrepreneurs with modest resources and capabilities, while the last category largely suits medium-to-high cost operations. The ***Mineral Permits*** category covers the digging of building materials and are mainly issued to traditional brickmakers and stone crushers through District Commissioners. The ***Non-Exclusive Prospecting Licenses (NEPL)*** and ***Mining Claims*** category is designed for the small-scale prospector and miner. The latter may be issued by the Commissioner for Mines and Minerals to Malawian citizen or companies; for others, the Minister of Forestry and Natural resources must be consulted. The licenses are valid for one year. The holder of a NEPL also has the circumscribed right to register a ***Mining Claim.*** It is illegal to prospect or mine a mineral without a license, except for traditional activities such as excavating clays for construction of homes in villages. (See Appendix A-3 for more information about Permits and Licenses.)

1.2 DEFINITIONS

There are three main categories of mineral resources: "metallic ores", "industrial minerals and rocks" and "energy minerals (including fossil fuels)". The metallic ores include gold, silver, copper, nickel, iron ores; to date no significant quantities of these have been found in Malawi. Industrial minerals include limestone, ceramic clays, building clays, vermiculite, kyanite, corundum, glass sands and gypsum; these are found in substantial quantities in Malawi and can be developed using simple technologies. Coal, uranium and petroleum are the energy minerals; so far, only coal and uranium have been located in Malawi.

The term "industrial minerals" is not as strictly defined as the terms "ore" or "fossil fuel" (Kuzvart, 1984). The characteristic feature of an industrial mineral lies in its physical properties, e.g., the insulation properties of vermiculite, the refractory nature (resistance to heat) of magnesite or kyanite, and the plasticity of clays, etc. Ores are characterized by the chemical properties of the metals.

Kuzvart ***(opcit)*** defines four categories of industrial minerals:

1. Raw materials that are used in industry in variously prepared forms of minerals (e.g. talc as a filler, glass sands for glass or abrasives);
2. Raw materials that serve as a source of non-metallic elements such as pyrite as a source of sulphur, fluorite for fluorine, and apatite for phosphorus;
3. Non-metallic raw materials that are sources of metals (e.g. bauxite as a source of aluminum, although it is also a source of refractories);
4. Building materials (e.g. granite, gravel and sand, brickclays, etc.).

The term "non-metallic minerals" is often synonymous with "industrial minerals". However, some raw materials may at times fall into the "ores" group, while at other times they may be an "industrial mineral. For example, chromite is both a source of the metal "chromium" and a refractory material. This report will use the foregoing terminology in relation to current practices in the commercial sector. The afore mentioned four categories of industrial minerals are modified into five primary areas of use in Malawi:

— chemical industry;
— refractories;
— fillers;
— building materials; and
— ornamental stone

1.3 IMPORTANCE OF INDUSTRIAL MINERALS

Industrial minerals are generally the least understood of all natural resources in developing countries. Consequently, most industrial minerals remain unexploited, while a high priority has been given to development of metallic and energy minerals for export to industrialized countries. That many Malawians may not perceive industrial minerals as a potentially lucrative investment area is a development problem often ignored by planners and financiers.

At present, over 80 percent of the consumption of industrial minerals takes place in industrialized countries. Additionally, many developing countries import a variety of commodities with a high proportion of industrial mineral materials in them. These commodities could be manufactured locally.

The importance of industrial minerals may best be illustrated by comparative world production figures in Table 1.1.

Table 1.1: World Production of Industrial Mineral Commodities

Commodity	Amount	
building materials	9.0	billion tonnes
fossil fuels	6.9	billion tonnes
industrial minerals	7.5	billion tonnes
ore concentrates (Fe, Mn ore)	0.93	billion tonnes
steel	0.6	billion tonnes
other metals (excluding Fe, Al, Ti, Cr, Ta, U and Zr)	0.019	billion tonnes

(after Kuzvart, 1984, p.20).

Furthermore, in the U.S.A., non-metallic mineral resources represent more than twice the value of ores in the Gross National Product, even though the United States is very rich in ore minerals.

In Malawi industrial minerals are generally consumed indirectly in the form of imported commodities. These include glass, fertilizers, ceramic ware, plastics, lime, acetylene, paints, chalk, ink, pesticides, soaps and detergents and pharmaceuticals. The value of these imports has ranged from K12 million in 1980, to over K13 million in 1987 (Table 1.2). Industrial minerals make up a large proportion of the ingredients of these imports. These raw materials could be supplied from Malawian deposits.

1.4 CONSTRAINTS ON MINERAL DEVELOPMENT

The development of mineral resources in Sub-Saharan Africa has been primarily directed towards the extraction and export of "metallic" ores: gold, copper, nickel, chromite uranium, diamonds, etc. As there is a ready and strategic demand for these minerals in industrialized countries, they have often attracted the most investments from international mining houses, in contrast to the "industrial minerals" which are most abundant in Malawi. Secondly, even those prospects with export potential, such as rare earths (RE), vermiculite, bauxite and uranium, have rarely been aggressively promoted, hence there was very little private sector exploration taking place prior to the 1980s.

Malawi's abundant resources of limestone, vermiculite, ceramic clay, graphite, pyrite and pyrrhotite could contribute significantly to local industrial development.

The failure to develop these resources to date has been due to a number of factors.

For example:

- The development of industrial minerals often goes hand in hand with that of metallic ores. Ceramic clays, kyanite, and limestone are some of the key resources in the smelting of ores, production of refractories; other industrial minerals are additives for fertilizers and pesticides.However, at present there is no coordinated effort to monitor potential demand and develop strategic plans for production of mineral-based commodities.

- Traditionally, Malawian manufacturers depend on the supply of raw materials from their mother companies in Europe, the U.S.A., Japan or South Africa. The demand for local raw materials is a recent phenomenon, thrust on the industry by economic difficulties.
- Often educated people are reluctant to take up business initiatives in the mining sector, and small scale mining is left to those who may least understand the need for improved technologies. Consequently, inefficient and poor quality production operations are common in the small-scale mining sector.

The biggest obstacles to overcome in order to develop industrial minerals seem to be a lack of technological methods and practices; an absence of coordinated research efforts; and the inability to convert research information and results into realistic commercial ventures.

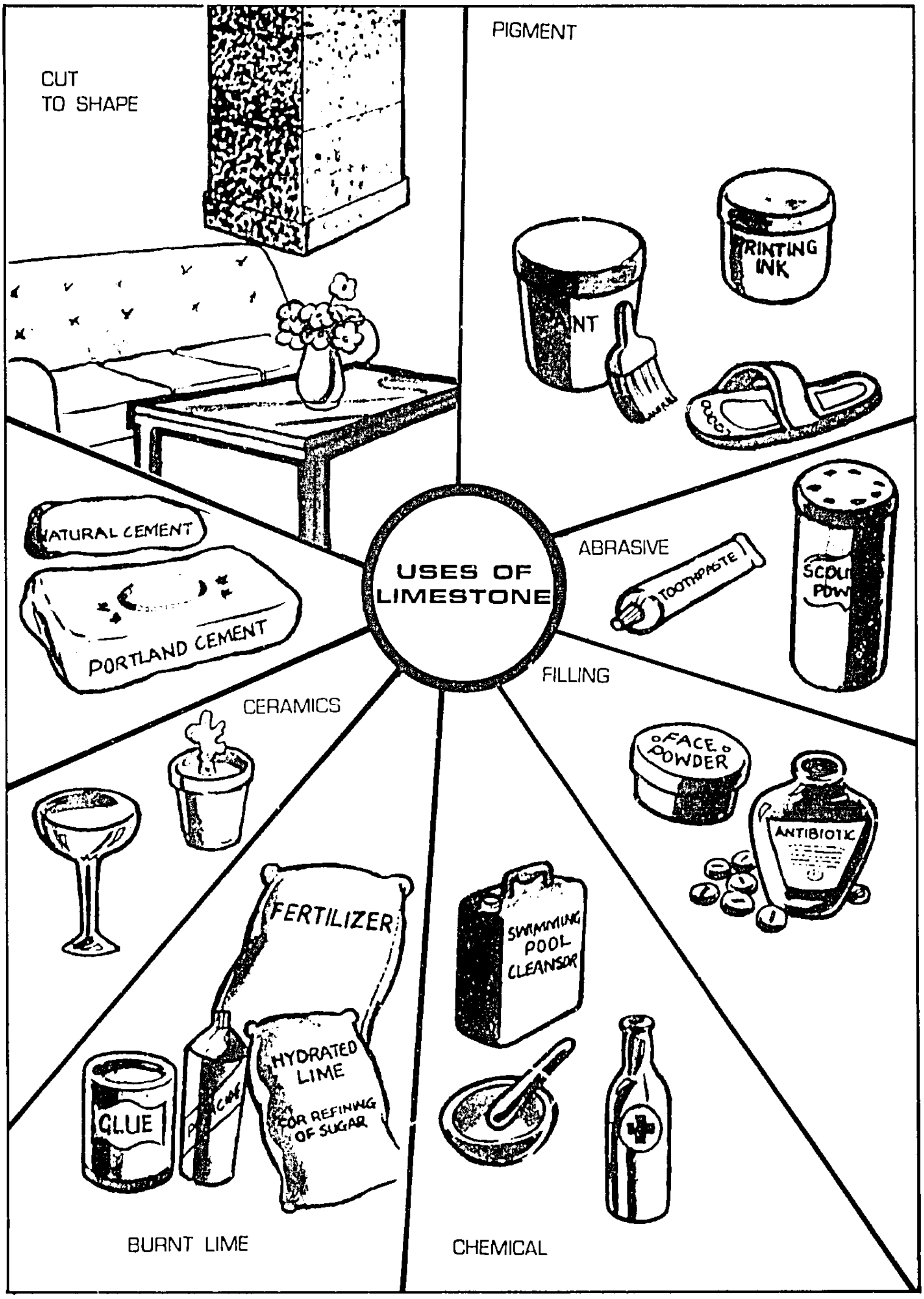
Mineral commodities are only one part of the required raw materials that are necessary for the production of consumable goods. There is, however, a lack of an integrated approach in determining actual demand of raw materials. For instance, because mining strategists and agricultural consumers do not communicate, agriculture's need for fertilizers, fillers and conditioners are not met by local resources and the mining industry misses out on local demand.

The only way to solve these problems is to maintain a consistent and continuous system of human resources development, through M.E.D.I., DEMATT, SEDOM and the rural technical schools. However, this requires a pool of trainers as well as mineral development research centres.

Table 1.2: Imports of Industrial Minerals and Mineral Products

Commodity	1980		1984		1985		1986		1987	
	Quantity	Value (MK)	Quantity	Value (MK)	Quantity	Value (MK)	Quantity	Value (MK)	Quantity	Value (MK)
Salt	12,970	1,578,519	15,848	3,986,483	24,590	5,283,564	11,726	2,839,636	14,402	4,890,656
Graphite	-	-	1	56[illegible]	-	-	1	3,523	-	457
Clay	-	-	63	27,976	85	30,101	53	47,449	54	35,007
Chalk	-	-	12	3,406	-	-	2	556	37	20,699
Ornament Stone etc.	-	-	359	79,599	519	115,120	398	155,546	342	142,624
Magnesite Product	-	-	-	-	-	80	71	82,796	71	116,372
Gypsum	-	-	3,205	404,246	2,076	273,934	3,102	413,207	3,096	448,563
Lime	3,143	526,068	3,293	723,956	2,172	503,877	1,931	393,251	3,953	1,153,327
Cement	30,629	2,933,959	4,382	586,567	10,839	1,225,221	23,318	2,223,273	16,044	2,111,925
Coal	65,383	3,189,323	41,266	4,220,308	32,752	4,159,153	27,746	3,050,539	24902	2,733,715
Sulphur	-	-	2.973	2,793	13.15	9,924	9.343	9,173	26.253	43,487
Sulphuric Acid	473,203	558,433	131.136	103,678	264.75	321,036	130.655	128,979	268.657	743,611
Glass/Glassware	-	2,561,862		2,732,740		2,448,780		n/a		n/a
Ceramic Product	1,121.5	957,125		1,692,059		1,101,708		n/a		n/a
Total Value in MK		12,305,289		14,564,377		15,472,498		9,347,928		12,440,443

- National Statistical Office Source.
- Values are in Malawi Kwacha
- Ornamental Stones include Quartzite, Dolomite (marble), Steatitite (soap stone), sands, granite, mica and feldspar.
- Magnesite/magnesium carbonate (natural)
- All quantities are in tonnes except for sulphur, sulphuric acid and ceramic products which are given in Kgs.


USES OF LIMESTONE
CUT
TO SHAPE
PIGMENT
PRINTING
INK
ABRASIVE
TOOTHPASTE
FILLING
FACE
POWDER
ANTIBIOTIC
CHEMICAL
SWIMMING
POOL
CLEANSOR
BURNT LIME
FERTILIZER
HYDRATED
LIME
FOR REFINING
OF SUGAR
GLUE
CERAMICS
PORTLAND CEMENT

2. LIMESTONE AND DOLOMITE

2.1 RESOURCES

Limestone and dolomite resources of Malawi are estimated to be over 800 million tonnes, mainly found as metamorphic marbles in the southern part of Malawi (Figs.2 and 3). All the resources may be divided into 5 types as follows:

- metamorphic marbles: (The term marble is used in the geologic sense, and not in the trade sense of a rock which can take a polish for decorative purposes.)
- carbonatites: igneous rock vents enriched in sovites (calcites of undoubted igneous origin);
- sedimentary limestones;
- vein calcite;
- travertine, (light coloured) tufa and (porous) soil limestones.

The most widely used limestones and dolomites are the metamorphic marbles and sedimentary limestones, hence further discussions will mainly refer to these.

In the commercial sector of Malawi, a clear distinction is emerging with respect to the terms:

(i) limestone
(ii) dolomite
(iii) chemical grade lime
(iv) building lime
(v) ordinary lime

These terms do not presume any geological or genetic interpretation of the raw material. This report maintains the meaning of these terms as they are applied in the Malawian commercial sector:

- Limestone is a term reserved for rocks in which the carbonate fraction is composed primarily of the mineral calcite ($CaCO_3$), with the magnesian (MgO) content less than 5 percent. (If the proportion of dolomite minerals is between 5 and 10 percent then the rock may be referred to as a magnesian limestone.)
- Dolomite is reserved for those rocks which are composed primarily of the mineral dolomite, $CaMg(CO_3)_2$ theoretically, some 21.9 percent MgO and 30.4 percent CaO;
- Chemical grade lime is as defined in the specifications given by the South African Bureau of Standards (see Tables 2.3 and 2.4);
- Building grade lime is as defined in the specifications of the South African Bureau of Standards.

Figure 2. Main Limestone, Brickclay, Talc, Kyanite and Phosphate Resources of Southern Malawi

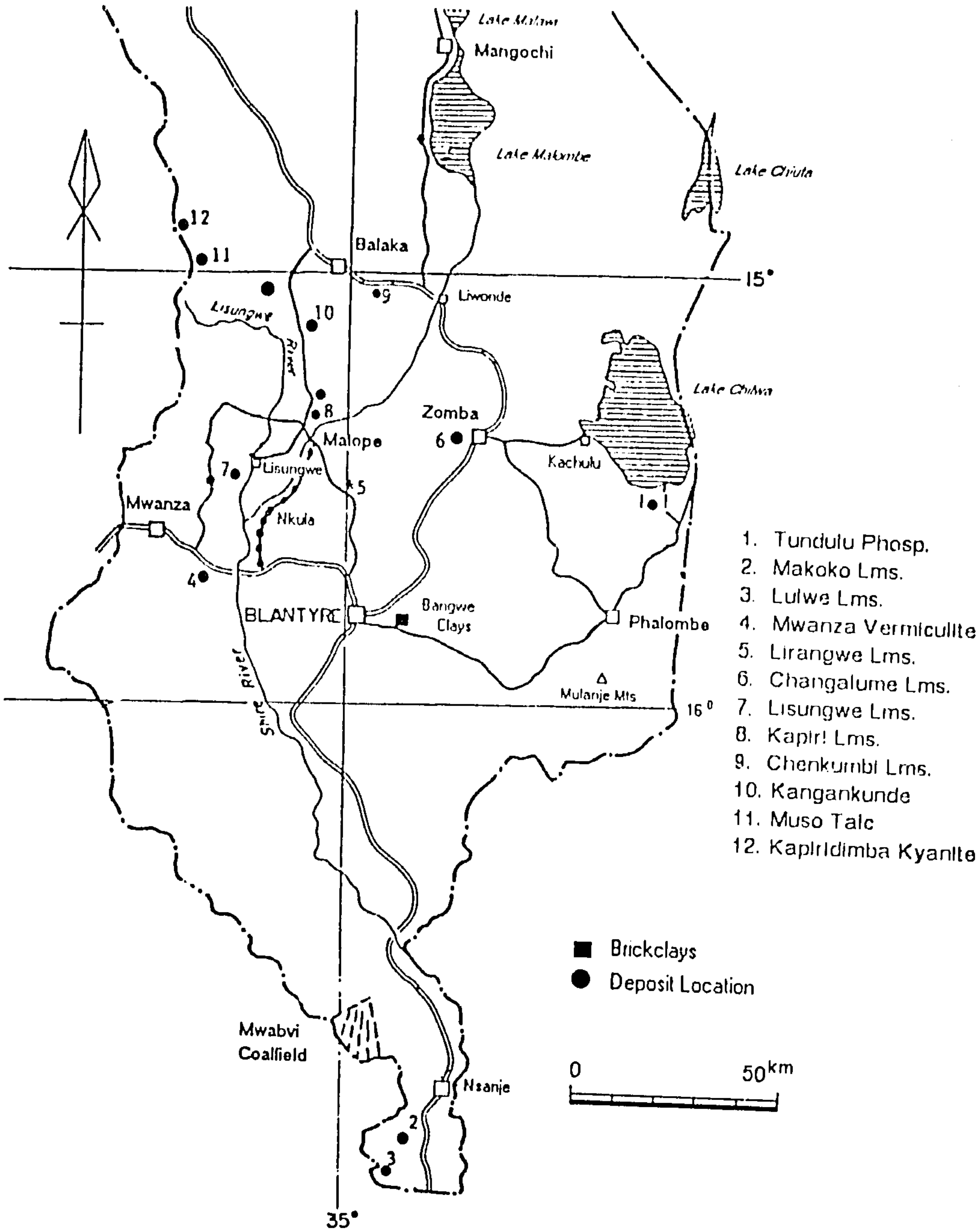
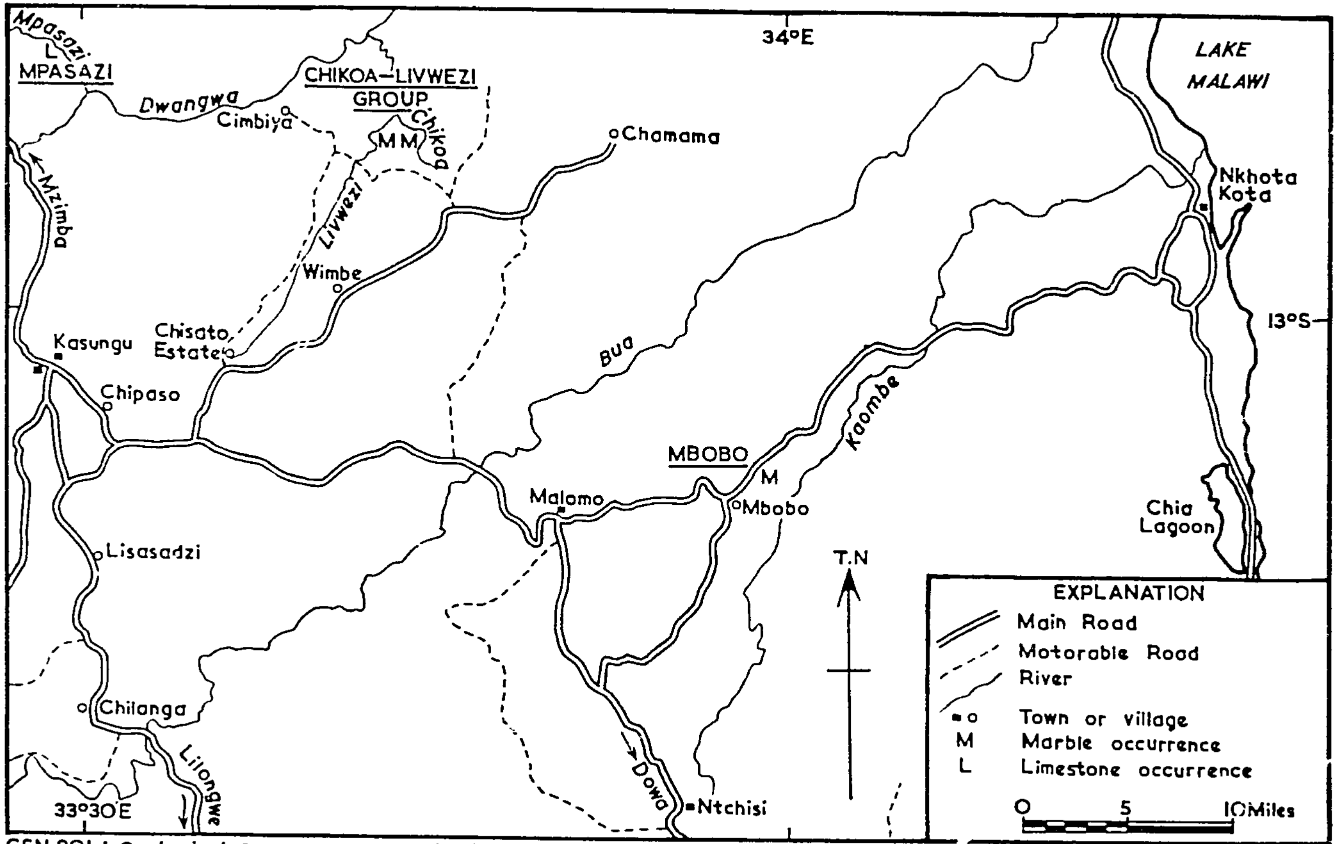


Figure 3. Location Map for Marble and Limestone in the Kasungu-Ntchisi Areas



GSN.901 J. *Geological Survey Dept. Malawi 1972.* DWL.

Most of the limestone and dolomite deposits which have been located by drilling and/or trenching have only been partially evaluated. The reserves and quality of these deposits are presented in Tables 2.1. and 2.2. Exploitation of limestone and dolomite is greatest at Lirangwe, Chenkumbi, Kholombidzo and Changalume (for cement production).

Table 2.1 Limestone: Total Estimated Resources

Deposit Location	District	Est. Resources . (mil. tonnes)	Percent CaO	Percent MgO	Percent Inso-luble
Changalume	Zomba	100	49.4	0.8	5.8
Chenkumbi	Machinga	300	46.1	6.3	-
Chikoa	Kasungu	25	53.1	0.3	2.5
Livwezi	Kasungu	18	53.7	0.5	1.8
Matope/Nkula	Blantyre	180	31.8	20.0	-
Lirangwe	Blantyre	5	31.7	19.1	3.2
Makoko/Malawi	Nsanje	20	47.2	5.6	3.8
Golomoti	Dedza	15	48.1	1.2	1.7
Uliwa	Karonga	5	45.6	1.9	10.6
Ngana	Karonga	6	45.4	1.3	16.3
Mwesia	Karonga	15	39.2	1.6	18.9
Chilwa Island	Zomba	25	52.1	0.2	3.3
Kangankunde	Machinga	5	46.4	1.2	10.8
Kapiri	Machinga	10	28.7	21.7	2.1
Lulwe Hills	Nsanje	2	51.9	0.9	2.6
Lisungwe	Blantyre	40	30.2	20.2	2.2
Nsengwa	Mwanza	30	-	-	-
Total Estimated Resources		801			

2.2 USES AND SPECIFICATIONS OF LIMESTONES AND DOLOMITES

"Literally any object that exists in man's home or his office (or virtually any manufactured product) has required lime or limestone (including dolomite) in some phase of its manufacture, directly or indirectly, either as a prime or incidental processing material. In fact, lime and limestone's basic essentiality has been likened to one leg of a 6-legged stool on which industry revolves; the other essential legs being iron ore, salt, sulphur, petroleum, and coal - these are the six building blocks of industry and commerce" (Boynton, 1980).

Table 2.2: **Limestone: Mineable Reserves (located by rotary core drilling or trenching)**

Deposit Location	District	Estimated Reserves (million tonnes)
Changalume	Zomba	25
Chenkumbi	Machinga	10
Chikoa	Kasungu	5
Liviwezi	Kasungu	5
Nkula	Blantyre	0.6
Matope Bridge	Blantyre	0.7
Golomoti	Dedza	0.5
Total Estimated Reserves		46.8

There are many uses of limestone and dolomite, but only a few of these are appropriate in Malawi:

— **Portland cement** - Limestone is quarried and burnt in kilns at Changalume. The clinker produced is then transported to Blantyre where, after the addition of gypsum, the resulting cement is bagged and sold.

— **Lime** - 70 percent of the lime produced in Malawi is building lime, but it is also used for a variety of purposes including for sugar production when there are import supply problems. The lime is mainly obtained from limestones with an Mg0 content below 5%.

— **Dolomite** is crushed and milled in the Blantyre area for agricultural purposes and for the production of scouring powders. The particles are milled to less than 80 mesh fineness. (See Appendix for mesh size explanation.)

Specifications for the different types of limes, limestone and dolomite used in industry are equivalent to those of the South African Bureau of Standards.

For **bedding mortar** (SABS 523-1972) the minimum combined CaO + MgO content should be 70 percent by weight. The minimum CaO content should be at least 40 percent by weight. At least 75 percent by weight of the particles must be hydrated lime finer than 0.600 mm.

Plaster must have a minimum combined CaO and MgO content of 80 percent. These particles must be finer than 0.075 mm.

Putty plaster should have a compared CaO + MgO content of 85 percent. The CaO proportion must be greater than 50 percent by weight. The particles should be the same as those of plaster.

The chemical and physical properties of lime for chemical, metallurgical and soil stabilization purposes are given in Tables 2.3 and 2.4.

Table 2.3: Chemical and Physical Properties of Slaked Lime for Chemical and Metallurgical Purposes (SABS 459-1955)

Lime Component	High-Calcium hydrated lime			Magnesian Hydrated Lime (% Wt.)	Dolomitic Hydrated Lime (% Wt)
	Grade I (% Wt.)	Grade II (% Wt.)	Grade III (% Wt.)		
Min. Available CaO	68.0	66.0	64.0	60.0	-
Min. CaO + MgO	-	-	-	-	64.0
Max. MgO	2.0	3.0	2.0	10.0	31.0
SiO_2 + insolubles	2.0	3.0	3.5	4.5	56.0
Residue on 0.15mm sieve, Max	5.0	8.0	12.0	10.0	10.0

Note: % Wt. + Percentage of total sample weight

Table 2.4: Chemical Properties of Hydrated Lime for Soil Stabilisation (SABS 824-1967) (% Weight)

Lime Components	High-calcium Lime (i)	Magnesian Lime (ii)	Dolomitic Lime (iii)
Min. CaO + MgO	75	75	75
Min. Available Lime	50	35	30
Max. Free Water	3	3	3
-0.075 mm particles	50	50	50

i. High calcium lime has a calcium-oxide (CaO) to magnesium-oxide (MgO) ratio greater than 14.0 percent of the total weight of sample.

ii. Magnesian lime has a calcium-oxide (CaO) to magnesium-oxide (MgO) ratio greater than 2.0 but less than 14.0 percent of the total weight of sample.

iii. Dolomitic lime has a calcium-oxide (CaO) to magnesium-oxide (MgO) ratio greater than 1.3 but less than 2.0 percent of the total weight of the sample.

2.3 POTENTIAL DEMAND

At present, demand for chemical grade lime in Malawi is about 3,300 tonnes per annum. 95 per cent of this is consumed by the sugar industry, and the balance by Lilongwe and Blantyre Water Boards, and Southern Bottlers. Production and consumption of building lime in the last three years were as follow:

Table 2.5: Production and Consumption of Building Lime

Year	Production tonnes	Sales in tonnes
1985	N/A	1462
1986	2681	2735
1987	1639	1544

Source: Economic Reports, EP & D.

The construction industry consumes most of the building lime as whitewash, plaster and mortars. Lime is also increasingly being used in agriculture, as dusting in the coal mines, for treatment of sewage by municipalities and for sanitary purposes. However, there are no consumption figures for these latter uses.

The demand for crushed and ground dolomite has dramatically risen in the last two years, largely for agricultural purposes. The quality of the dolomite required ranges from 20% to 40% $MgCO_3$ for this purpose. Other established users of ground dolomite are companies producing scouring powders and terrazzo. The actual and projected demand for dolomite follows in Table 2.6.

Table 2.6: Dolomite Demand: Actual and Projected

Company	Year	Estimated Dolomite Requirements (tonnes)
Optichem	1987/88	1000
	1988/89	3000
Naming'omba	1987/88	120
	1988/89	200
Lever Brothers	1986	244
	1987	217

Almost all the chemical grade lime is imported, mainly from Zambia. Most building lime and dolomite are locally produced at Lirangwe, Chenkumbi and Kholombidzo. It is projected that agriculture's demand for dolomite will grow rapidly in the near future.

2.4 MINING AND PROCESSING

Mining of limestone and dolomite is already well-established and production is adequate for the size of today's market. The shortages which often occur are due to the inefficiencies in the processing operations. Mining involves removing overlaying soils to expose the rock. Sledge hammers are used to reduce the size of the large pieces. When the rock face is too hard or too large to remove easily, a fire is lit on the outcrop until it is hot to the touch. The hot rock is then rapidly drenched with cold water, and the rapid cooling causes the rock to crack, and the resultant pieces are broken and removed. The stockpiling of rock in 2.0 to 2.5 tonne mounds is done on a piece-rate basis.

Limestone is then crushed using small hammers to sizes ranging from 50 to 150 mm, also on a piece-rate basis. Most small miners are aware that, for lime production, only limestone (i.e. calcitic limestone) is suitable. However, quality control at the quarrying stage is a major problem. Miners must ensure that only the high-calcium limestone is quarried. The Geological Survey Department has designs of field testing kits that could be used for distinguishing high calcite from other types of carbonates.

It is doubtful that small-scale lime producers could consistently produce chemical-grade lime to the specifications given in Tables 2.3 and 2.4. Consequently, studies carried out in the last 2 years focused on improving the efficiency of lime-burning by the traditional producers in order to produce high grade building lime. The ITDG report "Proposals for Upgrading the Small Scale Lime Producers in Malawi" comprehensively covers the production of lime using both the traditional and proposed new methods (ITDG, April 1988).


WALL BOARDS
SIDE WALK
USES OF VERMICULATE
PESTICIDE
Pesticide
FERTILIZER
PAINT
PAINT
FERTILIZER
PAINT

3. VERMICULITE

3.1 RESOURCES AND RESERVES

Vermiculite is found in the Mpatamanga-Feremu area in Mwanza District. Some 15 deposits have been discovered there (Fig.4). It is estimated that these vermiculite deposits contain over 5 million tonnes, and go to an average depth of 20 metres from the surface.

Vermiculite is a mica mineral, which on heating to 1100°C, swells up to 10 times in size by exfoliation. The name comes from the Latin, **vermiculose,** meaning "small worm".

Three of the vermiculite deposits were evaluated in detail in the late 1970s; these are Kapirikamodzi, Chitimbe and Ngolongonda. The extractable reserves of vermiculite are summarized in Table 3.1.

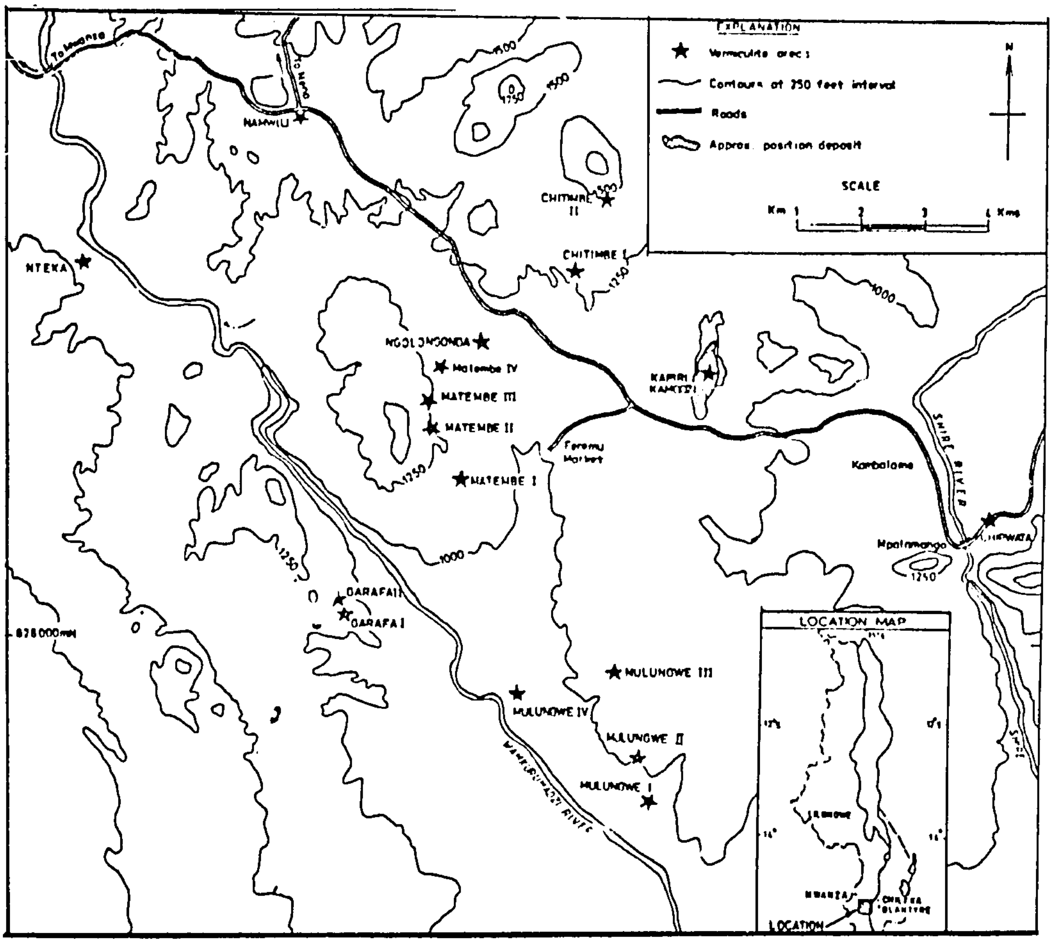
Table 3.1 **Vermiculite Reserves**

	Kapirikamodzi		Ngolongonda		Chitimbe		Total
Grain Size	Size Fraction %	Reserve in Tonnes	Size Fraction %	Reserve in Tonnes	Size Fraction %	Reserve in Tonnes	Reserves in Tonnes
+ 7	6	34 800	15	62 400	22	42 020	139 220
- 7 + 14	34	197 200	39	162 240	34	64 940	424 380
- 14 + 24	60	348 000	46	191 360	44	84 040	623 400
Total	100	580 000	100	416 000	100	191 000	1187 000

Size Fraction % = $\frac{\text{weight of sample retained on sieve}}{\text{total weight of sample}} \times 100$

At Kapirikamodzi, the deposits are delineated to a depth of about 18 metres, assuming a minimum grade of 10 percent vermiculite. These are very conservative estimates as the grade has only been assessed to the lowest level that appears to be economically viable. Reserves at the Ngolongonda deposits have been estimated to a depth of 20 metres, taking an average grade of 14 percent vermiculite. The Chitimbe deposit is also delineated to a depth of 20 metres at an average grade of 16 percent. In most commercial applications of expanded vermiculite, the required size fractions are blends of -7+14 mesh and -14+24 mesh. (See Appendix for mesh size explanation.) The total reserves of these two fractions are 1.05 million tonnes.

Figure 4. Location of Vermiculite Centres in Mwanza



Another factor that determines the quality of vermiculite is the rate of expansion, which is measured as the "expansion ratio". The "expansion ratio" is the ratio of the volume resulting from the expansion of 100 cubic centimeters of sample - i.e., if 100 ccs give 240 ccs after expansion, then the expansion ratio is 1: 2.4. Results from samples of various size ranges are given in Table 3.2.

Table 3.2: Results of Vermiculite Expansion Tests

	Expansion Ratio		
Size Range	Kapirikamodzi	Ngolongonda	Chitimbe
- 7 + 14 mesh	1:6.4	1:4.6	1:5.5
- 14 + 24 mesh	1:6.0	1:5.8	1:6.3

(See Appendix for mesh size explanation.)

These expansion ratios are equivalent to international grades that are marketed as "fine grades".

3.2 USES AND POTENTIAL DEMAND

The typical physical properties of exfoliated (expanded) vermiculite are given in Table 3.3.

Table 3.3: Physical Properties of Exfoliated Vermiculite

Loose bulk density (crude)	640 - 960 kg/m^3
Loose bulk density (expanded)	56 - 192 kg/m^3
Sintering (crusting) temp.	approx. 1260°C
Melting point	approx. 1315°C
Specific heat capacity	840j/kg °C
Specific gravity	2.6
Thermal conductivity	0.062-0.065 W/m^2 °C

These properties give vermiculite its distinctive characteristics of resistance to fire, acoustical and heating insulation, chemical inertness, and extreme light weight. It is the combination of these properties that makes vermiculite very useful for a variety of industries, including construction, engineering, agriculture, horticulture and metallurgy. Vermiculite is usually used in its expanded form, either in a loose or bonded state. The market for expanded vermiculite can be divided into four parts.

— Aggregate use (concrete)
— Insulation use (plaster board)
— Agricultural use (fertilizer filler)
— Miscellaneous (hydroponics, paint, etc.)

The larger grades of vermiculite (+7 mesh) are used in loose fill insulation, the medium grades (-7 +14 mesh) for bonded aggregated, and the finer grades for chemical and agricultural carriers.

Fine grades are preferred in the world market due to lower prices (there is more fine material available than coarse). Improved exploitation techniques produce greater yields and superior insulation performance at high temperature.

The world market for vermiculite is dominated by two supplying nations: the U.S.A. and South Africa. In 1985, the U.S.A. production was almost 300,000 tonnes, followed by South Africa at 175,000 tonnes, while the rest of the world's production (western countries) was less than 50,000 tonnes. Therefore, the significance of the Malawi resources is indeed substantial.

On the local market, vermiculite is starting to attract a number of consumers, including Valmore Paints Limited, the charcoal stove manufacturers (Energy Studies Unit of the Department of Forestry) and the agricultural sector. It is anticipated that Malawian demand for expanded vermiculite will grow to 100 tonnes in the next 3 years if the proposed pesticide formulation plant is established, and if it's use in paint production is expanded.

3.3 MINING AND PROCESSING

Vermiculite in the Mwanza area is exposed at the surface, and generally occurs as soft material. It can be excavated using hoes, picks and shovels, and by pitting, trenching and open-cast operations. Processing becomes more complex in sorting the material by sizes: + 7 mesh, - 7 + 14 mesh and - 14 + 24 mesh. For small scale operations, hand-operated screens are recommended.

Entrepreneurs interested in developing the vermiculite deposits could be divided into two groups:

— the mining and screening group; and
— the group exfoliating the vermiculite.

The first group would start by applying for NEPL's and Mining Claims from the Commissioner for Mines and Minerals. A typical mining and screening operation might require the following:

— Labor — 4 men excavating 2x2 m^3 each day
— 10 men handling 3 screens (7, 14 and 24 mesh), hand sorting, stockpiling and bagging

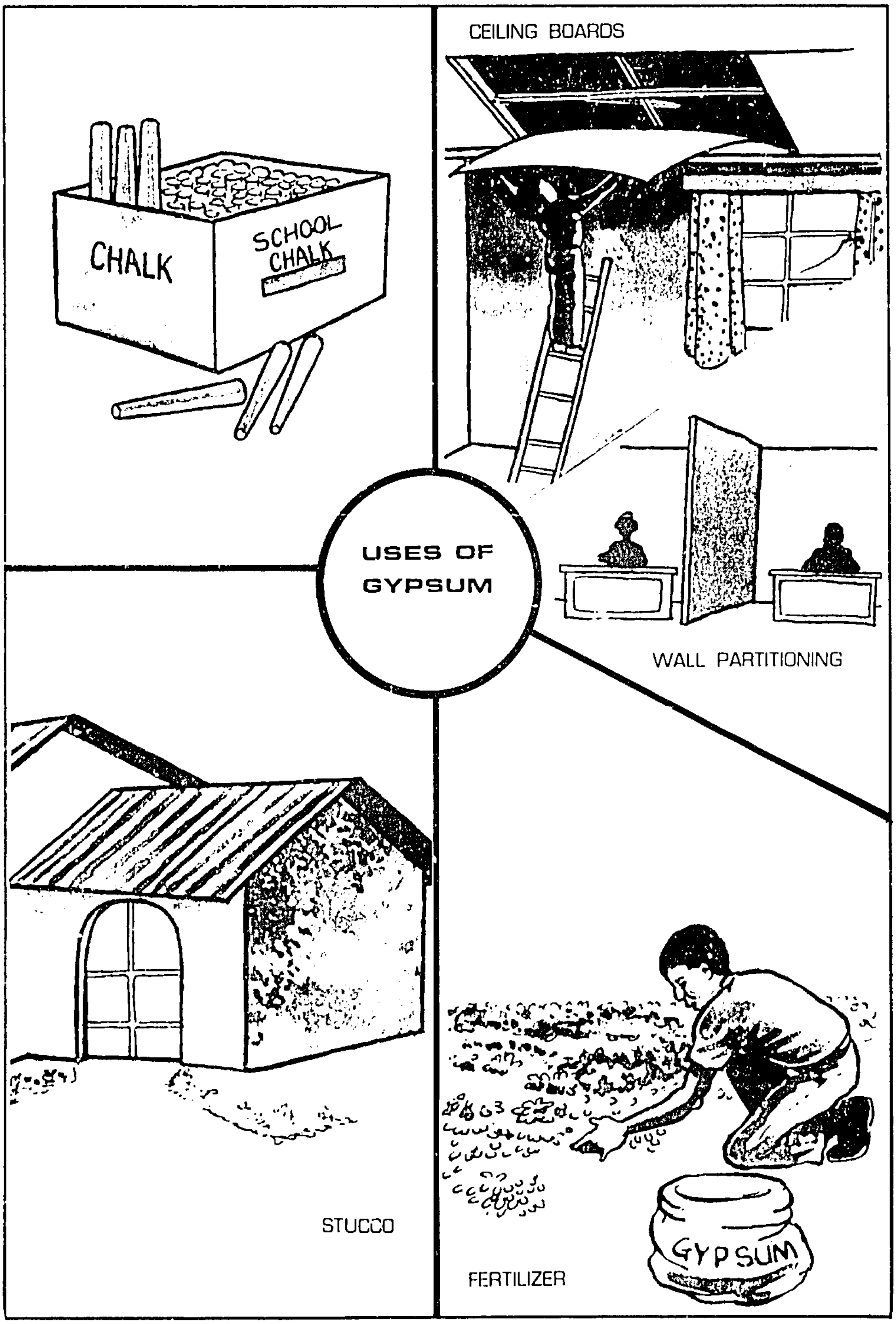
— Equipment — 2 picks
— 6 hoes
— 4 shovels
— 10 buckets (10 litre)
— 20 metres rope
— 1 30-m measuring tape
— 2 x 7-mesh screen
— 2 x 14 - mesh sieves
— 2 x 24-mesh screens
— 1 water pump (Honda single stroke size)
— 100 m hoses (high pressure/PVC)

— Vehicles — 1 5-tonne lorry

The estimated yield of vermiculite from 8 m3 of raw material excavated is approximately 2 tonnes each day. One operation on a 2-hectare plot, with estimated reserves of 10,400 tonnes, would annually produce 600 tonnes of vermiculite. This could be achieved, assuming that the **in-situ** raw material has grade of 10 percent with a density of 2.6, and that the mine operates 300 days in a year.

The new tarmac road from Blantyre to Mwanza passes within 2 to 20 km of all the 15 deposits of vermiculite. An electricity power line will also be constructed soon from Nkula Hydroelectric Station to Mwanza, along the tarmac road.

It is therefore recommended that the exfoliation of the vermiculite should be carried out near the main road, where electricity for the exfoliating furnaces is available. Exfoliation operations could meet both local and export demand.


CEILING BOARDS
CHALK
SCHOOL CHALK
USES OF GYPSUM
WALL PARTITIONING
STUCCO
FERTILIZER
GYPSUM

4. GYPSUM

4.1 RESOURCES AND RESERVES

Known gypsum resources in Malawi occur as low-grade deposits in dambos (the swampy drainage courses accounting for over 40 per cent of the Lilongwe and Dowa plains). Dowa and Lilongwe were selected as favorable targets for gypsum exploration because of the widespread occurrence of sulphur minerals (pyrite and pyrrhotite) in the rocks. The geological model that was developed envisaged that when such rocks weathered, the sulphur they contained was released to the drainage system. Then, in an appropriate chemical environment, such as an anaerobic one, the sulphur would combine with calcium to form gypsum ($CaSO_4 .2H_2O$). The abundant dambos, which were formed in the last 2 million years during the waning of the peneplanation processes, were selected as the most likely sites for the deposition of gypsum.

So far, 50 dambos have been found to contain gypsum, but reserves have only been located in 4 dambos:

- Matchenche Dambo, just south of Mponela Town
- Katete Dambo, near Nambuma
- Debza Dambo
- Linthembwe Dambo

Gypsum occurs as discrete crystals in clays and sands, ranging in size from less than 1.0 mm to over 4 cm. The grains are generally elongated and of angular shape. They are characteristically grey and tend to contain minute, fine clay particles.

The average grades of the gypsum range from 5 to 10 percent. These low grades make the dambo deposits unsuitable for mechanized or systematized mining techniques. The four (4) dambos are estimated to contain some 8,000 tonnes gypsum at an average grade of 7 percent (Table 4.1):

Table 4.1 **Gypsum Reserves of Some Dambos in Dowa District**

Dambo	Reserves in tonnes	Average Grade Wt. %
Matchenche	3500	5
Katete	2000	7
Dedza	?	8
Linthembwe	1000	10

4.2 USES AND POTENTIAL DEMAND

The name gypsum is derived from the Greek "gypsos", meaning "chalk" and some school board chalk is made from gypsum. A very pure, fine-grained gypsum is called alabaster. An important property that makes gypsum a very useful industrial mineral is its capacity for easy dehydration and rehydration when it has been calcined. That is, if a wet material is deposited in a calcined gypsum container, the water in the material (say clay) would be absorbed by the gypsum. Similarly, in a drying process, the container would very quickly release the water.

When gypsum is moderately heated at a temperature of 107°C for 2 hours, it changes to a calcined form, known as **Plaster of Paris** (POP). Mixed with water it hardens. This property makes gypsum useful for the building construction industry as a plaster. In this hardened form ***(stucco)***, it has good insulation properties (heat, sound), it is light weight, and has stability in fire. In recent years, 60-70 percent of gypsum (POP) has been used in the manufacture of plaster boards for partitioning walls in multi-story buildings.

Gypsum is also widely used in the production of Portland Cement in Malawi. An addition of 4 percent gypsum to ground cement clinker retards the setting of cement. In medicine, POP is used for making casts on sprained or fractured limbs. It is used in the production of ceramic casting moulds, ceiling boards and as a filler in paper production. In agriculture, raw gypsum may be applied to increase the porosity of soils and is also a fertilizer - a source of sulphur and calcium for groundnut production.

4.3 MINING AND PROCESSING

In all the dambos that have been explored near Dowa, the gypsum layer is overlain by a barren horizon, 0.2 to 1.0 metres thick. The gypsum band is 0.5 to 1.5 metres thick, in heavy plastic clay. The sand content in the gypsum bearing horizon may vary from 2 to 30 percent. The dambos are wet, often water-logged, most of the year, except for the months of September to November when they are dry enough to work.

Mining of gypsum is similar to that of the Mchinji glass sands (Fig.10). It is based on a "ndime" of 2 x 2 x 2 metres of excavation each day by a team of 4 men. The process starts with stripping the overburden layer, which is deposited in the direction of advance of the mining. The gypsum bearing horizon is then mined and carted to a stockpile site. The overburden material is then moved back to the "ndime" as a top soil, and planted with grass, banana or "nsenjere". Where the overburden is too thin,alternative ways of rehabilitating the dambos are being considered. It is possible to convert the holes that are created into fish ponds. There are proposals to request the Department of Fisheries to study this idea.

Gypsum is processed by washing. This requires an abundant source of water to wash out the clay and collect the gypsum and sand. The separation of gypsum from sand is a mineral processing problem that has not yet been resolved because the relative densities of gypsum and sand are almost the same. Consequently, one of the present criteria for determining whether a deposit is favorable for exploitation is its low content of sand. In such locations, the clay could be washed through sieves as shown in the flowsheet in Fig. 5.

Low grades of the gypsum deposits that have so far been found preclude the large-scale mining operations needed to meet the requirements of Portland Cement Co., amounting to some 2,000 tonnes each year. The most feasible approach would be to encourage rural homesteads to mine and process the gypsum as an off-farming season activity at production rates ranging from 20 to 200 kg of gypsum each day. The gypsum could then be sold in the same way as food crops. Tne advantages of this approach are sold:

- Low mining overhead costs for the farming community.
- Capital equipment would be essentially simple: hoes, shovels, screens (2 x 2 metres) at sizes of 5 mm, 1 mm, 7 mesh, 14 mesh and 25 mesh, 2- stroke water pump and hose.
- Mining would be carried out before crop planting resumes, hence there should be little interruption of food production activities in the villages.

The only real drawback would be that the villager's rate of production could not be relied upon if supplies of gypsum were expected to be regular and timely.

The calcination of gypsum would require electric ovens or coal/charcoal-fired kilns. There is no design available for an appropriate coal/charcoal-fired kiln, but a design is feasible.

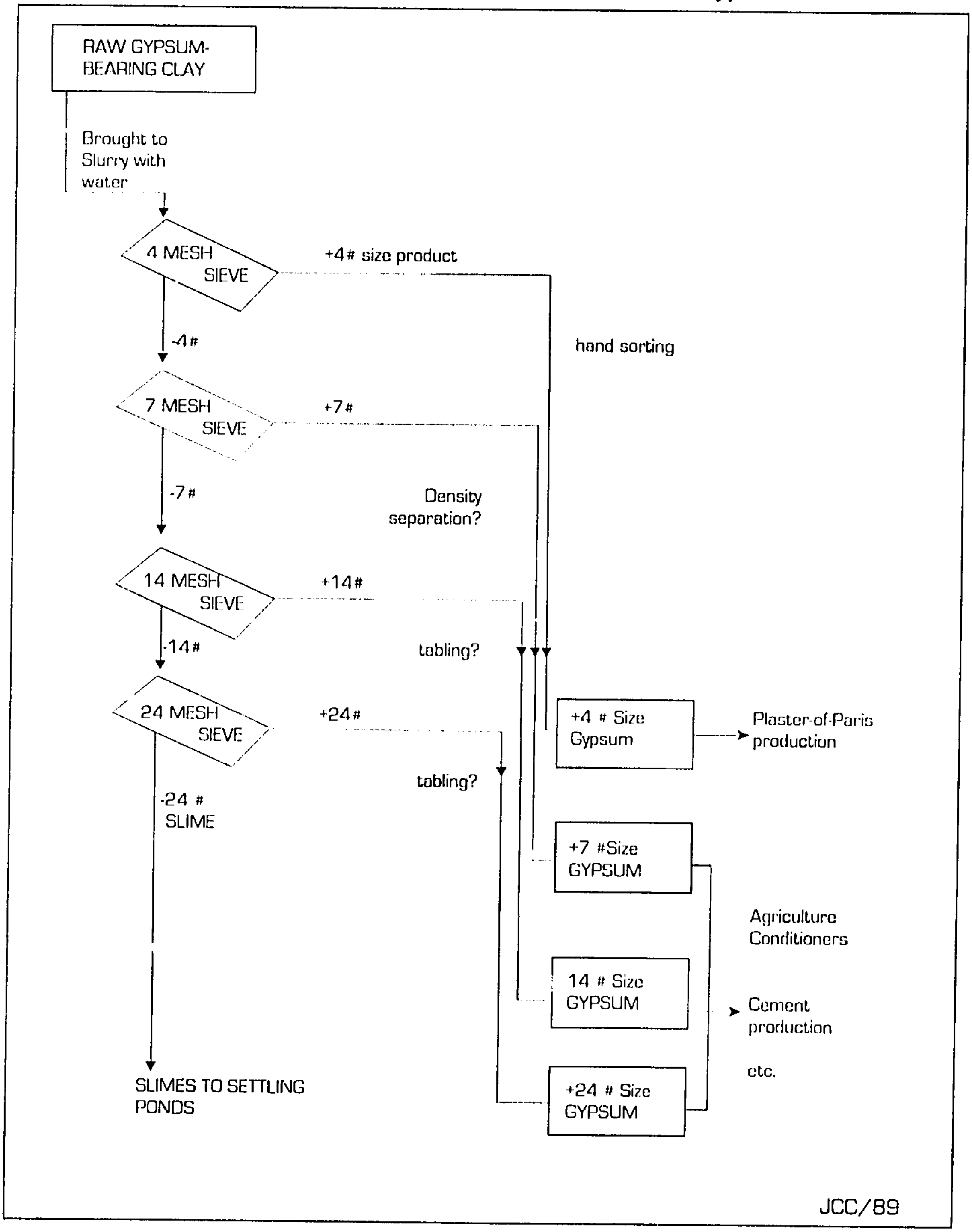
4.4 INFRASTRUCTURE REQUIREMENTS

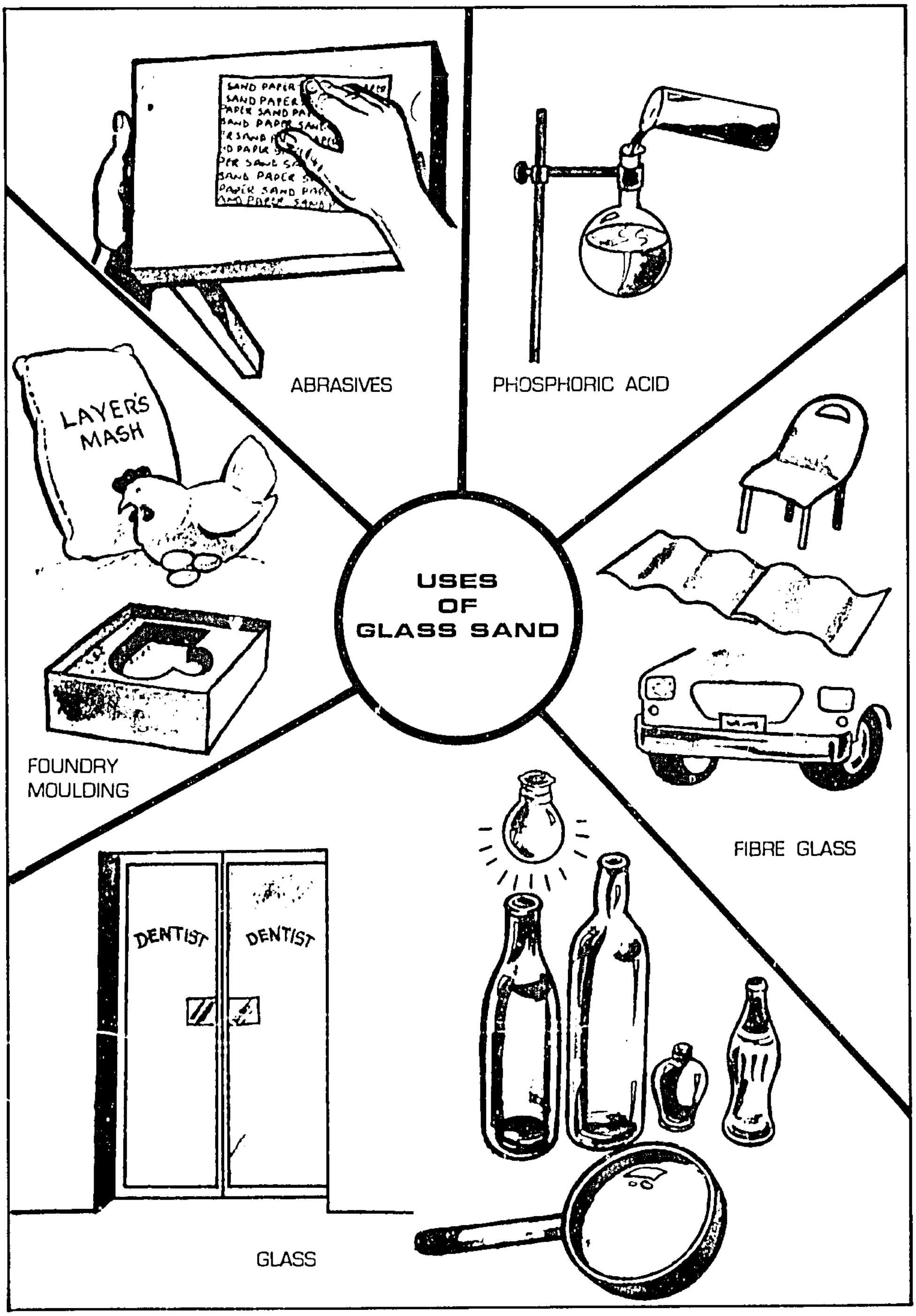
The gypsum deposits are generally located close to all-weather dirt or tarmac roads. Also, most dambo areas in the Central Region are not cultivated. This may be because of their water-logged nature, because they are livestock grazing grounds or because a Chief may have withheld permission to farm for some undisclosed reasons.

Before mining, an entrepreneur must apply for a NEPL, and be granted a Mining Claim. Required land holding for each farming family may be restricted 2 to 6 hectares in a District.

Through the Rural Electrification Programme, the electrical supply line from Kasungu to Lilongwe, via Mponela, is almost completed. Entrepreneurs who have access to this electricity source will have an opportunity to establish their own gypsum calcining plants.

Figure 5. Flowsheet for Washing Dambo Gypsum




USES OF GLASS SAND
ABRASIVES
SAND PAPER
PHOSPHORIC ACID
LAYER'S MASH
FOUNDRY MOULDING
FIBRE GLASS
DENTIST
DENTIST
GLASS

5. GLASS SAND

5.1 RESOURCES AND RESERVES

There are two large deposits of glass sand in Machinga and Mchinji Districts. The Machinga deposit occurs as the Lake Chiuta/Chirwa sand bar (Fig. 6). It is a 10-20 metre raised beach, some 40 km long. The Mchinji deposit occurs on the eastern pediment of the Mchinji Hills (Fig. 7). Many dambo areas and some swamps along streams and rivers also have accumulations of fluvial sands. Most of the sand horizons are well-developed at the heads of the dambos, close to the hills from which the sands are extracted.

The middle section of the Chirwa sand bar is fairly well-sorted, containing mainly quartz grains. Some 25 million tonnes of glass sand have been delineated in this section in Blocks A, B and C. (Fig. 8). The particle size distribution of the sand are shown in Table 5.1.

Both the western and eastern sections of the sand bar have very coarse to gravelly sand. No reserves have been delineated in these sections.

Quality of glass sand is generally classified by the size ranges of the sand and its chemical composition, particularly that of iron oxides (Fe_2O_3) and aluminum oxides (Al_2O_3). Assuming British Standards specifications, the -30+120 mesh size is preferred for most uses, including glass making. A deposit must contain at least 52 percent of the -30+120 mesh size for it to qualify as a glass sand. Also the fine fraction passing through the 120 mesh sieve should be less than 5 percent.

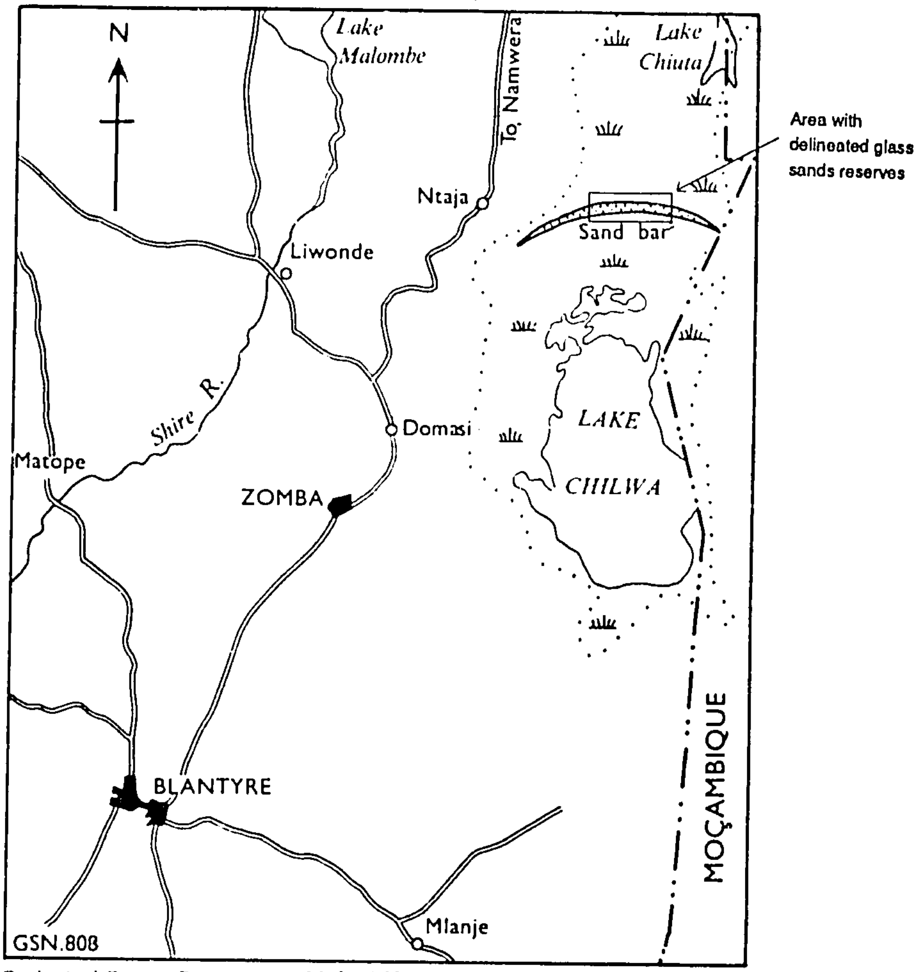
The classification of glass sands in terms of chemical composition is given in Table 5.2. In this case, the Chirwa glass sand may be regarded as 9th Quality amber, although this could be considerably upgraded by intensive beneficiation. The delineated reserves are described in Tables 5.1 through 5.3.

Table 5.1 Particle Size Distribution of the Glass Sand Deposit at Lake Chiuta/Chirwa

Block A

Sieve Size	Pit No. 7	Pit No. 8
+ 30 mesh	8.6	1.9
- 30 + 60 mesh	73.8	63.7
- 60 + 120 Mesh	15.3	30.0
- 120 Mesh	2.3	4.4

Figure 6. Location of Lake Chiuta/Chirwa Sand Bar



Geological Survey Department, Malawi 1969 RHG

Figure 7. The Mchinji Glass Sands Dambos

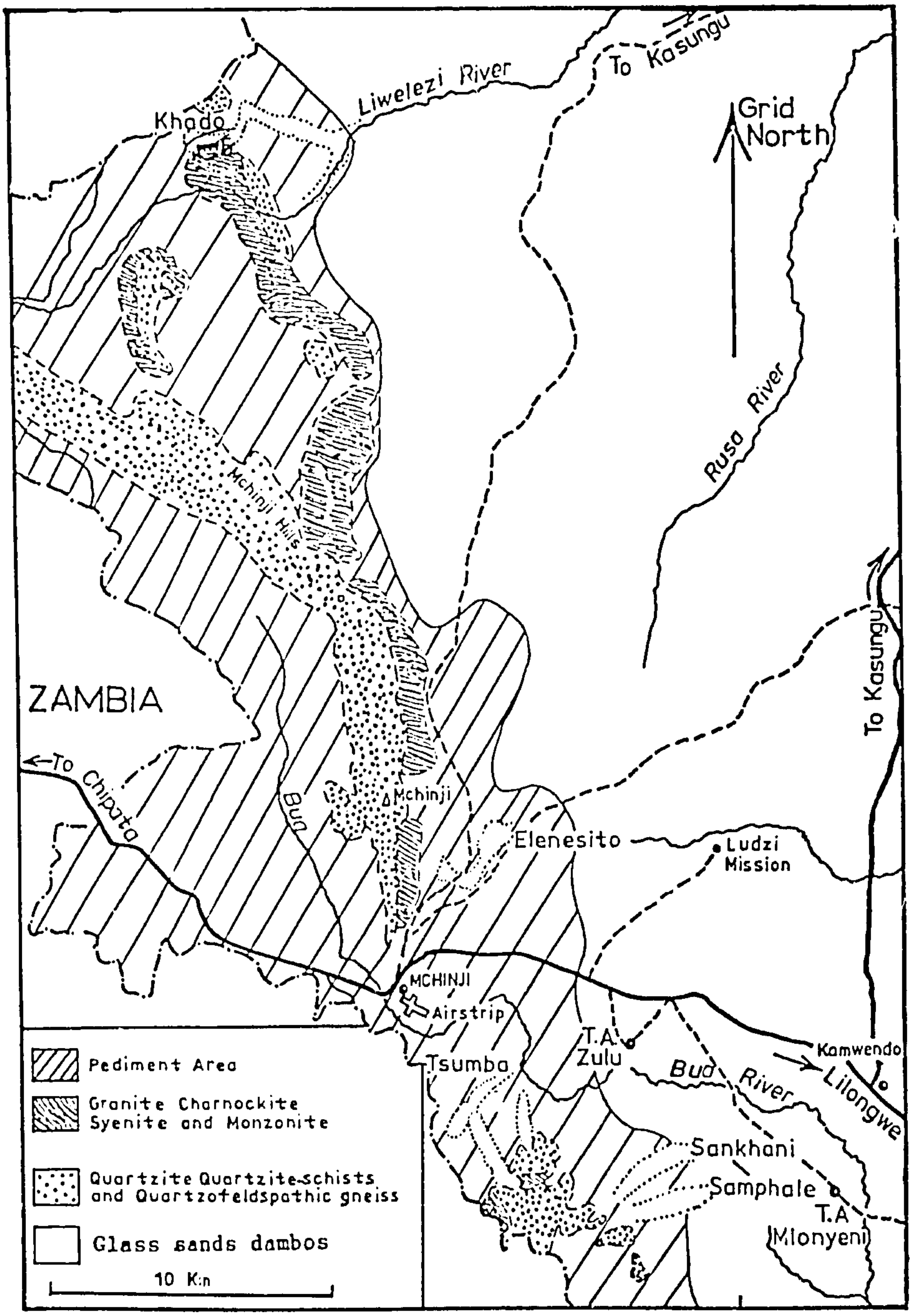
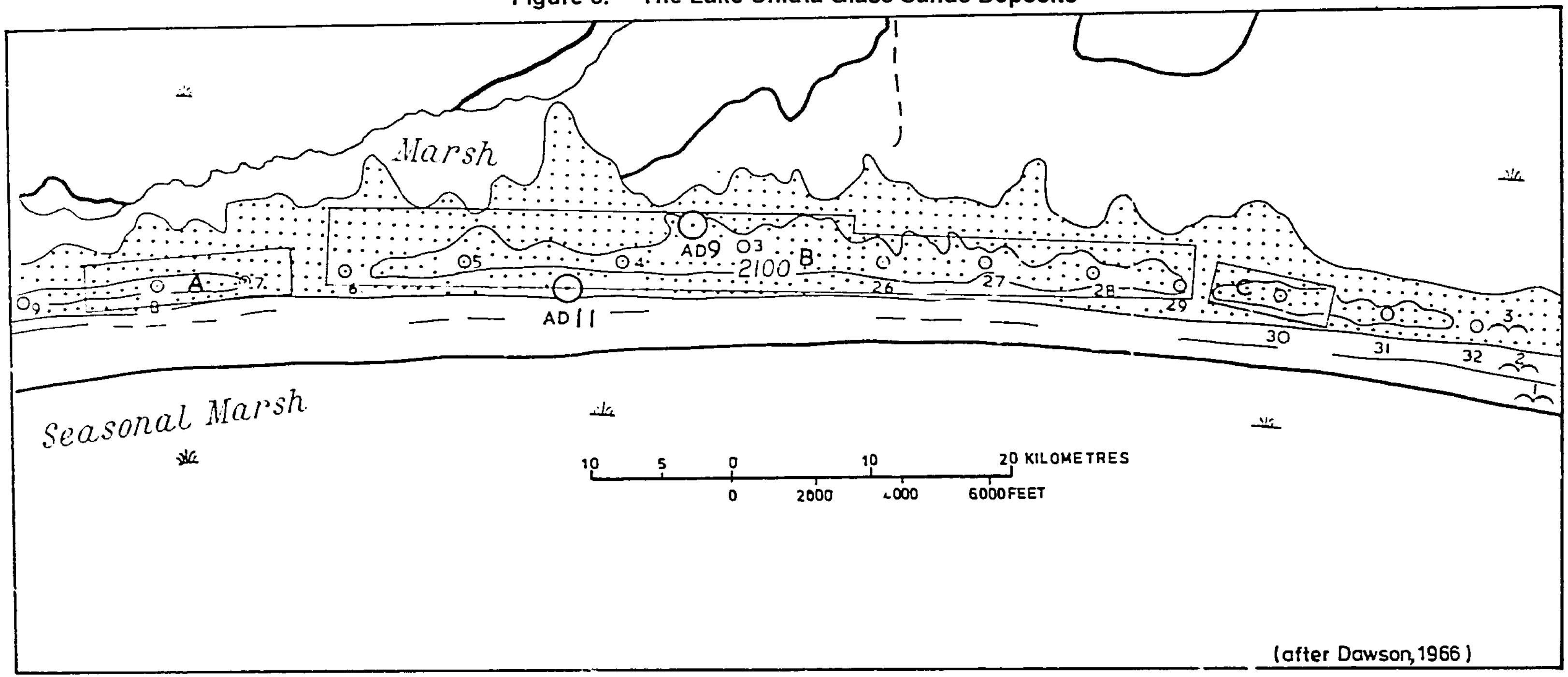


Figure 8. The Lake Chiuta Glass Sands Deposits



Block B

	Pit No.	3	4	5	6	26	27	28	29
+ 30 mesh		5.1	12.7	23.7	12.7	14.9	5.6	17.5	8.5
- 30+60 mesh		74.3	68.7	63.9	67.4	66.7	72.3	70.7	73.3
- 60+120 mesh		18.8	15.8	10.3	17.1	16.1	18.5	9.7	15.2
- 120 mesh		1.8	2.7	2.1	2.8	2.3	3.6	2.1	3.0

Block C

Sieve Size	Pit 30
+ 30 mesh	5.8
- 30 + 60 mesh	76.4
- 60 + 120 mesh	14.9
- 120 mesh	2.9

Table 5.2: Quality Classification of Glass Sands (as specified by the Ceramic Society and the National Bureau of Standards, U.S.A.)

Quality	Product	%SiO_2 min.	%Fe_2O_3 max.	%Al_2O_3 max.	%CaO/MgO max.
1st	Optical glass	99.8	0.02	0.1	0.1
2nd	Flint containers and tableware	98.5	0.035	0.5	0.2
3rd	Flint glass	95.0	0.035	4.0	0.5
4th	Sheet and plate glass	98.5	0.06	0.5	0.5
5th	Sheet and plate glass	95.0	0.06	4.0	0.5
6th	Glass containers and window glass	98.0	0.3	0.5	0.5
7th	Green glass	95.0	0.3	4.0	0.5
8th	Amber glass containers	98.0	1.0	0.5	0.5
9th	Amber glass containers	95.0	1.0	4.0	0.5

Table 5.3 **Reserves and Iron Content of the Glass Sands Deposits at Lake Chiuta**

	Tonnage	%SiO	Average FeO
Block A	3.0 million	93.3	0.40
Block B	21.0 million	94.9	0.84
Block C	1.0 million	90.0	-
Total	**25.0 million**		

The Mchinji glass and sand reserves have been located in six (6) dambos (Table 5.4).

Table 5.4 **Reserves and Iron Content of the Glass Sand Deposits in Mchinji**

Dambo	Recoverable Reserves	Average FeO %
Chimwang'ombe	128,212 tonnes	0.12
Chitapalume	95,388 tonnes	0.16
Tsumba II	134,390 tonnes	0.19
Kachusi-Thumba	185,915 tonnes	0.17
Nabviumi	36,650 tonnes	0.19
Elenesito	139,585 tonnes	0.20
Total	**720,140 tonnes**	

The dambos are essentially flat or slightly sloping at a shallow gradient. The sand occurs in layers, overlain by sandy clay horizon, with high organic matter content (roots, grasses, decomposed material). This top layer has an average thickness of 0.75 metre. The sand layer is also underlain by heavy clay horizons which in places are interbedded with hard weathered-laterite crusts (Fig. 9).

The sand is free flowing and clean except for laterite pebbles and minor dark minerals. Quartz predominates in the dambo sand, with the silicon oxide content ranging from 95.0 to 99.0 percent. The average size distributions of the sand are as follows, in Table 5.5.

Figure 9. Section of a Dambo Sand Horizon at Mchinji

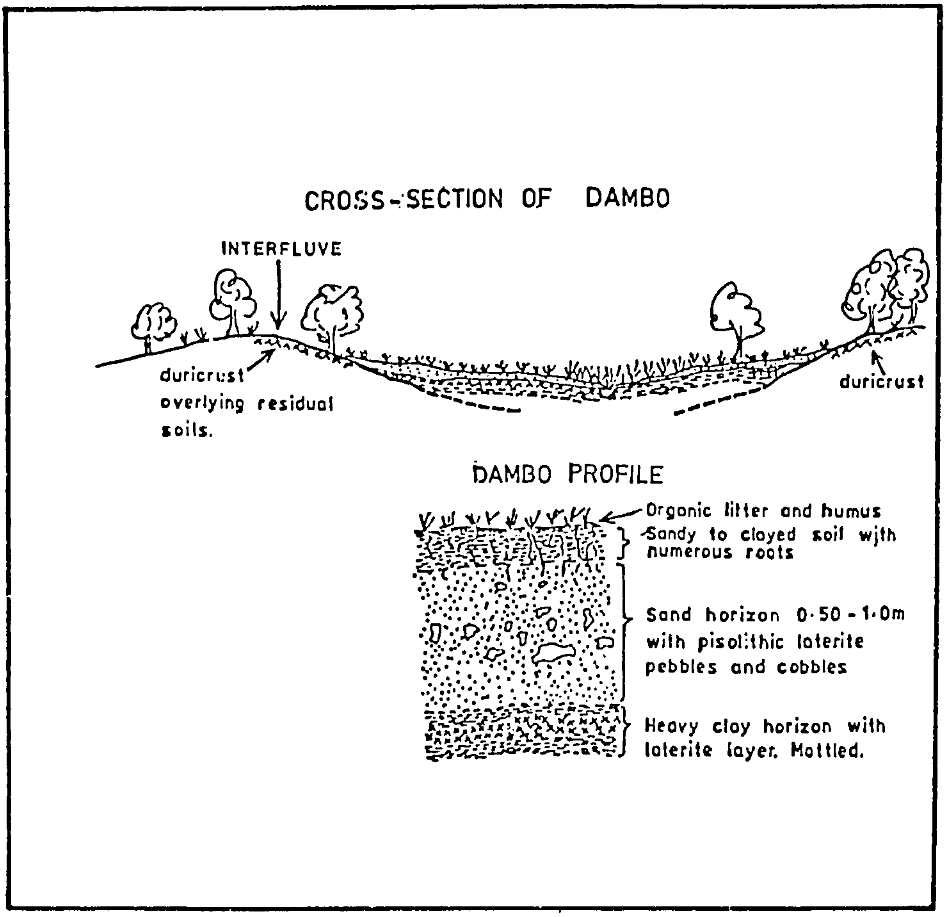


Table 5.5 **Grain Size Distribution of Dambo Sand**

Sieve Size	Percent Retained
- 120 mesh	30 percent (+ Clay)
- 60+120 mesh	30 percent
- 30+60 mesh	30 percent
- 30 mesh	10 percent

5.2 USES AND POTENTIAL DEMAND

The terms "glass sand" and "silica sand" are often used interchangeably. Glass sand is a natural raw material composed largely of the mineral "quartz", a "silicon oxide (SiO_2). Since quartz sand usually makes up 60-80 percent of glass, its quality essentially controls the technology of manufacturing and quality of glass. The important properties of glass sand are:

— Grain Size (affects the course of melting): The preferred size range is 0.1 - 0.3 mm, i.e. about 130 to 52 mesh size, although - 30 + 120 mesh material is widely utilized.

— Chemical Composition (determines the quality of the glass): Fe_2O_3 content (iron oxide) content must not exceed 0.040 percent for clear container and sheet glass, 0.013 percent for colorless glass and 0.008 percent for optical glass (see also Table 5.2).

Industrialized countries are the major consumers of silica sand. There exists a vigorous international trade of silica sand in both North America and Western Europe. The following is a list of ways in which sand is utilized:

— Foundry sand
— Glass manufacturing (including glass fibre)
— Smelter flux
— Refractory brick mixes, cements
— Artificial abrasives
— Metallurgy
— Chemicals
— Gypsum products
— Fertilizer, stock poultry feed
— Ceramics, frits (glass materials) and enamels, paper and paper products, and roofing material.

Table 5.2 shows glass sand quality classifications as specified by the Ceramic Society and the U.S National Bureau of Standards.

Silica sand is specified for foundry use because of its resistance to thermal shock. Silica sand is preferred over zircon, chromite and devine for use as foundry sand mainly because it is plentiful in most countries. For use in iron foundries a minimum SiO_2 content of 85 percent is required, while for steel foundries the silica content required should be at least 95 percent.

Specifications for foundry sands include silica content, particle size distribution and grain shape. Size distribution is defined by the AFS (American Foundrymen's Society) Number which is calculated by the following method:

1. A known weight of sand is passed through a series of sieves.
2. The proportion retained on each sieve is multiplied by a specific factor for that sieve.
3. The products obtained for all sieves are totalled, and divided by 100 to give the AFS No. In the U.K., a new system is being introduced for the "Average Grain Size" Number (AGS). The sieve factors are as follows in Table 5.6.

Table 5.6 **Sieve Factors**

Aperture size of sieve (mm)	AFS Factor	AGS Factor
+ 1.000	10	1180
0.700	16	1180
0.500	22	600
0.355	30	425
0.250	44	300
0.180		212
0.125	85	150
0.090	120	106
0.063	170	75
0.063	300	38

In Malawi, there is a growing demand for glass sand in foundries. The Malawi Iron and Steel Corporation (MISCOR) and Engineering and Foundry Co., both based in Blantyre, have been mining their own requirements on the Chilwa Sand Bar and at Mchinji. Their annual requirements are about 10 (ten) tonnes. There is also a potential demand for glass sand from other companies; such as, Brown and Clapperton, Petroleum Services Limited and Namig'omba.

Figure 10. Mchinji Sand Mining Trial. (Plan View)

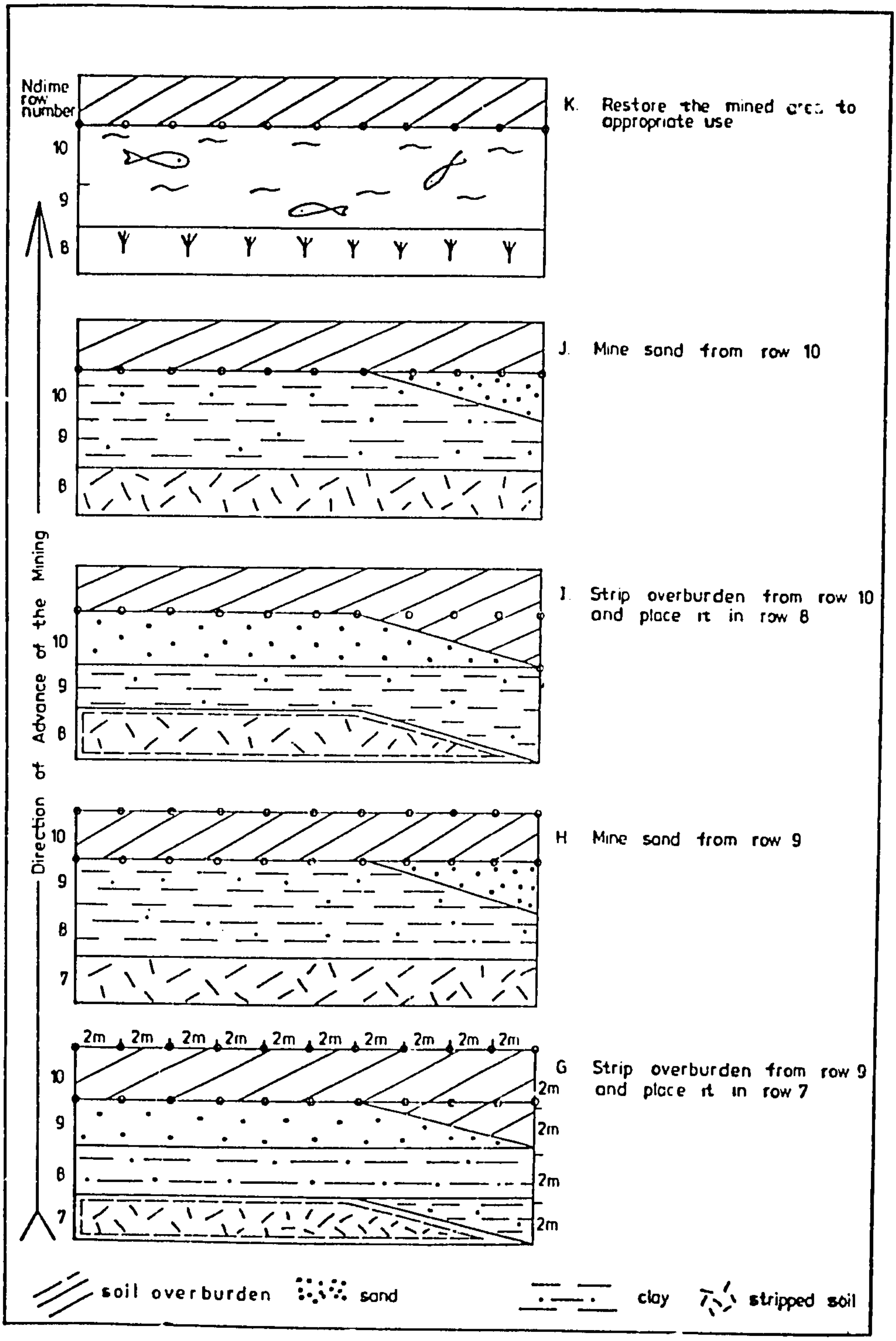
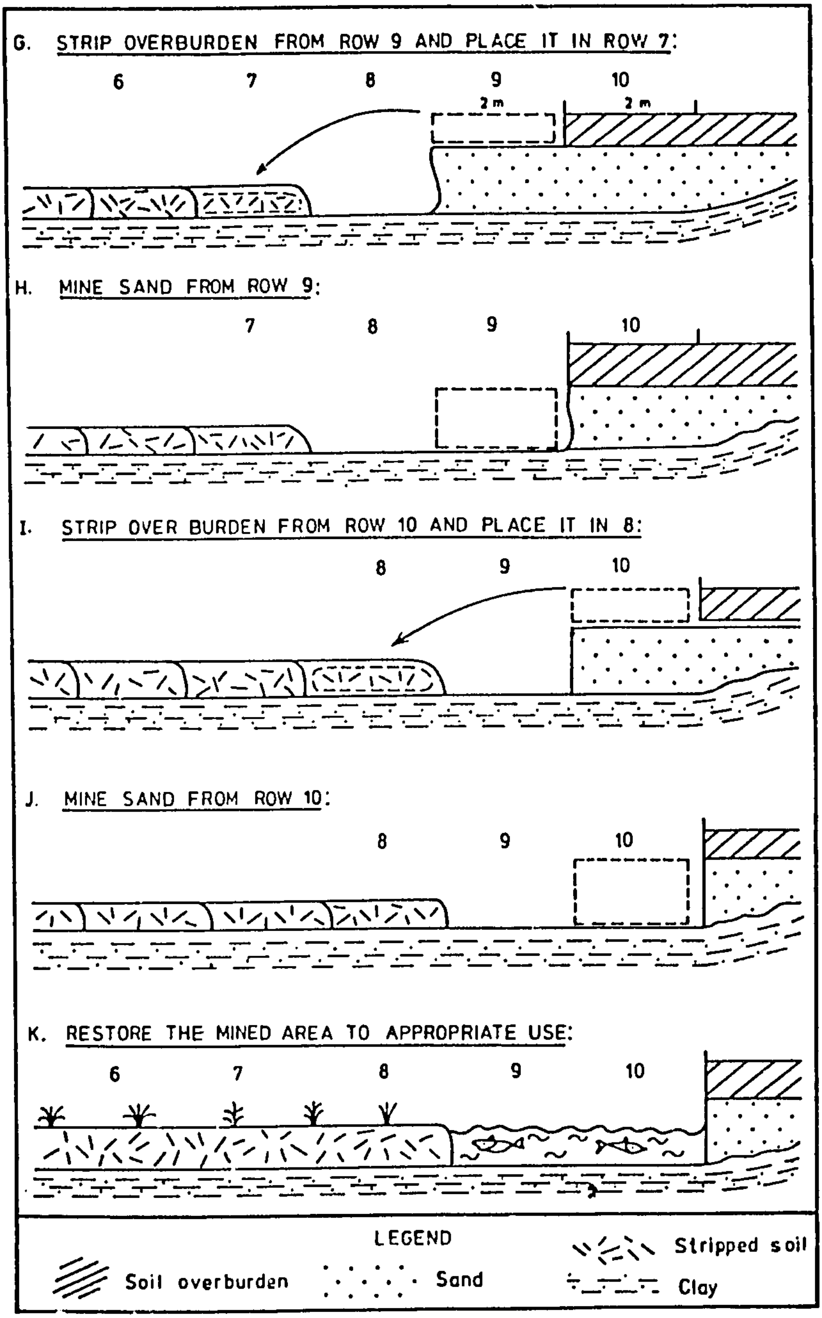


Figure 11. Mchinji Sand Mining Trial. (Cross-Section View)



Other potential users of glass sand in Malawi are producers of poultry feeds, water boards (for water filtration), furniture workshops (silica sand is used for "sand paper") and ceramic ware producers. These are comparatively small outlets for silica sand; their requirements should be easily met by small scale mining and processing entrepreneurs.

5.3 MINING AND PROCESSING

The glass sands of Mchinji were used by the GSD in the early 1980's in efforts to develop a mining procedure that would be labor intensive. The mining trials at Mchinji were repeated on the gypsum deposits near Mponela with equivalent results. The "Mchinji Mining Techniques" can be applied at all surface deposits which are comparatively soft, and for depths not exceeding 3.0 metres. The Mchinji mining trial sequences are illustrated in Figs. 10 and 11.

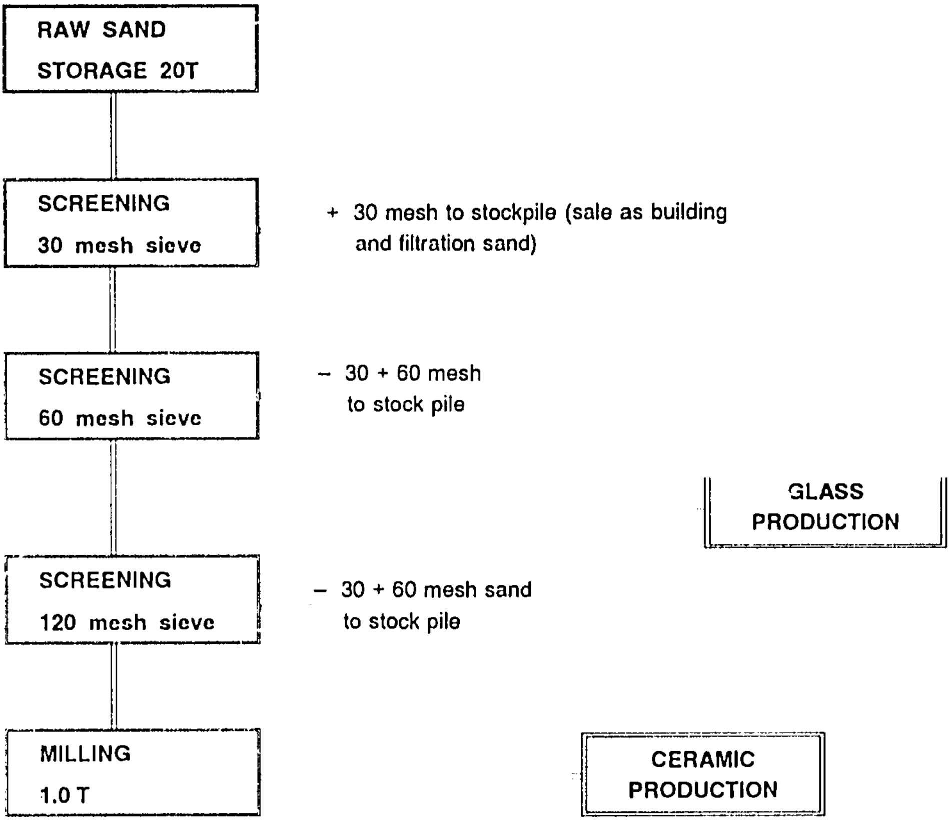
Sorting sand to the various grain sizes is done by washing and screening as shown on the flowchart in Fig. 12. For finer products such as silica flour, it is recommended that ball mills be used, with volume ranges of 5 litres to 50 litres depending on demand. There is already some demand for fine silica (some 20 kg per month) in the existing pottery works at Dedza.

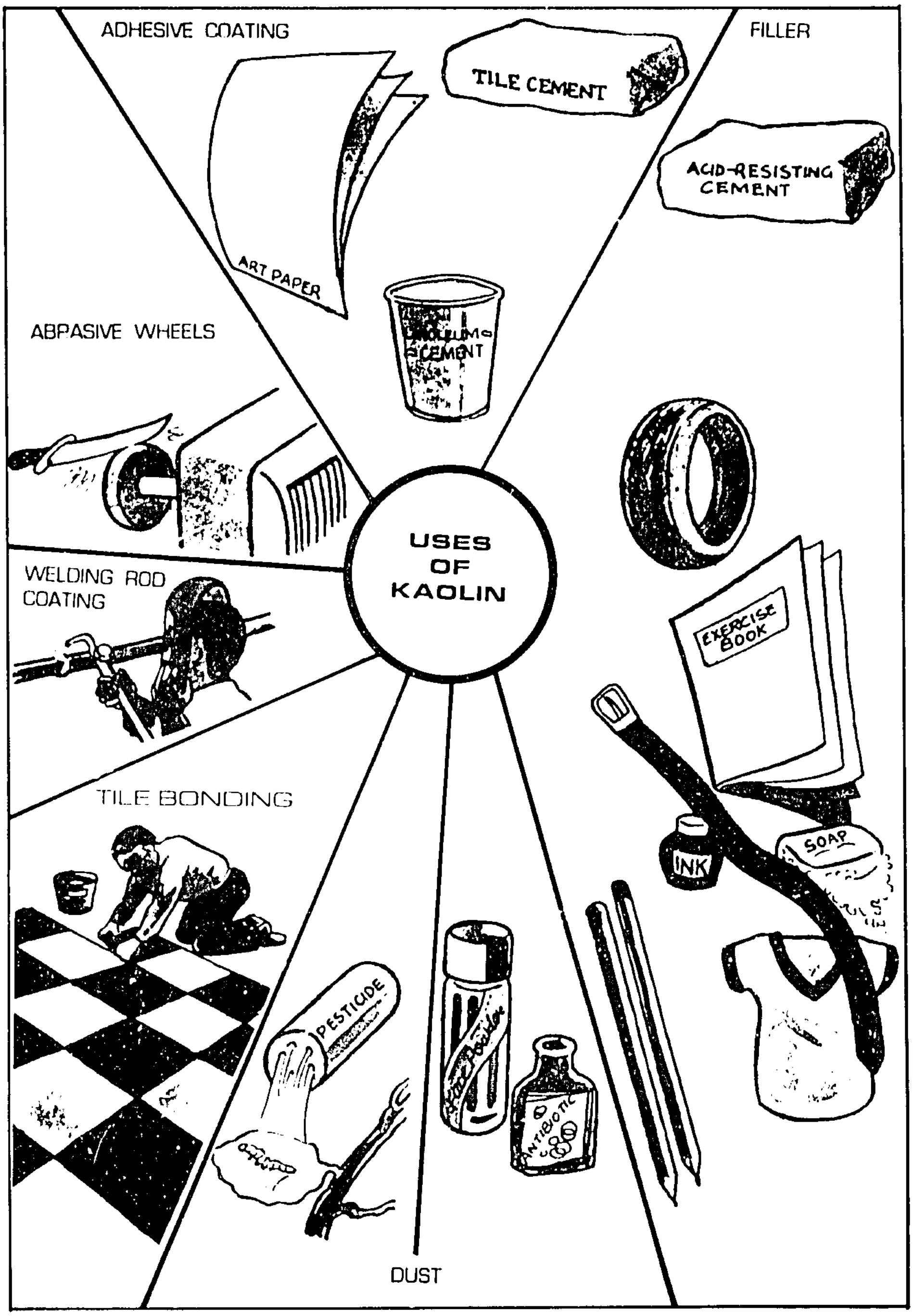
5.4 INFRASTRUCTURE REQUIREMENTS

The Chirwa/Chiuta glass sand deposit lies near the Liwonde-Nacala railway line. The most cost-effective procedure for exploiting this deposit would be to undertake mining and screening at the mine site. The -30+60 and -60+120 mesh grades of the sand would then be transported to Liwonde by rail. Further processing of the sand at Liwonde could be partly- mechanized as there is electricity and abundant water for partially automated cleaning and screening. Chirwa sands are preferred for foundry operations as they are close to Blantyre and may also possess a natural binder in the fines. It should be noted that the railway also follows the sand bar, hence a significant portion of the deposit may already be under the control of the railway authority.

There is electricity, an abundance of water and good access to both by road and rail at the Mchinji sand deposit sites. The dambos are normally not under cultivation, hence they could be brought under mineral rights without too many complications. However the rest of the land bordering the dambos is well-cultivated, and access to it will require the consent of the customary land owner. This may not be too difficult if employment is offered to the villagers.

Figure 12.   Flow Diagram for Glass Sand Sreening and Milling




ADHESIVE COATING
FILLER
TILE CEMENT
ACID-RESISTING CEMENT
ART PAPER
ABPASIVE WHEELS
USES OF KAOLIN
WELDING ROD COATING
EXERCISE BOOK
TILE BONDING
INK
SOAP
PESTICIDE
ANTIBIOTIC
DUST

6. KAOLINITIC CERAMIC CLAYS

6.1 RESOURCES AND RESERVES

Kaolinitic clays are the natural raw materials utilized in the production of ceramic ware and refractories. Known resources in Malawi include:

— Linthipe in Dedza, 40km from Lilongwe on the MI Road (Fig. 1[illegible];
— Nkhande, 3 to 5 km from Ntcheu Boma on the Road to Lilongwe;
— The headwaters of the Rivi-Rivi River in Ntcheu District;
— Senzani Village, towards Ntonda in Ntcheu District
— And the banks of the Chiula River, about 3 km east of Kaseye Mission, Chitipa District.

Only the Linthipe deposit has been extensively investigated as it is the largest and most strategically located in terms of access, availability of water supplies and geological continuity over wide areas.

The Linthipe clays were formed by the weathering of feldspar-rich (anorthosite) rocks. They are especially rich in silicon (Si) and aluminium (Al), hence they have high Aluminium to Silicon ratios which contribute to the refractory and ceramic characteristics of the clays.

There are over 14 million tonnes of kaolinitic clays at Linthipe, which have been delineated as shown in Fig. 13 and Table 6.1. They occur near the surface as residual clays, thinly covered by grey "makande" top soil. The ratio of waste (top soil) to ceramic clay averages about 1:6.

Table 6.1 **Reserves of Kaolinitic Clays at Linthipe (Density taken as 1.86 tonnes/m3)**

BLOCK	AREA (km^3)	OVERBURDEN THICKNESS, (m)	CLAY THICKNESS, (m)	RESERVES TONNES x 10^6
1	3.5	0.2	0.7	4.6
3	1.7	0.2	0.8	2.6
4	1.0	0.2	1.3	2.4
5	1.0	0.3	1.7	4.5
Total/Average	**7.6**	**0.225**	**1.1**	**14.1**

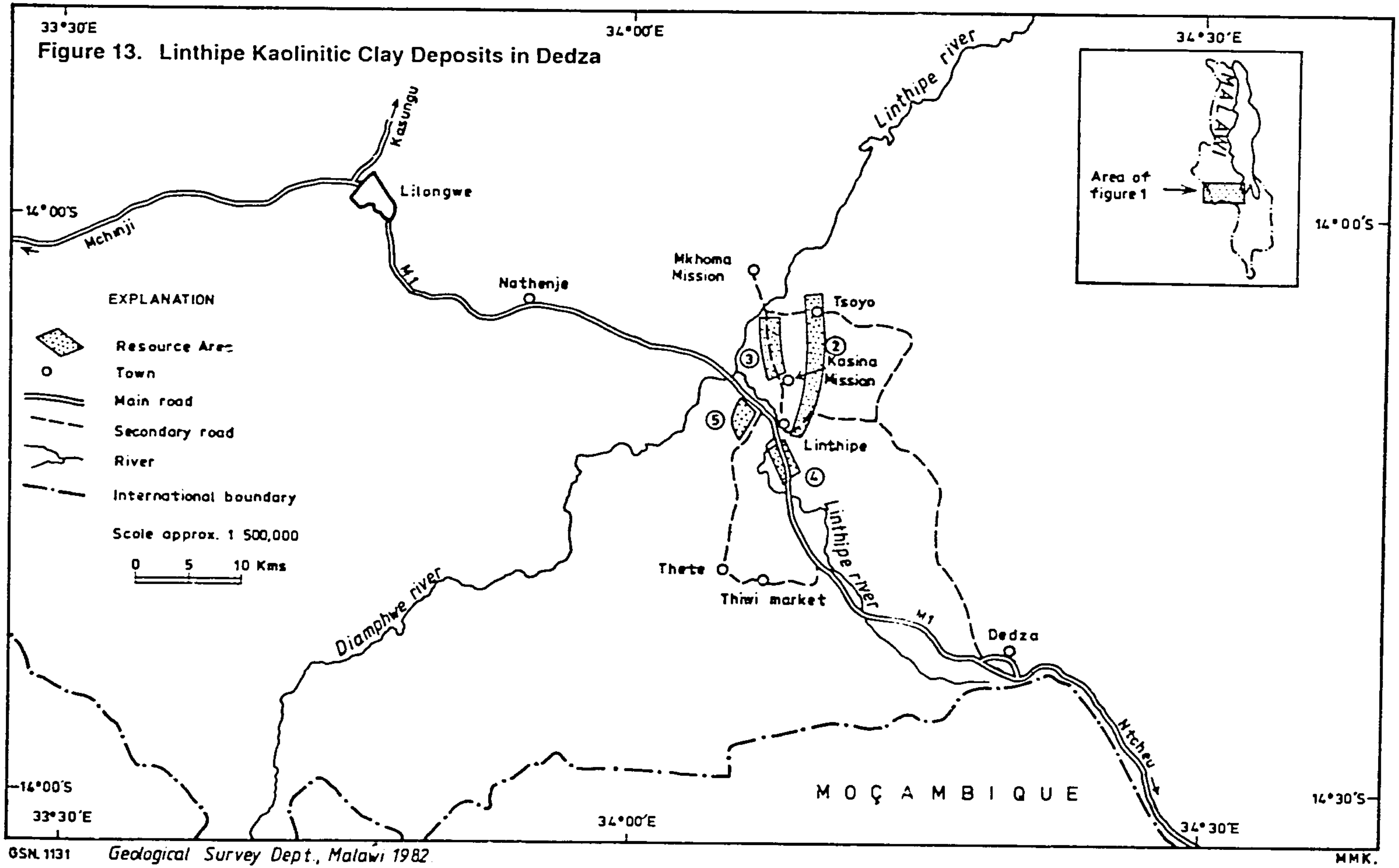


Figure 13. Linthipe Kaolinitic Clay Deposits in Dedza

The clays are generally pale-grey to buff in color and are very plastic. They occur on crests and gentle upper slopes of broad interfluves.

These clay resources are characterized as being ceramic and refractory by the following parameters:

- chemical composition,
- particle size distribution,
- plasticity as an indication of the workability of the clay, and
- ceramic characteristics.

The chemical composition of some samples from the resource blocks at Linthipe are given in Table 6.2.

Table 6.2: Chemical Analysis of Linthipe Clay and Equivalent Ceramic Clays from Europe, USA and South Africa

Percent Oxide	Sam.# 1	Sam.# 2	Sam.# 3	Sam.# 4	Sam.# 5	Sam.# 6	Sam.# 7	Sam.# 8	Sam.# 9
SiO_2	46.55	47.78	46.75	45.55	44.0	58.1	46.4	50.5	47.2
Al_2O_3	34.06	34.68	33.27	33.05	33.0	23.1	35.0	34.0	35.99
TiO_2	-	-	-	-	-	1.4	0.7	1.7	-
Fe_2O_3	1.07	1.73	1.60	3.59	1.1	2.4	1.1	2.3	1.19
CaO	1.45	1.63	1.11	0.26	0.35	0.8	0.3	0.4	0.54
MgO	0.21	0.31	0.28	0.23	0.09	1.0	0.1	0.5	0.21
NaO	0.39	0.60	0.39	0.07	2.19*	0.3	0.8*	0.2	-
K_2O	0.21	0.23	0.28	0.14		1.9		0.7	1.19
LOI	10.18	10.09	11.01	13.64	18.0	10.5	15.6	11.2	13.00

* Combined total of NaO and K_2O
LOI = loss-on-ignition

These are analyses of:

1. Buff to white plastic kaolinitic clay, Linthipe Block 1 (LPA 208)
2. Grey plastic kaolinitic clay, Linthipe Block 3 (LPA 318-1982)
3. Mottled grey-to-white plastic clay, Linthipe Block 4 (LPA 520)
4. Light grey, stained brown, plastic clay, Linthipe Block 5 (LPA 466)
5. English China Clay, Devon (Hywite Atlas)
6. Plastic fireclay, Lawrence Ohio, U.S.A.
7. Bonding clay for refractories, Limburg, Germany
8. Average Scottish fireclay
9. Fireclay from Olifants-Fontein, South Africa

Particle size distributions of the clay are summarized in Table 6.3.

Table 6.3 **Cummulative Particle Size Distribution of Linthipe Clays (Percent Cummulative)**

Percent Passing Sieve Size	LPA Samples				Bulk Sample		
	208	318	520	466	Block 1	Block 3	Block 5
2 mm	99.7	99.2	99.8	98.1	-	-	-
500 um	95.8	96.5	99.6	96.8	100.00	100.00	100
250 um	85.4	84.4	97.3	95.9	n.d	n.d	n.d
63 um	70.9	66.8	79.9	92.6	60.6	65.2	77.1
10 um	64.1	57.7	71.0	83.6	51.7	55.9	69.0
2 um	50.9	47.4	59.2	56.4	39.7	44.1	58.8

n.d - not determined
um - micron

Plasticity is generally defined in a qualitative manner, in terms of:

- "Liquid Limit (LL)": the moisture content at which a soil mass will begin to flow when jarred slightly.
- "Plastic Limit (PL)"; the minimum moisture content at which a soil mass can be rolled into threads 3 mm in diameter without crumbling to pieces. (Both limits are expressed as percent by weight of soil dried at 105°C)
- "Plasticity index (PI)": the arithmetic difference between LL and PL. It is a measure of the range of moisture contents over which soil mass is in a plastic state.

The Linthipe clays consist principally of clay minerals of the kandite (kaolinite) group. The proportion of kaolinite in the raw clays ranges from 60 to 88 percent of material that is finer than 63 ***microns*** (um). This also indicates that most of the fine clay (63 um fraction) is kaolinite (see Table 6.3). The Si_2O and Al_2O_3 contents conform to compositions of commercial ball clays and fireclays in Europe and South Africa. The clays are very plastic, with PI between 24 and 41 percent. The wide variations in PI are the result of variable contents of non-clay minerals.

Due to the high proportion of fines, the Linthipe clays tend to have high linear firing shrinkages (Table 6.4), ranging from 5 to 13 percent, when the clays are fired at 1100°C to 1250°C, respectively.

However, as silica sand and feldspar fillers are added to the clay, the shrinkages reduce significantly.

Table 6.4: Linear Firing Shrinkage of Clay Briquettes Fired at 1100°, 1180° and 1250°C

Sample No. LPA	Percent Shrinkage at			Composition of Ceramic Body
	1100° C	1180° C	1250° C	
520	7.08	9.94	12.37	Raw, 100% Linthipe clay
520 (a)	1.07	1.60	2.90	Added 25% feldspar, 25% sand
520 (b)	1.07	1.86	2.23	Added 25% feldspar, 35% sand 25% anorthosite

In all cases, a porous, fired-ware was produced. However, in the case of raw clay the ware often displayed conditions of crazing and cracking.

In summary, the Linthipe clays are high alumina, refractory clays. They are very plastic, with material finer than 63 microns accounting for more than 65 percent of the clay. Hence, the clays are not, on their own, suitable for pottery purposes. However, with mixtures of at least 50 percent non-clay fillers (silica sand and Ca-feldspar), the workability properties improve significantly for the production of pottery. Additionally, the incorporation of these fillers results in the reduction of shrinkage.

6.2 USES AND POTENTIAL DEMAND

The Linthipe kaolinitic clays have mineralogical, chemical and physical characteristics comparable to ball clays and fireclays. They have a chemical composition and refractoriness (stable at 1750°C) that likens them to firebrick. They can therefore be utilized in the manufacture of the following refractory products:

- firebrick and blocks of many shapes
- ceramic electrical insulators
- refractory mortars, grog and crude aggregates.

Additionally, the clays, after suitable processing and incorporation of fillers and fluxes, are a high quality component for the production of stoneware and earthenware.

There is a potential demand for processed kaolinitic clays in Zimbabwe and Zambia. There have been a number of enquiries for the commodity from these countries, however, there has been no indication of the quantities required.

The demand for Linthipe clays for the pottery and refractory business has been growing. Two Blantyre companies use the clay for production of refractory bricks in smelting recycled steel and cast iron, and as a bonding clay in foundry sands. Dedza Potteries Limited uses the clays for producing various types of pottery.

There is a potentially large market for Linthipe clays in the urban areas, particularly Blantyre and Lilongwe, however, most industries are not aware of the useful properties of the clay.

6.3 MINING AND PROCESSING

The Linthipe clays are generally overlain by top-soils averaging 0.2 metres thick. The kaolinitic clays are stiff and plastic, some 0.7 to 1.7 m thick. Although few village settlements are on the clay deposits, the surrounding countryside is densely populated.

The clay deposits are therefore well suited to small scale mining, using the "Ndime" mining method described in the Glass Sand Section. This is essentially crude strip-mining, in the following stages:

Stage 1 — The top soil is stripped on unit plots each with 2.0 m x 2.0 m surface dimensions.
The top soil is stockpiled at the back (opposite from the direction of advance of mining)

Stage 2 — The kaolinitic clay is mined and hauled to a loading area, outside the planned mining block, then clay is transported to the processing area.

Stage 3 — Top soil is then spread over the mined "ndimes" before re-starting Stage 1 on new section.

No studies have been undertaken on the viability of rehabilitating the mined-out areas. Hence, there is need for an Environmental Impact Assessment before extensive mining activities are promoted.

Extensive research has been carried out by the Geological Survey Department regarding clay processing. There are two basic techniques of processing, both appropriate for small scale entrepreneurs.

Processing Method 1:

— Clay is soaked in 5-10 liter plastic pails until it "sours" (about 10 days).

— "Sour" clay mixture is then washed:

- All clay is churned into suspension, then allowed to settle for a pre-determined time.
- At the end of such time, all clay remaining in suspension is decanted.
- The decanted clay is dried before storage for future use in the production of pottery or refractors.

Processing Method 2:

A "Clay Washing Plant" (Fig. 14) is built of burnt bricks and plastered with Portland Cement.

— "Soured" clay is mixed with water in Tank A, and churned into suspension. The clay is then allowed to settle for a pre-determined time. The procedure as in Method 1 is repeated through Tanks B, C, and D.

— This method allows production of large amounts of processed clay in a given unit time. Secondly, processed clays of varying particle sizes may be extracted for specific applications.

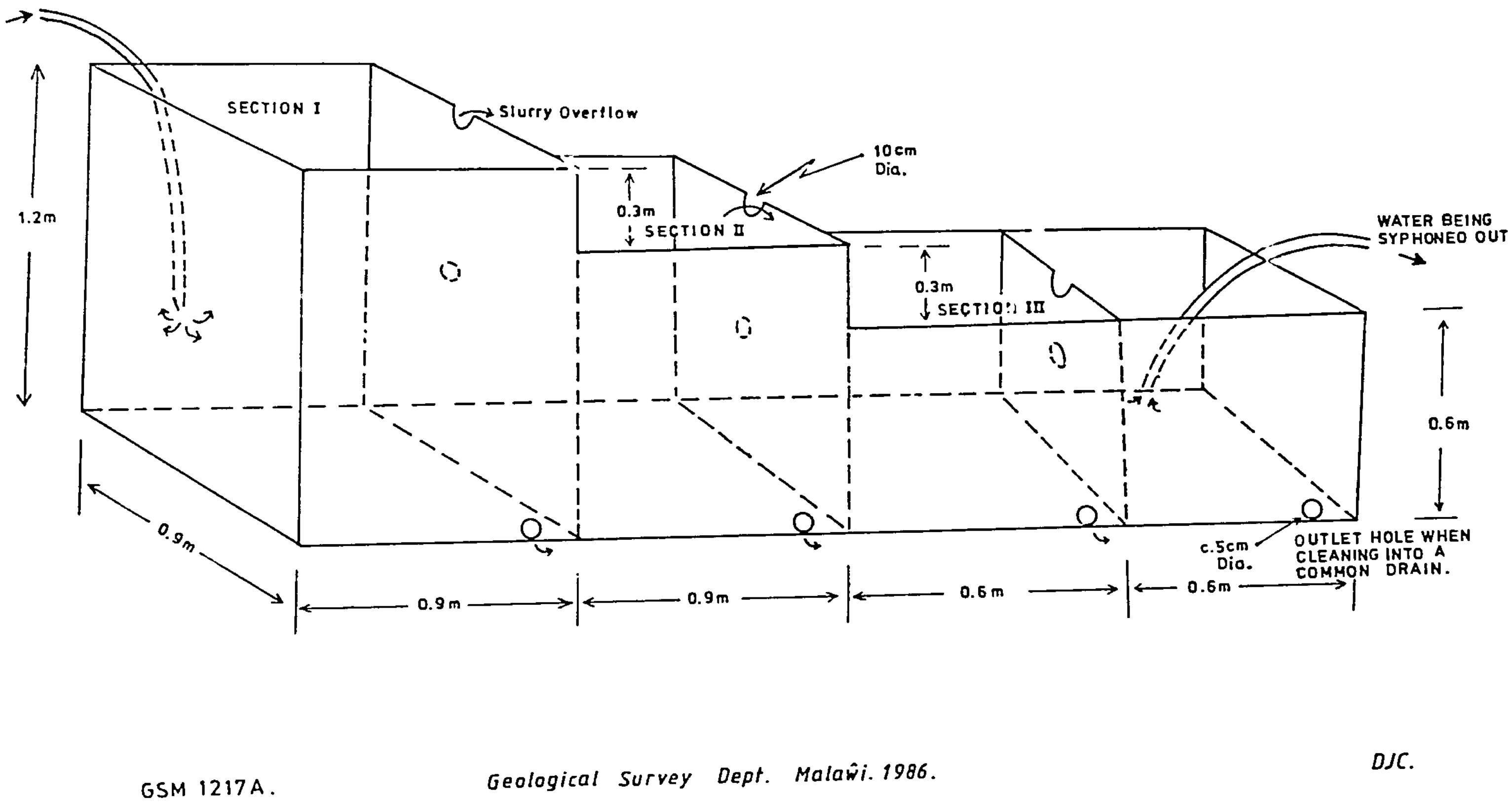
6.4 INFRASTRUCTURE REQUIREMENTS

All the Linthipe clay deposits are close to the M1 Road and are easily reached by good secondary dirt roads. The Linthipe and Diamphwe Rivers have adequate flow throughout the year. However, withdrawal of water by villagers from these rivers has been increasing in the last decade, hence, there is a likehood of more restrictions on rates of abstraction by the Water Resources Board.

The clay deposits are generally surrounded by densely settled villages, but most of the resource areas have not been sterilised by settlements. For small scale mining operations, the most appropriate licence would be the annual "Mining Claim", which would entitle the miner to 2 hectares of holding. The law permits a miner to have up to 6 hectares of Mining Claims, hence the entrepreneur could have claims on three separate Blocks, to have sufficient material to allow for blending.

A 33000 KV ESCOM power line ends at Mtendere turn-off, some 16 km from Linthipe Village.

Figure 14. Clay Washing Plant



In summary, the major capital cost elements would be the following:

Land :

— 6 hectares Mining Claims
— 0.25 hectares factory site
— Land rent and licence fees

Mining Equipment:

— Hoes
— Picks
— Shovels
— Wheel barrows

Processing and Firing Equipment:

— Construction of "Clay Washing Plant"
— Hydrometers
— Clay mixing equipment, (Blungers and Jiggers), etc(Optional)
— Potters' Wheels
— Slipcasting Molds
— Kilns (coal-fired and/or electrical)

Buildings:

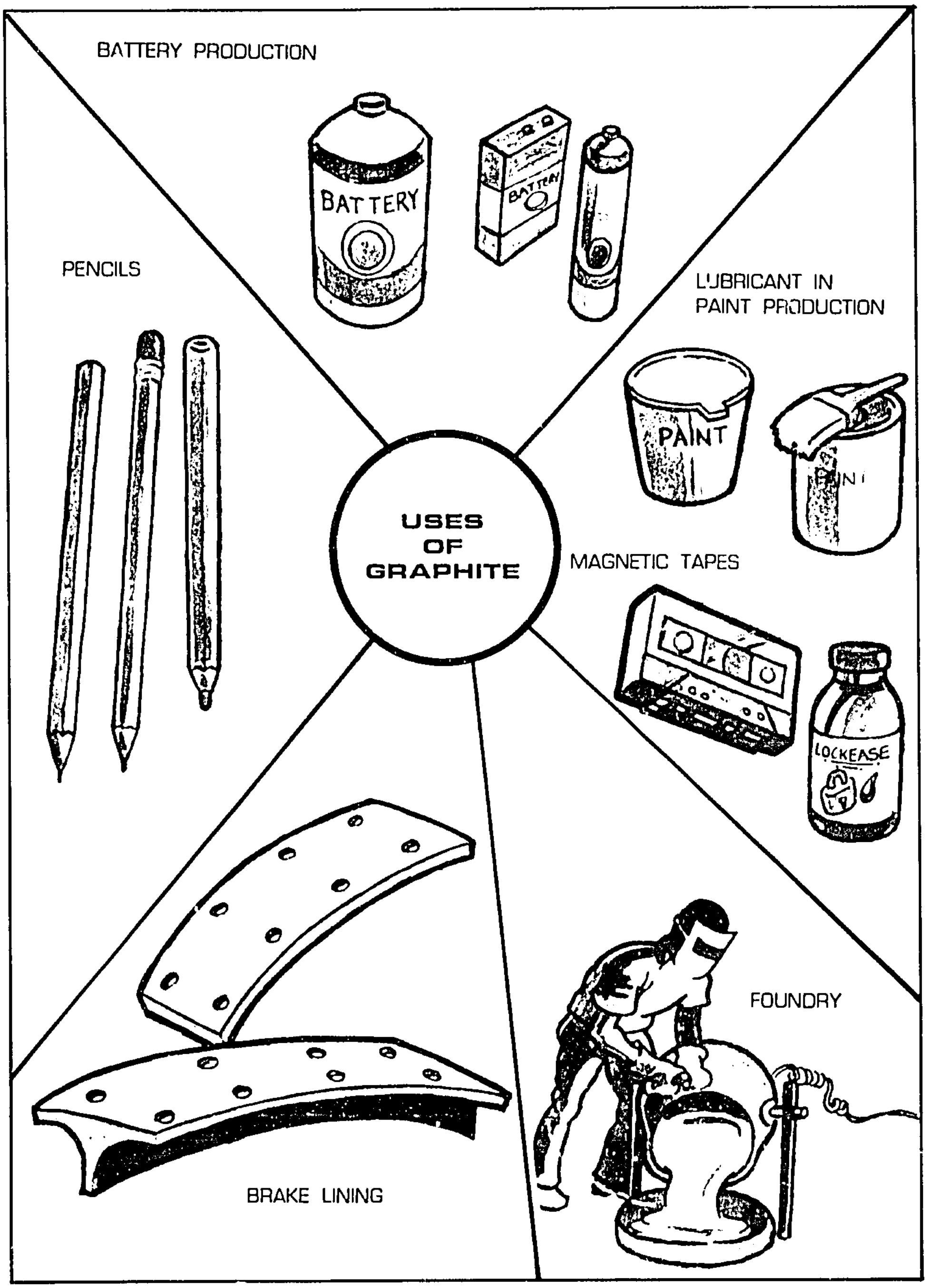
— 10m x 20 m workshed
— 50 m^3 clay storage bunkers and shelter
— 10 m^3 souring ponds (assuming processing method 2)
— 20 m^3 waste settling ponds
— 10m x 10 m air drying slabs

Electricity (optional):

— Extending power line from Mtendere turn-off to Linthipe, about 16 km

Water Supply

— Water tanks
— Pipes
— Pumps


BATTERY PRODUCTION
BATTERY
PENCILS
LUBRICANT IN
PAINT PRODUCTION
PAINT
USES
OF
GRAPHITE
MAGNETIC TAPES
LOCKEASE
FOUNDRY
BRAKE LINING

7. GRAPHITE

7.1 GRAPHITE CLASSIFICATION

Graphite (that is "natural" graphite) is composed entirely of elemental carbon as a crystallized mineral. In world trade natural graphite is divided into two groups: *"amorphous"* and *"crystalline."* The term "amorphous" is not strictly correct, as all graphite is crystalline, none-the-less, this group defines that graphite which is soft, black and has an earthy appearance. In contrast, the "crystalline" variety is normally flaky with a grey metallic lustre.

The crystalline graphite is further sub-divided into *"flake"* graphite of which (the bulk of the particles) do not pass through a 150 micron mesh) ; and *"vein"* graphite (mostly lumps chips and dust).

There is increasing demand in the world market for graphite, especially of the crystalline variety. It is in fact a strategic mineral resource in a number of industrialized countries because it is resistant to attack by ordinary chemical agents. Graphite is chemically inert and stable at ordinary temperatures. Graphite is an excellent conductor of heat and electricity. It melts at very high temperatures (over 3500°C), therefore it is stable in most high-temperature applications. Furthermore, it is characterized by an extremely low coefficient of friction and has a useful slippery feel.

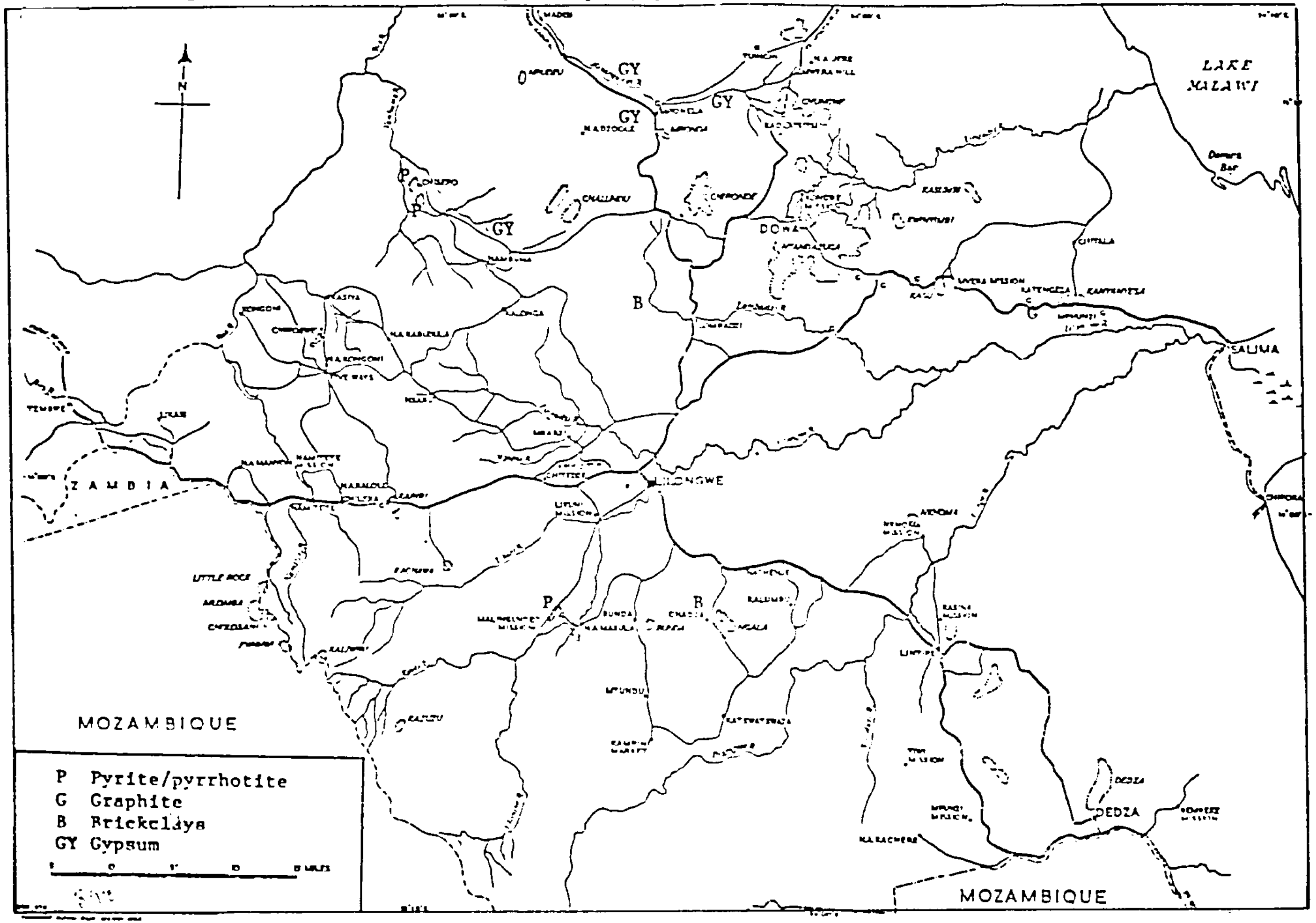
The world production of natural graphite was some 604,000 tonnes in 1984, and the forecast at that time was for increased production.

7.2 RESOURCES IN MALAWI

Occurrences of natural graphite have been recorded at many locations throughout Malawi. Natural graphite commonly occurs in gneissic rocks in a flaky form. Generally the outcrops are of limited extent, hosting resources measuring in tens of tonnes of ore and often of low grades. However, such resources are suitable for small mining operations provided there is demand. The major obstacles to mining efforts have been the lack of knowledge of demand for graphite for export and local use, lack of technological and marketing know-how, and lack of appropriate investment.

Most of the graphite deposits that have been investigated in some detail are in the Central Region of Malawi (Fig. 15). One of these, the Katengeza deposit, has been extensively evaluated.

Figure 15. Occurrences of Graphite, Pyrite/Pyrrhotite, and Brickclay Resources in Central Malawi



The flake graphite deposit at Katengeza, in Dowa District is on the M5 Road approximately 29 km from Salima (Fig. 16). It occurs in quartzo-feldspathic graphite gneisses and schists, and has well-formed flakes between 0.25 mm and 1 mm in diameter. The graphite is mostly enriched in the decomposed (weathered) gneisses rather than in the residual soils. This means that some crushing of the rock will be necessary to liberate the graphite. The section of the deposit that has been assessed is some 2300 m long and 100 m wide. The reserves of graphite are estimated to be 29,300 tonnes, grading 4.2 percent carbon on an ore horizon of 1.98 m.

The particle size distribution analysis shows that 63.2 percent of graphite is retained as a fraction coarser than 250 microns (0.25mm) (Table 7.1). This has a mean head assay of about 75 percent, which is within international specifications for a crucible-grade flake graphite.

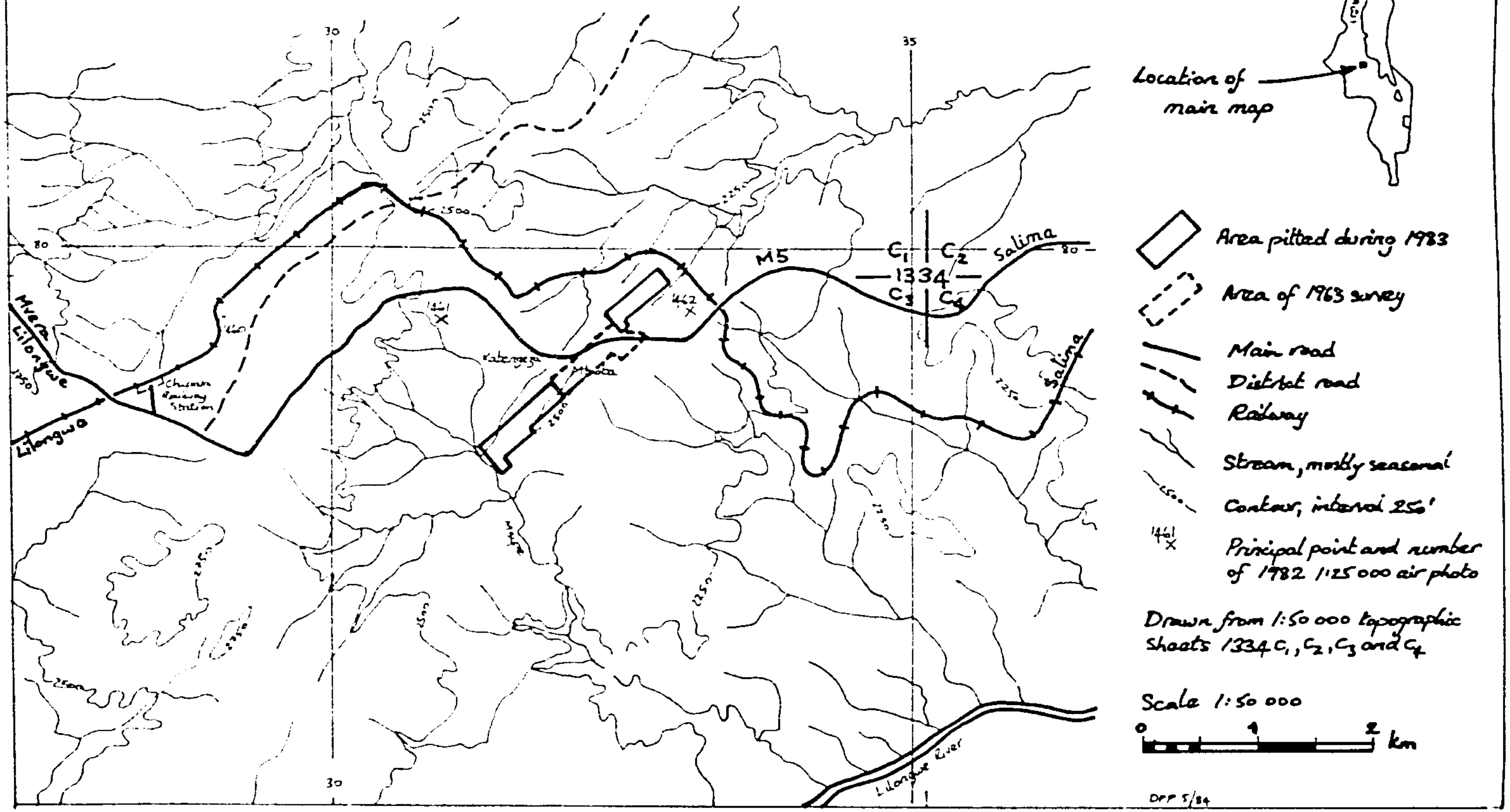
Table 7.1 Comparison of Mean Carbon Assay and Particle Size Distributions for Bulk Samples at Katengeza

Percent Retained on Sieve Size	Mean Contribution to Head Assay		Mean Particle Size Dist. (percent of + 63 um)	
	Percent Carbon (fraction)	Percent Carbon (cumulative)	Percent Total Wt. (fraction)	Percent Total Wt. cumulative)
+2 mm	1.0	1.0	4.1	4.1
+1 mm	4.8	5.8	7.1	11.2
+0.50 mm	30.6	36.4	24.6	35.8
+0.25 mm	38.4	74.8	27.4	63.2
+125 um	18.6	93.4	22.8	86.0
+63 um	6.6	100.0	14.0	100.0

7.3 USES AND POTENTIAL DEMAND

Graphite is an international commodity - a strategic mineral in some countries such as the U.S.A. It has a wide spectrum of uses due to its broad range of chemical and physical characteristics. It resists attack by chemical reagents, is infusible in most common fluxes, has a high melting point of 3650°C, and vaporizes at 4500°C hence its continued use in the manufacture of crucibles and other refractories for the manufacture of metals. It has a low coefficient of friction and its unctuous, or slippery, feel makes it useful as a lubricant, as an ingredient in paints and in foundry facings. The less pure grades, with lower carbon contents, are suitable for use as a recarburiser in steel production. Other uses are:

Figure 16. The Katengeza Graphite Deposit



GSM 1193G Geological Survey Department Malawi 1986

- production of batteries
- brake linings
- carbon products including bearings and carbon brushes
- crucibles, retorts
- foundries (lining in moulds, etc)
- lubricants including paints,polishes, insulation, magnetic tapes etc
- pencils
- powdered metals
- refractories
- rubber

The Malawi flake graphite has a definite export potential. More detailed assessments should also be made on the numerous deposits that are known in the Central Region. The small flakes such as those at Katengeza would find a market in the manufacture of lubricants.

In Malawi, there are potential uses of graphite in the following areas:

- battery production
- metal casting by MISCOR, Engineering Foundry Ltd, Petroleum Services, Brown and Clapperton
- paint manufacture by Dulux, Valmore
- pencil manufacture
- lubricants

7.4 MINING AND PROCESSING

Extraction of the graphite ore would be a simple quarrying and fossicking operation. The enriched zones can be easily delineated by eye, then mined as required. However, a rational mining plan would be imperative to minimize environmental damage and sterilization of payable ore.

Processing would be most productive if carried out at the site of mining in view of the low grades of graphite. The Department of Mines is planning to start a pilot project at Katengeza for a small scale processing operation.

7.5 INFRASTRUCTURE REQUIREMENTS

The Katengeza graphite deposit is favorably situated with respect to transportation. The deposit straddles the M5, Lilongwe-Salima road, about 29 km from Salima and some 5 km from Chipala Railway station. It is also close to the Lilongwe-Salima electricity powerline.

8. GEMSTONES AND ORNAMENTAL STONES

8.1 RESOURCES

Gemstones generally encompass diamonds, gem corundum, gem beryl, agates, amethyst and many other stones. The following are regarded as ornamental - sodalite, black granite, pink granite and some metamorphic marble. Districts where these stones are known to occur are given in Table 8.1.

Table 8.1: Districts with Gemstone and Ornamental Stone Occurrences

1. Gemstones

	Chikwawa	Mulanje	Zomba	Machinga	Ntcheu	Mzimba	Chitipa	Mchinji
Ruby					x			
Sapphire					x			
Aquamarine						x		
Amethyst					x	x	x	
Jade				x				
Tourmaline					x	x		
Smokey Qtz		x	x					
Rose Quartz				x	x	x		
Sunstone					x			
Agate	x							

2. Ornamental Stones

	Chikwawa	Mulanje	Zomba	Machinga	Ntcheu	Mzimba	Chitipa	Mchinji
Blk Granite								x
Sodalite			x	x		x	x	
Marble				x	x			

(Marble is also found in Nsanje, Blantyre and Rumphi.)

Almost all the gemstones are exported, especially to Europe and U.S.A.

8.2 POTENTIAL DEMAND

There has been a relatively strong growth in the gemstone mining sector in Malawi. This is a direct result of the introduction of the Mines and Minerals (Reserved Minerals Licence) Regulations (Government Notice No. 99 of 27th September, 1985). Principally, these regulations separated the responsibilities of a buyer of gemstones from those of a miner. There was, for the first time, no need for a buyer to obtain a mining licence. Instead, a potential buyer was only expected to obtain a Reserved Minerals Licence which entitled him to purchase stipulated gemstones throughout Malawi, and obtain an Export Permit to export such stones.

The result of this liberalization of legislation was the application and granting of many licenses in 1986 and 1987. In 1987, the following licences were granted:

- 106 NEPL's issued for gemstone prospecting (compared to less than 10 in 1985).
- 7 mining claims for gemstones (as opposed to one in 1985).
- There was one Mining Licence for M.D.C. to mine rubies and sapphires at Chimwadzulu, in Ntcheu District.

In 1987, the volume of exports of gemstones was as summarized in Table 8.2.

Table 8.2: Exports of Gemstones in 1987

Gemstone	Weight exported in gms
Sapphire	423.74
Ruby	4434.03
Aquamarine	11809.6
Tourmaline	1435.9
Amethyst	14253.9
Sustone	2220
Jade	260
Smoky Quartz	44900

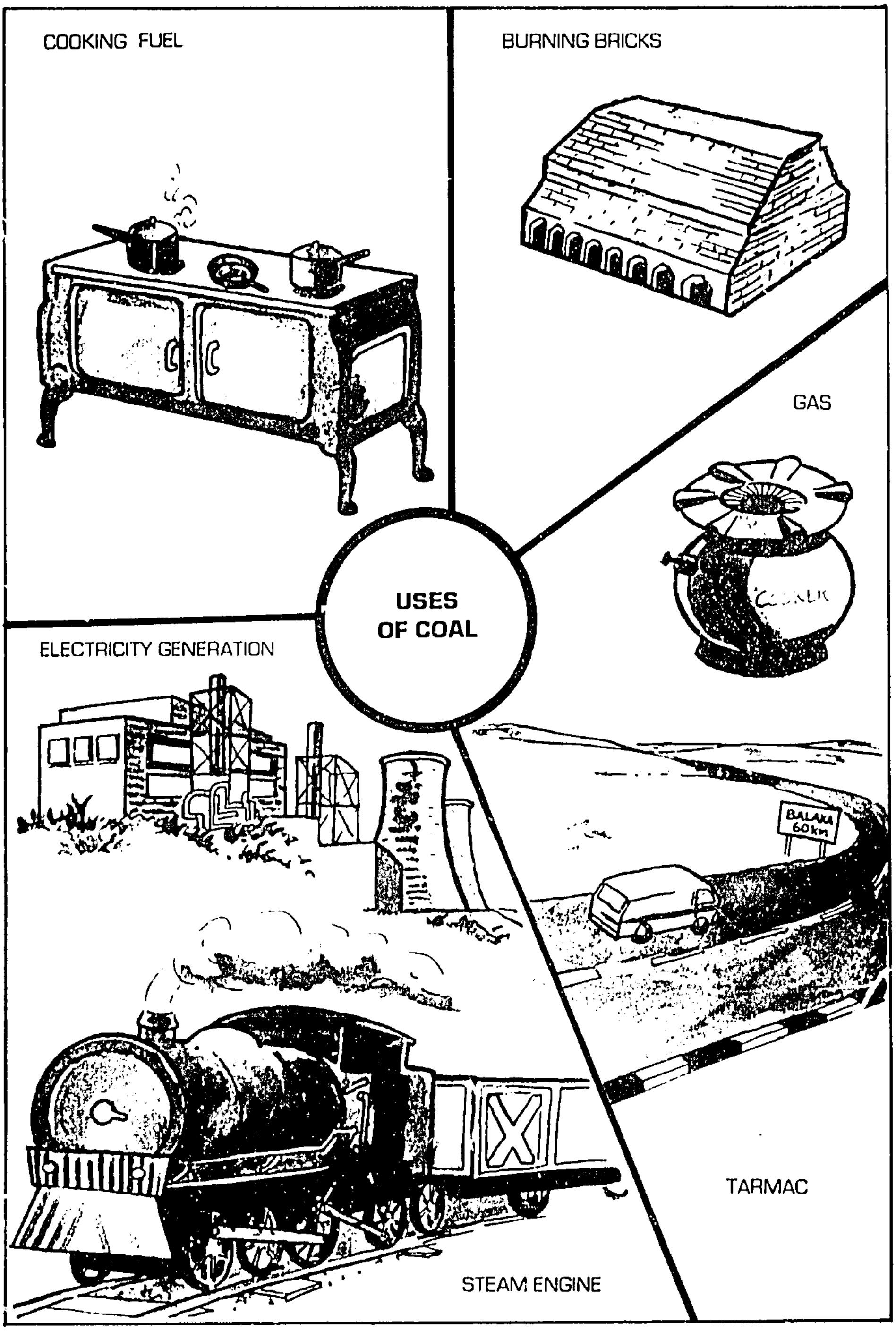
The total value of the exports was K45,205.93 in 1987; there are no records for the value of exports in 1986 and 1985.

The overall international forecast is that the demand for gemstones will continue to grow in Europe, North America and Japan. In the U.S.A., there is a strong trend toward the purchase of natural rather than treated stones. There is an urgent need, therefore, to

introduce better ways of marketing Malawian stones.
Similarly, there is growing demand for ornamental stone, especially dimension stone. Malawi has large resources of "black granite" in Mchinji and sodalite syenite in Chitipa. Both have strong export potential, but they remain unassessed and unexploited.

8.3 MINING AND CUTTING OF STONES

The mining of gemstones is largely by trenching and fossicking by small scale miners. The demand for gemstones has given mining an incentive to expand operations, particularly in Mzimba and Ntcheu Districts. The establishment of local gem cutting and polishing businesses could improve the "value added" potential of the stones.


COOKING FUEL
BURNING BRICKS
GAS
USES
OF COAL
ELECTRICITY GENERATION
BALAKA
60km
TARMAC
STEAM ENGINE

9. COAL

9.1 RESOURCES AND RESERVES

All the coal resources located so far in Malawi are found in sedimentary rocks of the Permian Period (some 200 million years ago). They unconformably overlie the Precambrian metamorphic basement rocks. Most of the rocks are similar in age to the Karroo sedimentary system of South Africa (Table 9.1). However, the Malawi Karroo sediments were deposited in trough-like basins, in contrast to the South African deposits which are found on a stable, platform-like basement.

The Karroo sedimentation was preceded by tectonic upheavals. Sediments were laid on flood plains and in fresh water lacustrinal (lake) and fluvial (river) environments in temperate weather, possibly during receding ice age climates. This accounts for the high ash contents in most southern African coal measures.

Malawi coals are largely sub-bituminous to bituminous, high ash, highly volatile and very low sulphur coals. Locations of the coalfields are given on Figs. 17, 18 and 19. Basic information regarding the main coalfields is given below (Table 9.2). For many years the ash content has posed a major constraint in the utilization of these coals, specifically as a steam-raising fuel for boilers. However, technological advances are finally making it possible to use such coals for electricity generation and steam-raising.

The coal resources of Malawi are described by 3 categories which conform to international convention.

- "Proven" *reserves* are those where coal has been delineated by drilling at depth in an accurately surveyed block of ground.
- "Possible" *resources* are those whose continuity has at least been mapped on outcrop, and geological inferences at depth merit a very high degree of confidence.
- "Probable" *resources* are those inferred on the basis of broad geological extrapolations from limited observed outcrops and data, and the existence of a favorable geological host rock (i.e Karroo sedimentary rocks). Although the assumed extent of such resources is speculative, it is based on experience of comparable data in the same environments.

The size of these resources, as revised in 1988, are given in Table 9.3.

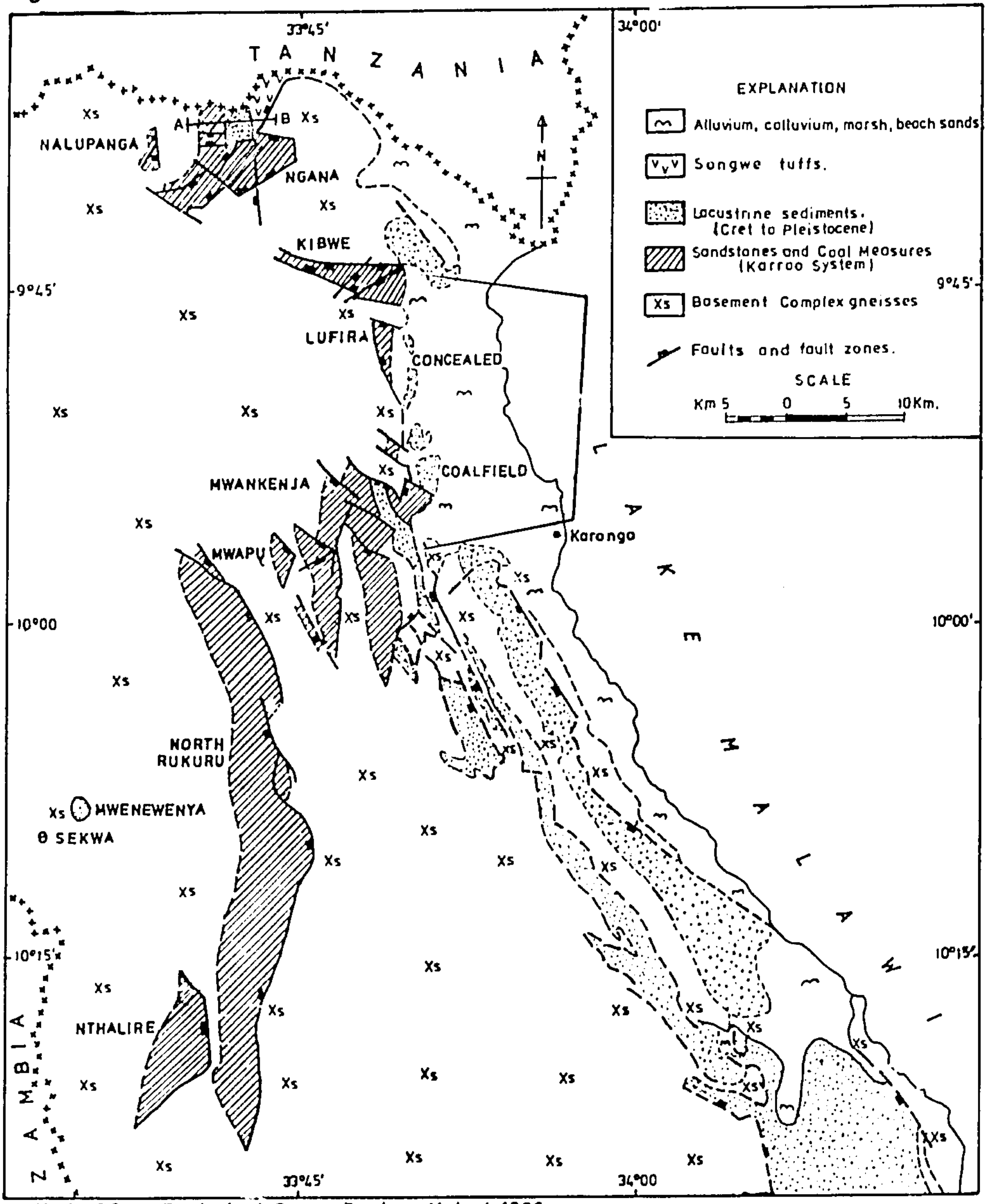
Table 9.1 Correlation of the Karroo Sequences in Malawi with those in Neighbouring Countries

	NGANA, MALAWI	LIVINGSTONIA, MALAWI	LENGWE, MALAWI (Southern Coaltiled)	RUHURU, TANZANIA	UPPER LUANGWA VALLEY, ZAMBIA	SOUTHERN AFRICA	
						Series	System
U. Trias/ Rhaetic Upper Triassic			Basalt Lavas (1070) Red Sandstones (152)	K8. Manda Beds and Upper Bone Bed (134)	Upper Grit (915) Red Marl (70-122) Ntawere Fm (122-1070+)	Stormbe.g	UPPER KARROO
Upper Permian		Chiweta Grits (46)	Upper Sandstones (610)	K7. Kingori Sandstones (370)	Escarpment Grit (70-213+)		
	Lupumba Beds (280)	Chiweta Beds (260) Calc. Siltstones (122) Mudstones (305)	Red Beds (305) Shales (915)	K6. Lower Bone Beds (92)	Upper Madumabisa Mudstone (610)	Beaufort	LOWER KARROO
Lower Permian	Ndamutakwa Beds (470)	Arkosic Siltstones (18) Green Mudstones (90) Arkoses (145)	Lower Sandstones (1220)	K5. Ruhuru Beds (213-305)	Lower Madungisa Mudstone (915)		
	Ngana Coal Measures (15-90) (Upper shale Member with coal seams)	Coal Measures (30-170)	Coal Formation (610) Basal Beds (?)	K4. U. Coal Measure (102) K3. Intermed. Sandstones and Mudstones (137) K2. L. Coal Measure	Luwumbu Coal Formation	Ecca	
Upper Carb.	Kapembe Basal Beds (107-460)	Basal Beds (0-76)		K1. Basal Beds (515)		Dwyka	

Thicknesses in brackets, in metres

Geological Survey Dept. Malawi MMK.

Figure 17. Coalfields of Malawi - Karonga Sector



GSM 1140C. Geological Survey Dept. Malawi, 1988.

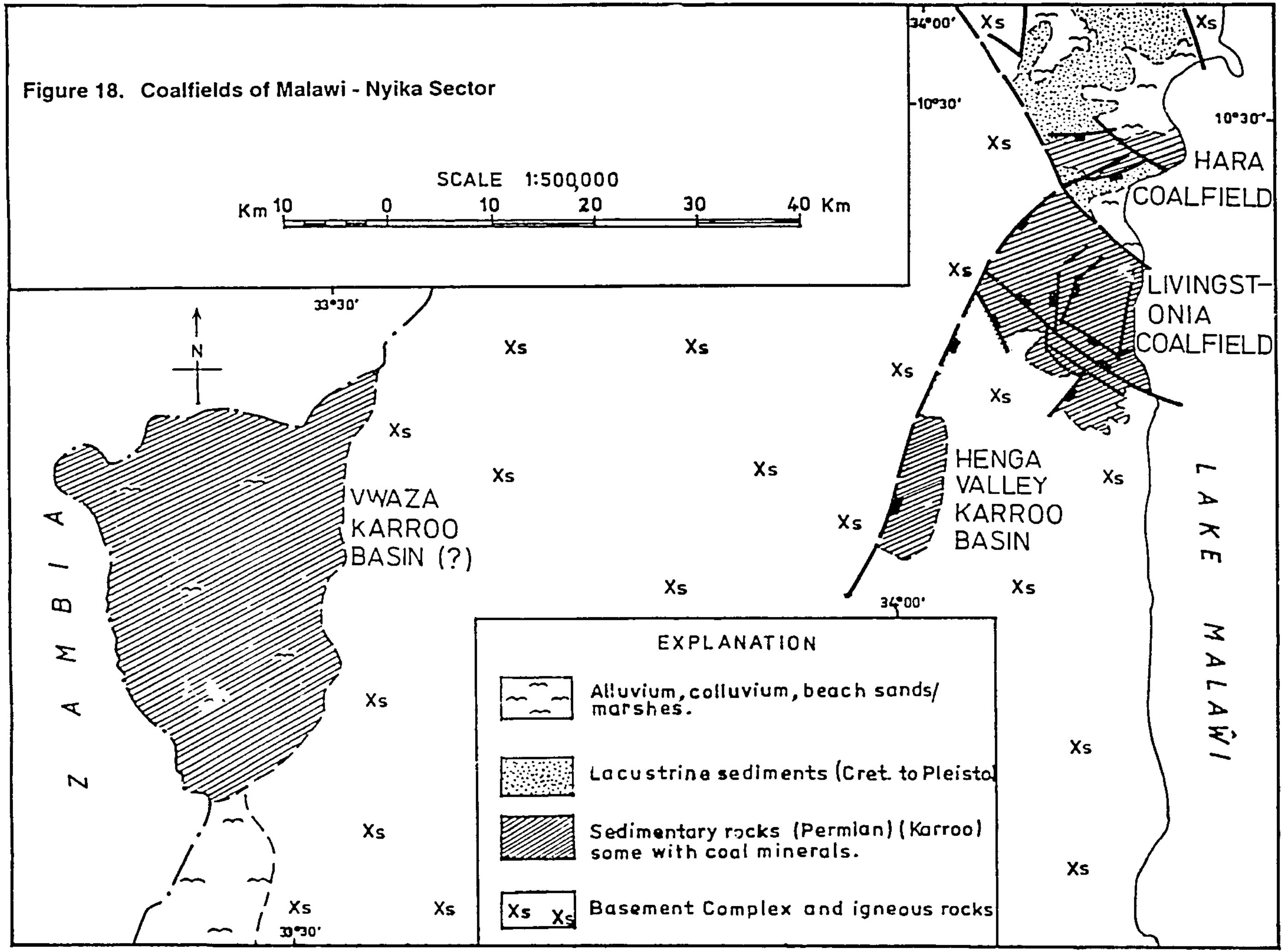
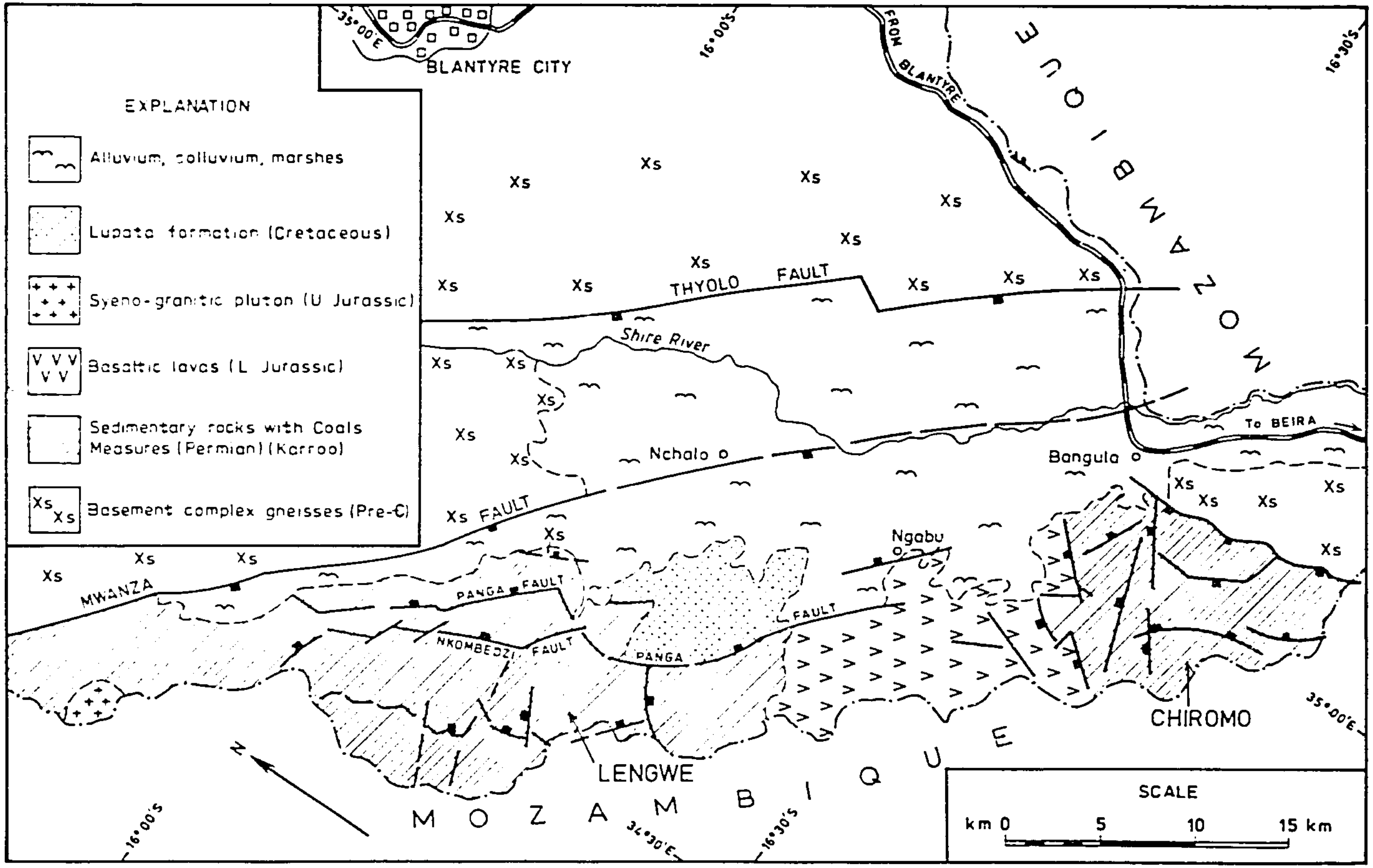


Figure 18. Coalfields of Malawi - Nyika Sector

GSN1140E *Geological Survey Dept. Malaŵi. 1983.* *DJC.*

Figure 19. Coalfields of Malawi - Southern Sector



GSN. 1140F *Geological Survey Dept. Malawi 1983* MMK

Table 9.2 Proximate and Ultimate Analyses of Coal from Some Malawi Coal fields (Ash Dried Basis)

Coal field	C.V. (Kcal/kg)		Percent Ash		Average Percent V.M.	Average Percent C	Average Percent H	Average Percent S
	Max.	Average	Max.	Aver.				
Mwabvi	4235	2200	70	45	6.5	22.2	1.4	0.6
Lengwe	5674	2500	79	40	8.4	-	-	-
Livingstonia	7603	4780	86	28	22.0	-	-	0.5
LV-Kaziwiziwi	7355	6790	25	18	20.5	75.5	3.5	0.3
LV-Mchenga								
North Rukuru	6282	5410	32	28	27.4	-	-	0.6
Nthalire								
Lufira	5019	3819	62	35	25.9	-	-	0.8
Ngana	4947	4708	65	30	24.9	-	-	1.2

C.V. - Calorific Value measured in kilocalories per kg
V.M. - Volatile Matter content
C - Total Carbon content
H - Hydrogen content
S - Total Sulphur content

Both Kaziwiziwi and Mchenga Mines are in the Livingstonia Coal field.

Table 9.3 : Coal Reserves and Resources of Malawi (million tonnes)

Deposits	Area (sq. km)	Proven	Possible	Probable	Total
Ngana	60	15	70	N.A.	85
Lufira	6	0.6	2	-	2.6
Kibwe	15	-	3	-	3
Mwankenja	52	-	1	5	6
Kaporo	140	-	-	300	300
N. Rukuru	150	-	5	350	355
Nthalire	40	-	-	15	15
Wenenya	16	-	-	-	-
Sekwa	3	-	-	-	-
Livingstonia	90	1.4	5	120	126.4
Hara	40	-	-	10	10
Henga	30	-	-	-	-
Vwaza	100	-	-	10	10
Lengwe	350	-	-	10	10
Mwabvi	400	4	10	150	164
TOTAL	1,492	21.0	96	970	1,087

1988 Estimates by Geological Survey Department of Malawi.

9.2 USES AND POTENTIAL DEMAND FOR COAL

Coal is primarily used as a fuel. It is also a feedstock for petrochemicals, fertilizers and gaseous and liquid fuels. The residue left after burning, coal ash, is also a useful building and road-stabilization material. As a fuel, it is utilized in the following areas:

- boiler fuel for steam-raising
- cement production
- electricity generation
- railway locomotives
- domestic fuel - coal as it is

Worldwide, the primary use of coal is as fuel for generating electricity. However, coal in this country is used mostly for steam-raising and cement production.

There is also a potential use coal in rural and/or peri-urban settings. The following scenarios are envisaged:

- In conjunction with the promotion of afforestation, people in peri-urban areas may be encouraged to use coal as a domestic fuel. However, appropriate coal fired stoves and technologies, to prevent pollution of the air by coal smoke, would be required.

- Increasing industrialization will simultaneously create an increased demand for good homes. Hence, there will be an increased demand for building materials such as bricks, cement, lime wall and floor tiles. Small scale firing of bricks, lime, etc. utilizing coal could potentially increase the demand for coal. An increased supply of coal might help reduce the level current level of deforestation.

- Thermal power generation has a high tolerance for high ash coals such as those found in Malawi. Technology now exists for small-scale thermal power stations (0.5 - 2 MW) that could be fed by small coal mines. Such coal mines and power stations would then become focal points for the growth of other industries.

The aforementioned concepts could help alleviate the problems created by Malawi's dense population and demanding local conditions. Secondly, there are many Malawians with skills in mining who could benefit from an increased level of small scale mining. In addition, coal inevitably could become an important source of energy to support accelerated industrial growth.

9.3 MINING

Presently small scale mining is carried out at Kaziwiziwi and Mchenga Coal Mines in the Livingstonia Coalfield. Both mines apply block-and-pillar methods of mining. Although these mines do not fall within the scope of small-scale enterprises as defined at the beginning of this report, there are aspects of the initial mining in 1985 which may be applied to coal extractions at rates of 1-5 tonnes per day of coal. Most of Malawi's coal is deposited in a way that lends itself to drift mining or shallow shaft-sinking. Such methods of mining would only require picks, shovels, wheelbarrows and hoes for mining. The small quantities of coal that could easily be supplied by these mining methods could then be used in the drying of crops and burning of bricks or lime.

10. SALT

10.1 RESOURCES AND CONSUMPTION

The tradition of making salt in Malawi is a very old one, possibly dating from the Pre-Iron Age, around 500 A.D. Some recorded accounts report of extensive salt trade in the last century in the Kasungu/Mchinji area, Henga Valley in Rumphi, Phalombe Plain in Zomba/Mulanje/Chiradzulu and the Chikwawa/Nsanje area. The technology for producing the salt was basically the same whether it was being extracted from vegetation or soils. It involved pouring water over the ash of burnt vegetation or saline soils; filtration of the solution through a straw basket or clay pot; and the boiling of the filtrate to dryness. The rock salt residue after evaporation was then collected and stored for subsistence use or trade.

Much of the local production disappeared in this century with the introduction of imported salts. The growing urban centres came to rely on such imports, while many rural areas experienced perennial shortages. Assuming that theper capita requirements for human consumption yearly is 6 kg of common salt, it is evident from levels of present imports (Table 10.1) that there are significant shortages in many parts of Malawi. As a result, in many rural communities the traditional salt producing industry is being revived, albeit in an uncoordinated manner in terms of manufacturing and marketing.

A recent survey by the Department Geological Survey revealed that salt making is practiced in all the districts especially in Chikwawa, Nsanje, Mulanje, Mangochi, Kasungu, Mzimba and Rumphi.

The salt is derived from salt-encrusted soils and powdery crusts (efflorescence) from the edges of rapidly evaporating natural pans, ponds and swamps. In some areas, saline soil horizons are mined, as in the Lake Kazuni area, or the powdery crust is scraped with a "Likombe" or knife as in Chikwawa and Nsanje. Saline soil horizons are evidently evaporites in recent sediments buried during flash floods and preserved at shallow depths in river valleys, and near the edges of swamps and ponds.

Efflorescent crusts form on fairly damp soils during periods of strong sunshine. It is generally a white or bluish residue from the rapid evaporation of saline waters. The terms "efflorescence," "evaporite" and "ephemeral evaporite" are sometimes used interchangeably.

These salts are not deposited in the same manner as salt is found in the major producing areas of the world. Hence, they often pose difficulties with respect to delineation of reserves. There is need to determine methods of assessing such resources. This is best illustrated by a case study of the salt-making area of Nchalo in Chikwawa District.

In the Nchalo area, exposed metamorphic rocks are visible north of the Mwanza River (Fig. 20). To the west, in the Lengwe area, sedimentary and volcanic rocks can be found. Most of the landscape around Nchalo is flat-lying, the soils are recent colluvium 3 to 500 metres thick. The Elephant Marshes of the Shire River flank the area east of the Nchalo Plain.

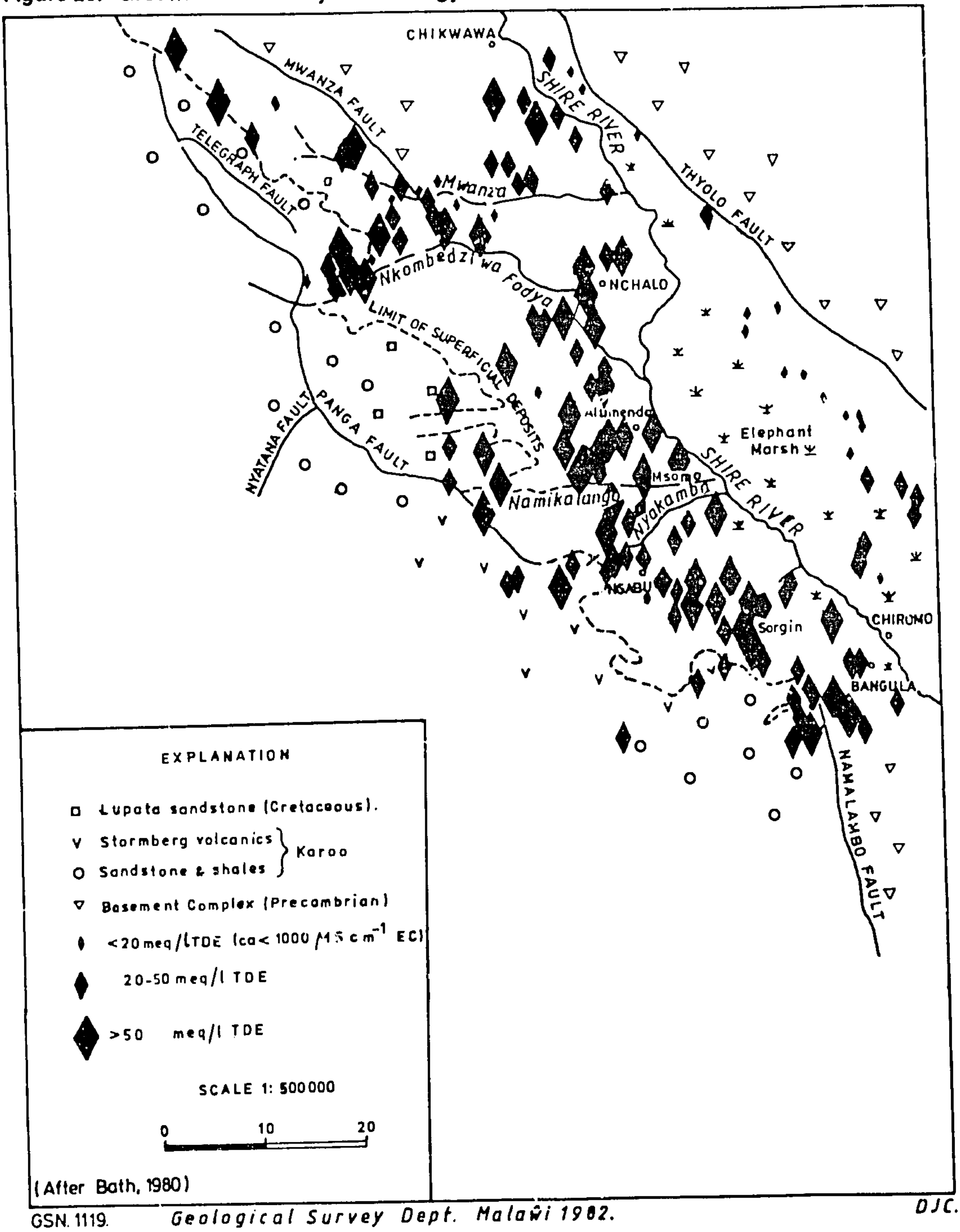
Saline groundwaters are widespread from Chiromo to Chikwawa as illustrated in Fig. 20. Various origins have been proposed to account for the high salinities. In early government "Water Supply Investigation Reports", salinity was considered to have been derived from evaporites in Cretaceous Age sediments. Rapid evaporation of water from unconsolidated valley fill increased the salinity in groundwater in a zone of restricted drainage. Another suggestion was that saline water welled up from sedimentary rocks near impermeable fault barriers.

The difference in the chemical make up of the groundwater from the east and west banks of the Shire River suggests that the origin of the high salinity is associated with the sedimentary and volcanic rocks flanking the Nchalo Plain on the west. A zone of consistently high saline water occurs down-gradient of the Cretaceous Lupata Series. Water compositions of the west bank are mainly Na-Cl, Na-HCO_3-Cl and Ca-HCO_3, with electrical conductivities up to 17500 minihos/cm. There is also a very significant difference in the chemistry of ground and surface water from the Shire, Namikalango and Mwanza Rivers. The range of sodium in the rivers is 15-27 ppm, while it is 120-3035 ppm in groundwater.

Table 10.1: Annual Salt Consumption in Malawi

Year	Imports (tonnes)	Per Capita Consumption (kg)	Estimated Population (million)
1977	11,930	2.15	5.55
1978	3,452	n/a	
1979	15,931	2.87	
1980	12,970	2.34	
1981	8,965	1.62	
1982	13,452	2.1[illegible]	6.34 (calc.)
1983	9,850	1.54	
1984	15,848	2.48	
1985	24,590	3.85	
1986	11,726	1.84	
1987	14,402	2.26	7.96
Average		2.31	

Figure 20. Groundwater Salinity and Geology of the Nchalo Area, Chikwawa



The saline soils collected along the marshes south of Nchalo sugar plantations show tremendous increases in sodium (Na), sulphates (SO_4) and chlorides (Cl) (Table 10.2). This phenomenon may to some extent, reflect an artificial source for these salts.

Table 10.2 Chemical Analyses of Saline Soils from Nchalo

Sample	Ca ppm	Mg ppm	Na ppm	K ppm	SO_4 ppm	Cl ppm	EC x 10^2 mmhm/cm
TT 2	3960	2160	32500	252	12000	257420	8.8
TT 3	6688	12100	81250	850	-	209934	-
TT 5	10560	720	3500	250	25758	222434	4.4
SU 1	4840	1080	85000	288	9000	289911	14.1
SU 2	4400	1680	41250	325	10000	274915	11.0
SU 3	5500	1800	30000	450	9375	274915	8.6
SU 4	4840	960	8125	300	9500	207436	4.0

electrical conductivity (EC) measured in micro-mhms/cm

TT2 A dark, clayey, saline soil, reportedly collected from Mphoza dambo. Sample is from a salt-making operation in Kholongo village, west of Nchalo township.

TT3 A dark-grey clayey, very saline soil from a stockpile of the salt-maker at Kholongo

TT5 Slime from the alt-making operation at Kholongo.

SU1 Sandy-clay soil, light-grey, from Sanjama dambo on the edge of a pond. High proportion of efflorescence scraped together with 3 mm top layer of soil.

SU2 As SU1, but included a thicker component of underlying soil

SU3 As SU2, but added 10mm layer of underlying soil

SU4 Sandy soil only, underlying the efflorescent-rich layer. 20mm layer sampled.

These results indicate that groundwater is a major source of the natural salts. The salts in the groundwater may not be easily quantified without an extensive and expensive exploration programme to measure the extent of the groundwater aquifers in the area.

New areas have been recently located in Karonga and Mzimba where there are mappable horizons of saline soils. Detailed work will be carried out on them to delineate extractable reserves.

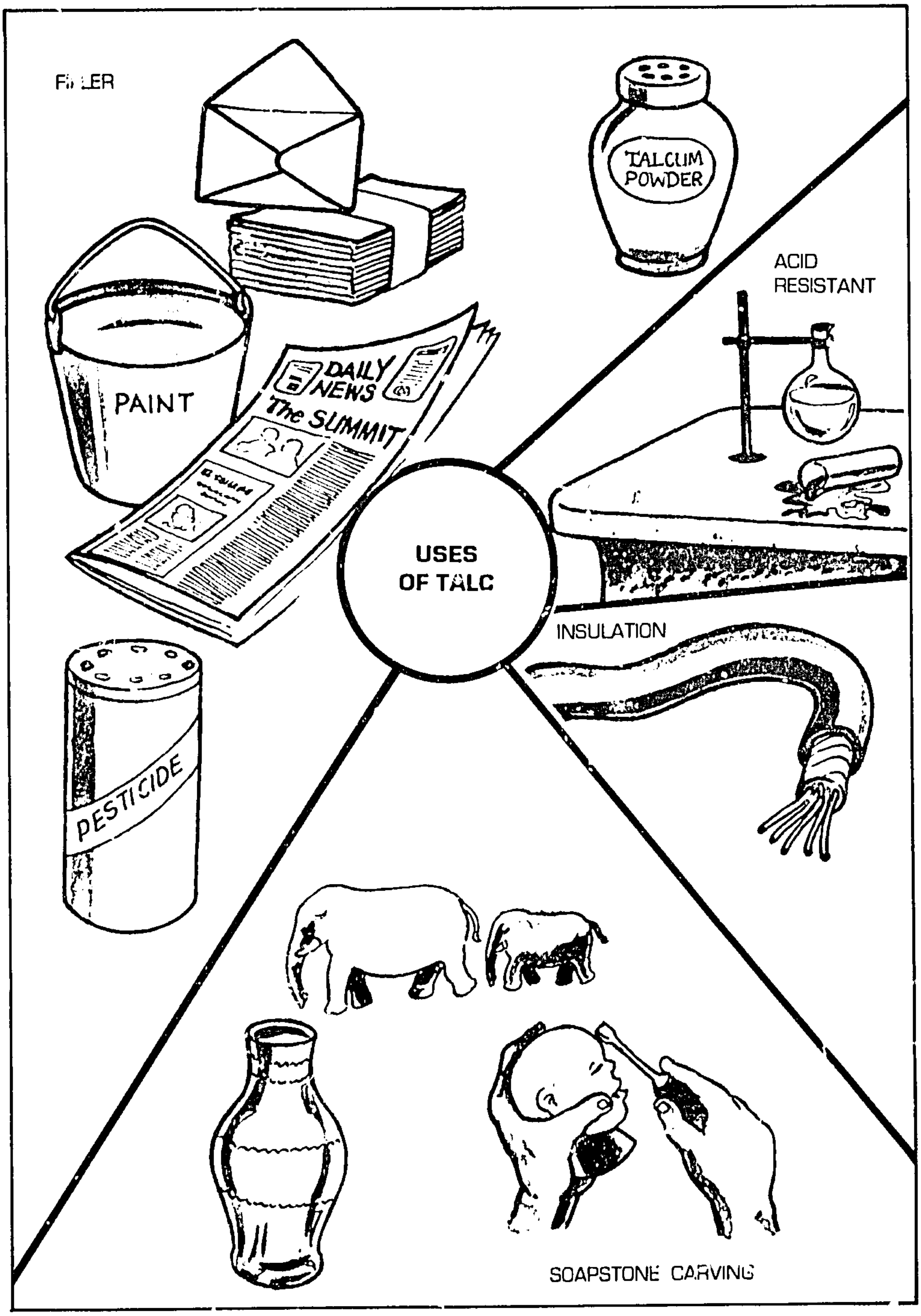
10.2 INVENTORYING OF SALT RESOURCES

A countrywide survey of areas where salt making is being practiced has been made and this information is being collated by the GSD. The next stage will be the assessment of economically feasible and extractable resources. The village technologies for collecting the salts also require improvements. Laboratory trials, for instance, showed that removal of fine suspensions from the filtrate (brine) resulted in the production of a cleaner salt than that which is commonly sold in the village markets.

Producing brine from the solution and the evaporation of the brine are the greatest obstacles to increasing production. In the laboratory, only 20 to 50 litres of brine in a 6-hour day could be extracted in a simulated village operation. It also took some 5 hours to boil to dryness about 10 litres of brine. The quantity of fuelwood used for the boiling brine in the village was not determined, but is assumed to be substantial.

Other factors that need to be evaluated are:

- The use of alternative sources of energy for evaporating the brine in order to prevent further deforestation in areas where salt-making is carried out.
- Methods of iodizing the salts for human consumption.
- Simple technologies for removing unsavory chemicals from the salts, to make them suitable for consumption.


FILLER
TALCUM POWDER
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USES OF TALC
INSULATION
PESTICIDE
SOAPSTONE CARVING

11. TALC

11.1 RESOURCES

Talc is frequently apple-green and pearly in colour. It occurs as foliated masses, greasy to the touch. It is formed from the hydrothermal alteration of magnesium silicate rocks such as olivine pyroxenes and amphiboles. It is insoluble to acids and difficult to fuse.

Talc occurs widely in Ntcheu District, mainly associated with ultra basic greenish rocks. It normally occurs as elongated pods, measured in tens of metres and of very limited width. The deposits that have been located are shown back in Fig. 2. Two deposits, Muso and Joshua were sampled in detail. Talc is greyish to greenish when fresh, with dark to brown specks of iron oxides.

4,000 tonnes of talc have been located at the Muso deposit and nearly 2,000 tonnes at Joshua, to a depth of 5 metres. The talc is intermittently used as a carving stone in the Southern Region.

The other deposits on the map have not been investigated, but it is likely other deposits may be discovered in the same area.

11.2 USES AND DEMAND

Talc (also commonly known as soapstone) is widely used as an ingredient in many commodities, including:

- carving stone
- ceramics
- cosmetics (talcum powder etc)
- acid-resistant slabs for laboratory bench tops in schools, research laboratories, etc
- lubricant
- electrical and thermal insulation
- refractory slabs in kilns and low-temperature furnaces
- filler in paints and paper
- filler in pesticide formulations

There is a definite potential demand for talc in Malawi, but it is essentially small.

Discussions with artists have revealed that soapstone sculpture has declined in Malawi because the extraction and transport costs of the soapstone from Ntcheu on an individual basis are generally too high. This is an obvious industry an entrepreneur could take up; to supply artists in urban areas with the soapstone they require. Judging from the popularity of soapstone art among tourists going to Zimbabwe, it is reasonable to assume that similar artwork could be promoted here.

Research on pesticide formulations is presently underway within Malawi. One of the minerals being researched amongst vermiculite, kaolinitic clay and limestone is talc. Recent research by ICI indicates that for local pesticide formulation the Muso prospects may be suitable material as filler for "actellic" dust.

11.3 MINING AND INFRASTRUCTURE

The mining of talc is essentially a trenching and quarrying operation using picks, hammers, hoes, shovels and wheelbarrows. The demand for talc is so small that this would be a seasonal activity with stockpiles kept close to the areas of demand.

Fresh talc is often found at depths of 3-10 metres. Mining would therefore have to be done in a planned and safe manner to avoid rockfall and landslides. In addition, the Muso and Joshua deposits are very close to the Malawi/Mozambique border, and work has to be carried out carefully due to safety concerns arising from the civil war in Mozambique.

12. PYRITE AND PYRRHOTITE

12.1 RESOURCES AND RESERVES

Pyrite and pyrrhotite are primarily a source of sulphur, but elemental iron can also be an important by-product in future iron and steel production. There are extensive low-grade resources of pyrite and pyrrhotite in Lilongwe and Dowa Districts. Minor deposits are also known in Mchinji.

These resources are strategically important if the following industrial ventures are to be established in Malawi:

- sulphur based fertilizer production (ammonium sulphate, superphosphates, etc)
- mining and processing of uranium ore
- pulp and paper production

Such ventures require large quantities of sulphuric acid, which is produced from the sulphur by-product.

There are two main pyrite/pyrrhotite deposits that have been evaluated in detail; the Malingunde deposit in Lilongwe and the Chisepo deposit in Dowa.

Malingunde Hill is located 26 km southwest of Lilongwe City, adjacent to Kamuzu Dam on the Lilongwe River. It is connected by a good road tarmac, surfaced as far as Likuni Mission, and gravel the rest of the distance. The pyrite/pyrrhotite occurs mainly on the eastern side of the hill disseminated in granulite gneisses. Eight inclined holes were drilled on the eastern side to an average depth of 30 metres. The "body" has an average thickness of 40 m, but its extent at depth was not determined, hence the reserves are likely to be much larger than those so far estimated.

The reserves of pyrite/pyrrholite delineated at Malingunde are estimated to be 2.6 million tonnes with the content of sulphur averaging 10.7 percent. A representative distribution of pyrite/pyrrhotite in the rock is given in Table 12.1 The results show that the heavy fraction of pyrite/pyrrhotite tends, on grinding, to produce a lot of fines. Consequently, the amount of available sulphides on processing could be lower.

Table 12.1 **Pyrite/Pyrrhotite Size Distribution in Malingunde Granulitic Gneiss**

Size Fraction	Total Wt. %	S. G. 2.96		
		Wt %	% Distribution	% in Fraction
- 250 + 75 micron	78	33.7	73.3	43.2
- 75 micron	22	12.3	26.7	55.9
Total	100	46.0	100.0	99.1

— S.G. (Specific Gravity) of 2.96 of tetrabromoethane used to remove light waste material from the heavy sulphides.

The Chisepo deposit is located west of Dowa and northwest of Lilongwe City. Two prominent series of hills, Kadamsana and Nkhanyu, are the host rock for the sulphides (pyrite/pyrrhotite). The rock is a kyanite-graphite-mica-bearing gneiss of quartz, feldspar and biotite composition.

Two holes were drilled at Kadamsana Hill and one at Nkhanyu in 1964. The sulphur content of the samples from the drillholes are summarized in Table 12.2.

Table 12.2 **Sulphur Content of Pyrite/Pyrrhotite Rock at Kadamsana and Nkhanyu Hills, Chisepo**

Drillhole 1			Drillhole 2			Drillhole 3 (Nkhanyu)		
Samp. No.	Depth (m)	Percent Sulphur	Samp. No.	Depth (m)	Percent Sulphur	Samp. No.	Depth (m)	Percent Sulphur
CH 1/1	0.9-6.1	11.4	CH 2/1	19.5-25.6	4.8	CH 3/1	1.1-1.5	10.7
CH 1/2	6.1-12.2	9.3	CH 2/2	25.6-31.7	16.0	CH 3/2	1.5-6.1	11.6
CH 1/3	12.2-18.9	9.9	CH 2/3	31.7-39.6	15.2	CH 3/3	6.1-12.2	9.9
CH 1/4	18.9-25.6	7.3	CH 2/4	39.6-48.2	11.5	CH 3/4	12.2-18.3	13.1
CH 1/5	25.6-32.3	6.0				CH 3/5	18.3-24.4	16.0
CH 1/6	32.3-39.0	6.7				CH 3/6	24.4-30.5	12.2
CH 1/7	39.0-45.7	12.2				CH 3/7	30.5-43.6	10.1

On the basis of the earlier work at Chisepo, Nkhanyu was selected for detailed exploration and feasibility studies in 1975-77. These latter investigations delineated 34 million tonnes of sulphides at Nkhanyu, grading 8 per cent sulphur. A summary of the 1977 information is shown in Table 12.3.

Table 12.3: Pyrite/Pyrrhotite Reserves at Nkhanyu Hill, Dowa

Drill Hole	Area m^2 vert	Vol. $m^2 \times 10^6$	Tonnes ore $\times 10^6$	Average S %	Tonnes of S $\times 10^6$	Average % S x Vol $\times 10^6$
NK 1	3224	.310	.99	6.761	.067	2.096
MK 5	1600	.154	.491	8.659	.042	1.333
NK 2	1920	.23	.737	8.913	.066	2.05
NK 6	3360	.202	.645	8.259	.053	1.668
NK 8	7776	.913	2.906	9.488	.283	8.663
NK 9	12700	1.524	4.877	7.424	.362	11.314
NK 10	8200	0.984	3.149	7.833	.247	7.711
NK 11	13600	1.632	5.222	8.402	.439	13.712
NK 12	11000	1.32	4.224	7.702	.325	10.167
NK 13	9200	1.144	3.533	8.834	.312	9.753
NK 14	4800	.576	1.843	9.123	.168	5.255
NK 15	12000	1.44	4.6	8.78	.404	12 643
NK 3	3080	0.249	.798	11.934	.095	2.971
Total		**10.638**	**34.093**		**2.863**	**89.333**

Percent Sulphur calculated by block volume:

$$\% \text{ Sulphur} = \frac{\text{Ore } \% \times \text{Vol.}}{\text{Total Vol.}}$$

$$= \frac{89.333 \times 10^6}{10.638 \times 10^6}$$

= 8.397% average

12.2 USES AND POTENTIAL DEMAND

Sulphur is a key commodity in modern civilization, followed by limestone and iron ore. An indication of the world supply scene is given in Table 12.4.

Table 12.4 World Sulphur Supply (million tonnes)

	1986	1987
Sulphur Products:		
Elemental Sulphur (brimstone)	36.29	37.83
Pyrite	9.23	9.70
Other Forms	10.72	11.01
Net Stock reduction	0.46	0.31
Total World Supply	**56.70**	**58.85**

Sulphur is mainly used in the production of fertilizers. In 1987, over 60 per cent of world sulphur supplies were consumed by the fertilizer industry. Sulphuric acid is also an important raw material for the chemical industry, pulp and paper production, in pharmaceuticals and as reagent for the mining industry.

In Malawi, there is a potential demand for pyritic sulphur in a proposed pulp and paper production project. If significant uranium resources are located in Karonga, a potential demand also exists for sulphuric acid in uranium processing.

Fertilizer production is also a potential use of domestic sulphur. Sulphur is required in the production of both superphosphate and sulphate fertilizers. However, remaining to be studied is the production of sulphuric acid from pyrite/pyrrhotite using small-scale industrial plants.

12.3 MINING AND PROCESSING

Production of sulphur and sulphuric acid is essentially a heavy industry operation, and the discussion above may be outside the scope of this report. However, there are a number of aspects of mining that show some potential for development as small scale enterprises in Malawi.

— The deposits of pyrite/pyrrhotite at Malingunde and Chisepo are hosted in hills, hence they lend themselves to easy quarrying.

- Since Malawi only consumes small quantities of sulphuric acid and sulphur, there are good prospects for establishing small scale sulphuric acid production units to meet domestic demand.

- Research work on direct application of phosphates rock (PR) has recently been started in Malawi. One aspect of this research is to investigate means of producing "partially acidulated phosphate rock, (PAPR)" by weathering the PR with partly beneficiated pyrite. When pyrite rock is exposed to the atmosphere it weathers over time (2-3 years) emitting sulphuric acid that, in turn, attacks the host rock, producing a gossan. So PAPR could be produced by small scale entrepreneurs as a direct phosphatic fertilizer that is more soluble in soils than PR (see section on PR).

There are indications of the availability of large resources of pyrite and pyrrhotite in the Central region. There are also potential export possibilities for large scale production of sulphur, particularly to neighbouring countries. Zambia, in spite of having its own sulphuric acid production, now needs more acid since beginning heap-leaching operations as a method for extracting copper. (This method consumes large quantities of acid).

There is, however, a serious environmental aspect to the production and utilization of sulphur and sulphuric acid. Proper environmental impact assessments (EIA) must be undertaken before decisions are made to invest in this industry. Certainly, small scale enterprises working in pyrite would have to be severely controlled to avoid pollution altogether, otherwise the consequences could be more costly to correct than the benefits earned from using sulphur.

13. ROCK PHOSPHATES

13.1 FERTILIZER DEMAND

Future increased crop production in Malawi will rely heavily on the wide application of synthetic fertilizers and pesticides. Factors that will affect achievement of increased food production are: the cost of imports; the development of systems for appropriate use of fertilizers; and the adoption of schemes that promote the use of local raw materials in fertilizer and pesticide formulations.

Fertilizers are essential since soils lose fertility with the increased use of land for agriculture.

During weathering, the primary earth surface materials go through three stages of transformation:

Stage 1 — Original rock constituents are dominant. Only minor plant nutrients are available in partially formed secondary clay minerals.

Stage 2 — Rock constituents wholly decompose, making plant nutrients readily available in clay phases for uptake by plants.

Stage 3 — Natural, primary plant nutrients become depleted due to repeated cropping; an infertile and leached soil remains.

The major element constituents in these three stages are shown in Fig. 21. Due to leaching, erosion, and consumption of nutrients by plants, the soils eventually lose their fertility and evolve into the refractory silica-alumina-iron oxide-rich (SiO_2 -Al_2O_3) compositions. At this stage, counter-acting processes to re-fertilize the soils are required to improve crop yields on a unit area.

The most important fertilizers imported into Malawi are compounds of nitrogen (N), phosphorus (P) and potassium (K) as shown in Table 13.1. Fertilizer imports and sales by ADMARC and OPTICHEM are the main indicators of fertilizer consumption patterns. From 1972 to 1978, consumption of all fertilizers generally increased at an approximate annual rate of 5.6 per cent to reach 104,000 tonnes in 1978. (This is the equivalent of about 29,714 tonnes P and K). The trend from 1978 to 1985 has been to increase the amount of imported high-analysis N.P.K. fertilizers at the expense of sulphur-based fertilizer (from ammonium sulphate at 21 percent nitrogen (21N) to CAN (26N) and Urea (46N)). The average nutrient content of all fertilizers used in Malawi in 1978 was equivalent to 28.7 kg of NPK per tonne of produce sold. This low level of inputs is undesirable, as the benefits of concentrated synthetic fertilizers are not fully realized.

Figure 21. Major Element Constituents of Soils

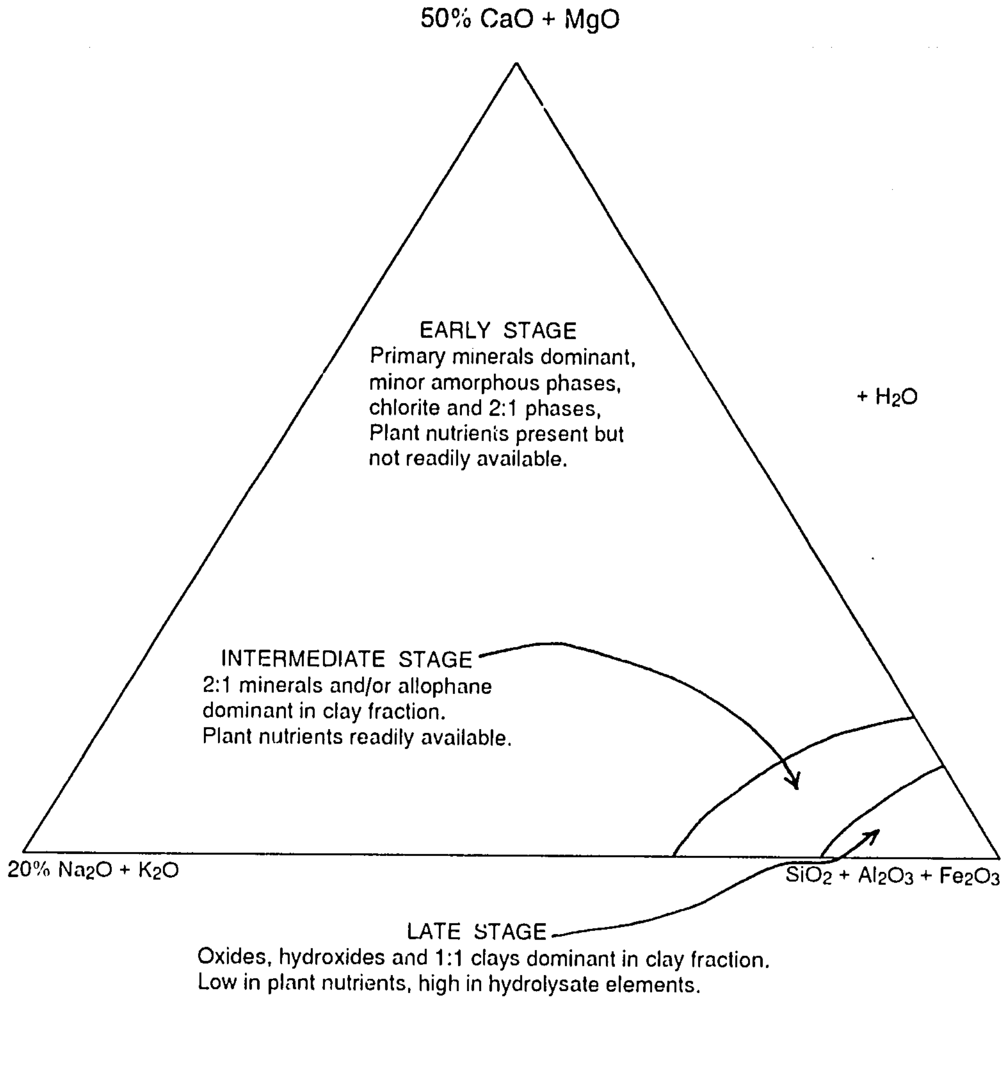


Table 13.1

Fertilizer Imports by Types

	1976		1979		1980		1981		1982		1983		1984		1985	
Types of Fertilizer	Tonnes	Value	Tonnes	Value	Tonnes	Value	Tonnes	Value	Tonnes	Value	Tonnes	Value	Tonnes	Value	Tonnes	Value
Sodium Nitrate	430	105,947	700	130,227	2,300	460,667	-	-	-	-	556	220,330	-	-	442	240,720
Nitrate	2,846	347,719	11,275	1,510,101	-	79	3,500	813,431	125	23,017	14,318	3,575,290	21	3,486	-	-
Ammonium Sulphate	61,884	7,697,724	11,961	1,494,449	35,142	4,648,866	79,285	15,888,144	43,042	7,438,753	24,846	5,548,648	22,553	7,271,722	8,835	2,562,101
CAN	7,767	931,353	14,800	1,608,382	5,426	1,217,488	2,498	636,926	8,228	2,052,728	36,152	8,623,860	38,030	12,644,282	27,798	10,935,058
Urea	839	208,120	3,420	583,115	10,230	2,422,264	7,678	2,326,949	11,229	3,613,479	7,360	2,426,546	15,868	5,416,087	11,420	5,729,403
Nitrogenous Fertilizers	20,362	719,369	13,696	2,356,805	3,264	764,403	5,500	1,163,910	2,002	414,740	722	182,039	299	114,655	1,316	995,756
Super, Phosphate Single	2,619	202,458	2,201	298,881	1,804	287,711	1,499	263,303	1,491	267,634	796	177,285	788	140,387	1,782	413,675
Super Phosphate Double, Tripple	3,173	440,544	7,809	1,241,669	10,721	2,299,622	9,896	2,322.534	9,424	2,305,636	15,157	5,490,926	6,643	2,121,154	7,196	2,170,600
Phosphate Fertilizers	1,350	197,948	1,818	341,206	2,351	633,689	161	50,812	4,277	795,716	5,386	1,832,181	536	148,236	1,995	701,123
Potassium Chloride	750	80,351	2,300	286,209	2,553	583,488	2,500	557,631	250	52,326	4,098	1,151,198	1,165	3,99,448	3,658	1,733,931
Potassium Surphate	300	44,141	5,368	692,366	3,000	699,211	2,717	739,862	4,524	699,991	3,225	1,233,285	-	-	2,081	1,065,359
Potassic	500	50,422	5,874	1,107,409	4,000	897,402	1,420	434,428	2,750	951,645	2,371	1,055,803	2,136	1,010,688	2,682	1,215,689
Fertilizers (other)	600	179,016	-	-	9	5,188	18	4,205	29,998	8,239,277	48	51,460	22,099	8,504,332	23,502	9,603,008
Total	103,470	14,205,139	81,222	11,650,819	80,000		116,672	25,262,215	117,340	26,854,943	115,098	31,658,901	110,138	37,774,482	92,707	37,366,429
	K137/tonne		K143/tonne		K185/tonne		K216/tonne		K228/tonne		K274/tonne		K343/tonne		K403/tonne	

Table 2 - Imports of Agricultural Disinfectants Insecticides

	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
In Liquid Form (litres)	251,673	526,226	283,520	1 008,009	233,214	1,095,615	260,076	1,045,647	432,845	2,177,269	418,960	2,100,009	303,334	2,569,927	333,613	2,430,048
In Powder Form (kg)	1,185,258	1,767,897	427,737	1,584,534	277,872	892,01	85,555	408,891	287,586	1,362,381	203,727	1,179,837	299,558	1,153,942	437,253	1,733,783
Total	-	2,294,123	-	2,592,543	-	61,987,631	-	1,454,538	-	3,539,950	-	3,279,846	-	3,723,869	-	4,163,831

Fertilizer import levels continued to decline from 1982 to 1985, from 117,340 to 92,707 tonnes, respectively. The nutrient content of NPK was 26,488 tonnes in 1985.

13.2 RESOURCES OF ROCK PHOSPHATES (RP)

One of the major constraints for establishing a fertilizer manufacturing plant in Malawi has been lack of investment capital. Because of this, several feasibility studies for projects, for instance a nitrogen plant, have been shelved more than once.

Now, there is an opportunity to examine low-cost techniques for utilizing local mineral resources to produce some fertilizers. A method that is being widely researched is the *direct application of rock phosphates as a phosphorus (P) fertilizer.* Malawi has several mineral deposits rich in phosphorus. Some of the phosphorus (as the mineral **apatite)** is in the soil and in deeply weathered rock overlaying such deposits. When these soils and rocks are milled and applied to farmland, the phosphorus is released from the apatite and becomes available for use by the plants.

The Tundulu phosphate deposit on Nathace Hill (Fig 2.) is the most promising deposit of rock phosphate at present. The levels of phosphorus in some samples are given in Table 13.2. There are, however, other factors that must be taken into consideration in utilizing PR:

- It is the *phosphorus available for release* from the rock that must be determined, rather than the absolute phosphorous content in the rock.
- Acidic soils would seem to be the most like[illegible] benefit from application of PR as the acid would attack the apatite allowing the release of phosphorus at a faster rate.
- PR can be of immediate beneficial use to perennial crops such as tea, coffee, macadamia, fruit trees and forest plantations, rather than for seasonal cereals. PAPR is the most appropriate composition for fertilizing cereal crops.

Other prospective deposits of phosphorus are given in Table 13.2.

13.3 MINING

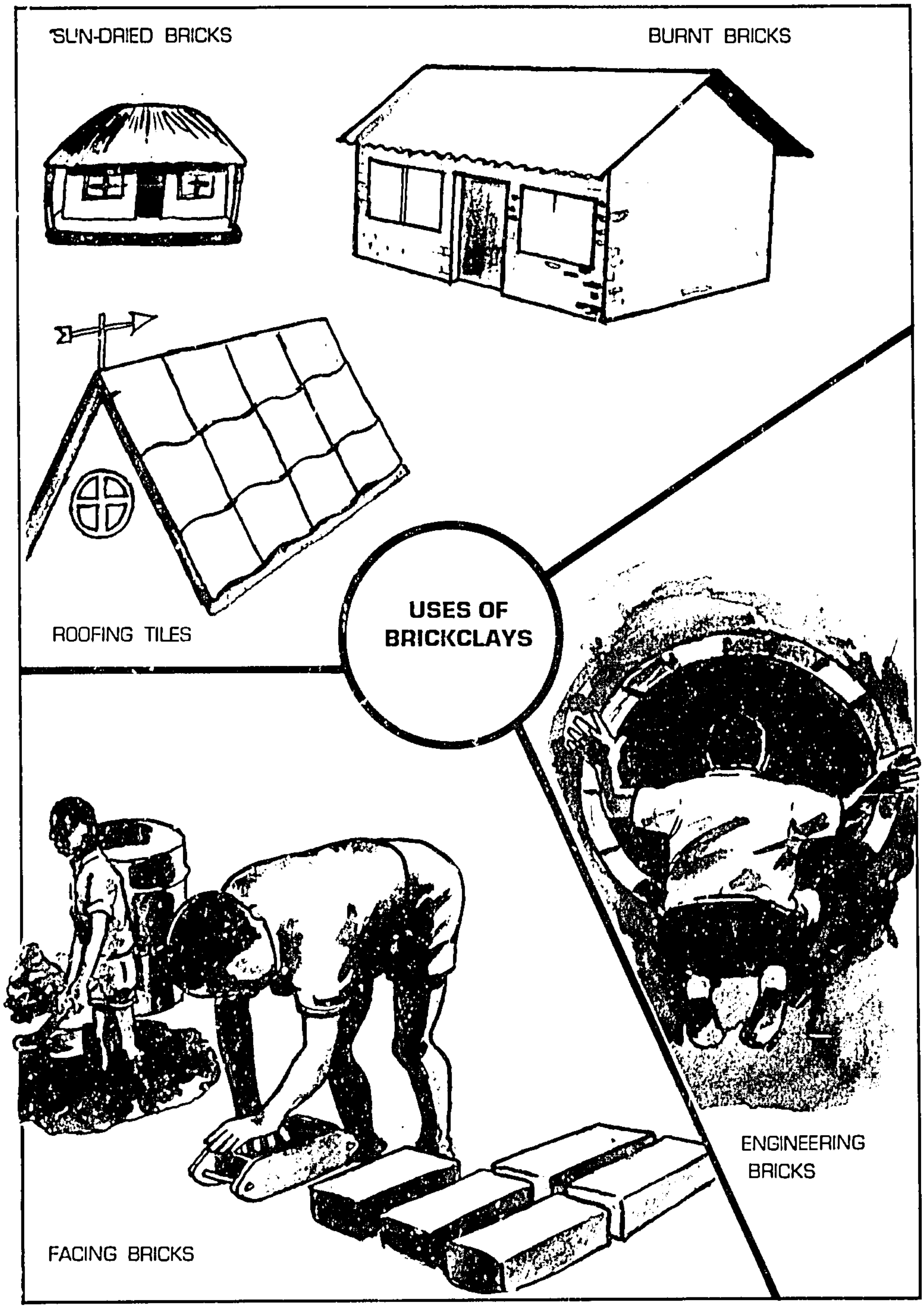
Presently, the investigations into PR are at the research stage, and various Malawian, American and British institutions are involved in the research work. There are potential opportuities for small scale enterprises to mine, mill and package PR for distribution to farmers. The mining would involve extraction of fairly soft rock within 5 to 20 metres of the surface.

13.4 INFRASTRUCTURE REQUIREMENTS

The Tundulu area is far from electricity. The roads to the area need to be upgraded to carry frequent heavy traffic. There is abundant water from nearby Lake Chilwa. However, land would be expensive as the area is extensively cultivated and has a dense population.

Table 13.2: Phosphate Resources and Percent of Phosphorus (P_2O_5)

Area	District	Estimated Reserves	Percent P_2O_5	Remarks
Tundulu	Mulanje	1.25 mil. tonnes	+ 25	suitable for direct PR
Chingale	Zomba	0.32 mil. tonnes	3.7	eluvial apatite, requiring processing
Mlindi	Mwanza	2.4 mil. tonnes (inferred)	7-14	vein and eluvial apatite
Bilila	Ntcheu	not delineated	0.01-3.32	eluvial apatite
Chirwa Is.	Zomba	not delineated	2.5	in carbonatite
Kangankunde	Machinga	not delineated	1.3-8.9	in carbonatite


SUN-DRIED BRICKS
BURNT BRICKS
ROOFING TILES
USES OF BRICKCLAYS
ENGINEERING BRICKS
FACING BRICKS

14. BRICKCLAYS

14.1 RESOURCES AND RESERVES

Bricks are a major building material in urban areas of Malawi. For that reason, planning authorities have always been conscious of the need to set aside areas for brickmaking as close as possible to urban centres. On the other hand, shortages of good quality bricks have perennially affected building construction programmes.

Good quality brickclays have been located in both Blantyre and Lilongwe to support mechanized brickmaking operations similar to those carried out by the Ceramic Co. at Chirimba, in Blantyre.

Additional resources of clays suitable for brickmaking are located east of Bangwe Mountain, (near Limbe), over a 40 km^2 area (Fig. 2.). The clays are orange to red-brown in colour, generally "Katondo" residual soils derived from perthite gneisses and perthosites. The quality of the clays for brickmaking was determined using the following parameters:

- Test briquettes were moulded (79mm x 38mm x 24mm) and fired in electric furnaces (mouldability being a useful parameter for assessing workability of the clay and the required moisture).
- The briquettes were fired to 1000°C and 1050°C respectively. This provides data for assessing wet-dry shrinkage and dry-fired shrinkage.
- Particle size distribution was determined.
- Loss-on-ignition (indicating removal of inherent moisture carbon and carbonates) was also determined.

From these tests the main characteristics of the Bangwe brickclays were determined as summarized in Table 14.1.

Table 14.1 Characteristics of the Bangwe Area Brickclays (percent by wt.)

Block	Moulding Moisture Content (%)	Wet-Dry Shrinkage percent of orig. wt)	Dry-Fired Shrinkage (% of orig. wt)		Particle Size Dist.		
			1000°C	1050° C	+1mm (%)	-1+75um (%)	-75um (%)
Likhomo	20.4	7.4	1.8	3.3	6.4	43.0	50.6
Chimangansasa	19.8	7.6	2.0	2.9	9.7	43.4	46.9
Rest of Area	19.9	7.2	1.8	3.6	8.0	41.7	50.3
Average	20.2	7.4	1.8	3.2	7.4	42.9	49.7

The sizes of the clay deposits in the Bangwe area are given in Table 14.2. There is sufficient clay to produce 17 billion bricks, adequate for 60 years, at a rate of consumption in Blantyre of 250 million bricks a year. There are, of course, some variations in the characteristics of the clays. The very high shrinkages on the tests suggest that they have short vitrification ranges, and if fired by traditional methods, these clays may become plastic and distorted at 1000°C temperatures. In order to ensure that firing results in the maximum number of well-fired, undistorted bricks, the soils used should be at least 60 per cent silt and clay and less than 60 per cent clay. Mechanized brickmaking becomes more appropriate than traditional methods as it allows for effective blending of various clays to produce a uniform brick.

Table 14.2 **Brickclay Reserves of the Bangwe Area (Assuming mechanized brickmaking)**

Block	Area km^2	Average Thickness m	Clay Volume $m^3 \times 10^6$	Total No. of Bricks $\times 10^6$	Net No. of Bricks (Assuming 30% wastage) $\times 10^6$
Likhomo	3.05	3.1	9.4	7000	4900
Chimangansasa	1.80	2.2	4.0	2960	2070
Rest of Area	8.55	2.4	20.5	15200	10630
	13.4	-	33.9	25160	17600

NB

— assumptions: Malawi standard construction brick has external dimensions of 213mm x 110.5mm x 63mm 1000 bricks require approx. 1.35m^3 clay

— In mechanized brickmaking, the blending of clays of varying compositions is feasible, hence, estimates are higher by 30% compared to resources which would be available to traditional brickmaking.

— Only resources of areas where thickness of clays is over 1.0 m have been considered in Table 14.2.

— These resources are only of clays which mature at temperatures of 1000°C or less, and which are at least suitable for brickmaking by traditional means.

In Lilongwe, suitable brickclays have been located south of Nathenje, in Chief Chadza's area, over a survey area of 140 km^2. In Chadza Block I, clay deposits suitable for the production of some 900 million bricks have been assessed. Chadza Block II is estimated to have 1.29 million m^3 of clays suitable for producing over 940 million bricks (Table 14.3). The fired quality grades of briquettes from Chadza are found in Table 14.4.

Table 14.3 **Brickclay Reserves in the Chadza Area II**

Block	Area (km^2)	Average Thickness (m)	Volume of Clay (m^3)	Net No. of Bricks (assuming 30% wastage) x 10^6
A	0.16	2.63	41,0940	212
B	0.55	2.20	1,207,470	626
C	0.21	2.52	525,105	272
	0.92		2,143,515	1,110

NB.

- assume 1000 bricks require approx. 1.35m^3 clay when the Malawi standard brick of 213 x 110.5 x 63 mm dimensions is taken.
- Reserves calculated assuming mechanized methods are used for brickmaking.

Bricks which fall in firing Grades 2,3 and 4 are essentially of suitable quality. Based on this information, the Chadza clays are suitable quality even for mechanized brickmaking. Other characteristics of the Chadza clays are shown in Table 14.5.

These resources are, however, threatened with sterilization once permanent buildings and structures are located on them. There is an urgent need for such areas to be set aside for production of building materials. However, this does not preclude use of the land for agriculture.

Table 14.4 **Firing Grades for Chadza Samples**

Firing Grade and Description	Proportion of Samples at 1000° C	Proportion of Samples at 1050° C
1.U Underfired and not weather resistant (U)	7.8%	1.0%
2.UD Underfired and weather resistant (UD)	14.6%	7.3%
3.SU Slightly underfired and weather resistant (SU)	10.7%	10.7%
4.GB Well-fired and weather resistant (some partially vitrified)	66.9%	81.0%

Table 14.5 Characteristics of the Chadza II Clays

Firing Grade	Particle Size Distribution (%)			Range of Shrinkage	
	- 4 + 2.8 mm	- 2.8 mm +75um	- 75 + 53 um	Drying Shrinkage	Fir. Shrink
GB	2	44	54	6.1 - 10.2	1.3 - 4.3
SU	2	51	47	7.0 - 10.2	0.3 - 5.3
UD	2	52	46	6.8 - 11.4	0.6 - 1.9

NB.

— drying shrinkage is obtained after samples are fired to 375°C
— firing shrinkage at 1000°C

14.2 USES AND POTENTIAL DEMAND

Common residual clays are widely used as a building material in Malawi, especially for the construction of mud houses in rural areas. On the other hand, the population is also aware that fired (or burnt) bricks are of better quality for construction of buildings. Also, many people believe that burnt bricks are stronger than dry "green" (unburnt) bricks. Burnt bricks are favored, however, for their water-proof qualities, since they impart durability to structures where rainfalls are frequent. Dry "green" bricks, on the other hand, tend to lose their high dry-strength once they are wet, and wash away rapidly.

Residual clays may also be suitable for the production of roofing tiles, wall and floor tiles, claypots and vases, sanitary clay pipe and other earthenware. The ceramic properties of the clays makes them suitable for the production of simple refractory bricks for a variety of kilns.

Bricks may be divided into various groups as follows:

Common bricks, which have no particular finish on any surface and are generally intended for use on internal work or any which is to be covered, or where appearance is of secondary importance. These are the most commonly used bricks.

Facing bricks, which have a finished surface, either sanded or smooth textured. They may be uniform in colour or multi-coloured. They are used for facing buildings, and to provide a durable and pleasing finish.

Engineering bricks, which are dense and are used for

— walls or piers which have to carry heavy loads
— lining of concrete chimney shafts
— brick sewers and any type of walling which may be subject to exposure, abrasion or acid attack.

There is an unmet demand for **facing** and **engineering** bricks. In addition, there is often a chronic shortage of common fired bricks in most of the urban areas. The result is a high proportion of new houses are built with poor quality bricks, which are subsequently plastered with cement and lime. However, there is no data available on actual consumption of bricks in Malawi at present.

14.3 PROCESS OF BRICK PRODUCTION

The clay, after excavation, is stockpiled in an open area and moistened so that it "weathers" or "sours". In mechanized operations, the clay may be dug and immediately transported to a grinding mill where a small amount of water is added. The clay is finely ground, before passing on to the brick-making machines. (This method of brick production can be applied to the production of other clayware.)

For machine-pressed bricks, the clay is "pugged" (mixed) with water before moulding. The stages of brick production are summarized below in Fig. 22.

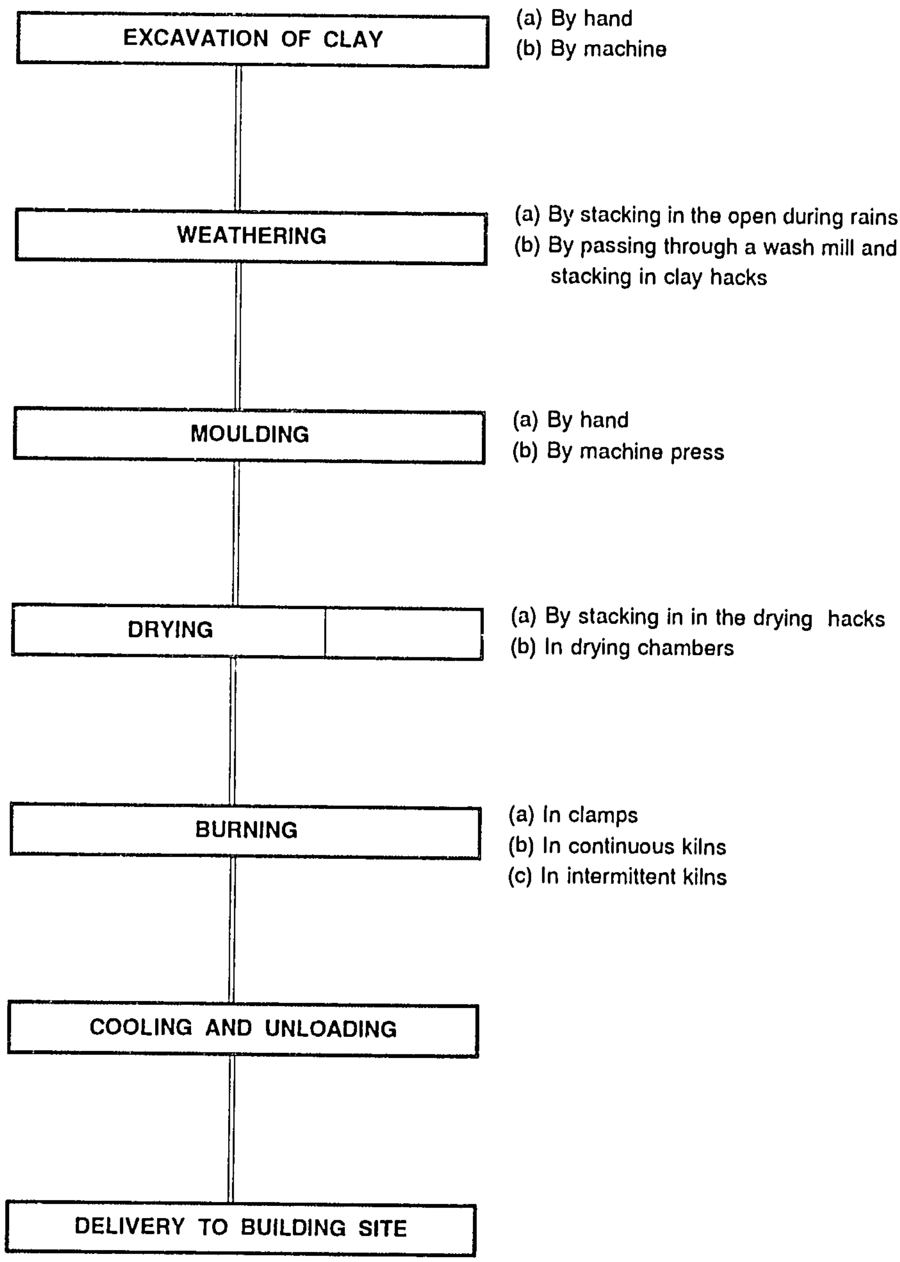
Brickmaking, however, causes a couple of environmental problems:

— The use of fuelwood to burn bricks has resulted in extensive deforestation. In the Southern and Central Regions, lorries travel hundreds of kilometres to fetch fuelwood. The alternative to fuelwood would be to use coal.

— The pits left after the excavation of clays often become health hazards. Simple and effective methods for rehabilitating the areas are available, but there is a need to train entrepreneurs to practice good mining methods. These methods include filling in the pits, re-forestation, terracing of the area and planting grass, fruit or vegetables.

Presently, brickmaking, especially by traditional methods, is often regarded as work for the illiterate and unsophisticated. Perhaps it is precisely because of this attitude that the quality of bricks continues to be poor. The potential for making good quality bricks is apparent. Appropriate technology, using a variety of techniques, is available for upgrading small scale mechanized brickworks.

Figure 22: Stages of Brick Production



15. KYANITE

15.1 RESOURCES AND USES

Kyanite is a member of the "sillimanite" group of minerals; the other members being sillimanite and andalucite. The minerals have the ability to be converted to the refractories, high-performance, mullite phase ($3Al_2O_3.2SiO_2$) at high temperatures. Brick and also monolithic applications occur within the steel and glass manufacturing industries. There is also a demand for kyanite in making cement kilns and in the ceramic industries.

Areas with concentrations of kyanite in Malawi are Ntcheu, Dedza, Lilongwe and Dowa. In Ntcheu, the kyanite occurs as lumps, weighing up to 10kg, in colluvium and metamorphic rocks at Kapiridimba Hill (Fig. 2). There are also minor deposits throughout the Kirk Range. Reserves of 300,000 tonnes are believed to be disseminated in hard rock at an average of 15 percent of content at Kapiridimba. Another 14,000 tonnes are in colluvial cover extending over the vicinity of the hill.

Kyanite is also widely associated with graphite schists and sulphide granulite gneisses in Dedza, Lilongwe (Malingunde) and Dowa (Chisepo). It is also widespread as pebbles in soils around Malingunde and Chisepo. No exploration work has been carried out on the kyanites in the Central Region.

15.2 POTENTIAL DEMAND

There are opportunities available to export lump kyanite, particularly if vermiculite is exported; most users of vermiculite also require kyanite as a refractory.

Malindi Potteries has already experimented with the production of refractory kyanite/ ceramic clay bricks as lining for their kilns. There is also a potential demand for kyanite/Linthipe clay refractory bricks in smelters in Blantyre.

15.3 EXTRACTION

There are sufficient kyanite resources in colluvium at Kapiridimba (at least 14,000 tonnes) to meet any potential local demand that might develop in the foreseeable future. The recovering of any additional kyanite would merely be by fossicking in the colluvium. Similarly, in Lilongwe and Dowa, the kyanite could simply be sieved from the soils and stockpiled for sale. The available resources would be sufficient to satisfy local demand.

16. CONCLUSION

This report largely outlines domestic inventories of "industrial minerals" that offer viable economic explcitation opportunities for small scale entrepreneurs. The mineral resources that can best satisfy local needs, as well as those for which an export potential exists, are also identified. Coal that can be extracted by small scale entrepreneurs, and can be used to meet low-level energy demands, is also included in this inventory. The use of coal is important since it reduces the demand for fuelwood for limestone mining and processing operations.

The "industrial mineral" resources which have the best potential for meeting existing in-country demand, are in order of priority:

— Limestone and dolomites
— Kaolinitic ceramic clays and glass sands
— Brickclays,
— Gypsum
— Rock phosphate
— Pyrite/pyrrhotite

The world demand for vermiculite, graphite and to some extent kyanite is high, and it is expected to remain so well into the 1990s. Vermiculite and "flake" graphite (or crucible graphite) have no competitive substitutes, so in-depth evaluations for the purpose of extracting and exporting these mineral resources should be undertaken.

Gemstones and ornamental stones have export potential. On the other hand, gemstone marketing is complex and there are no data available for evaluating the potential market. The amount of exports in the last year indicates that there is a growing market for Malawian stones in Europe and the U.S.A. Cutting the stones locally will increase the "value added" of the exports; this is an area of investment that has yet to be exploited.

Malawi's imports of minerals and mineral products have been increasing in the last 5 years, totaling over K15 million. However, these same minerals and mineral products can be produced locally, many by small scale enterprises. Small scale enterprises are appropriate since the national demand for most mineral commodities is relatively small. Small enterprises would fit in well in terms of economies-of-scale of production. However, for exportable minerals, both large and small scale operations could be mounted.

Accelerated development of the mineral sector is imperative, and it is evident that development will eventually take place with or without regulated assistance. Mining and mineral processing policies should be coordinated so as to assure environmentally-sound practices in mining, minerals processing and mineral-commodity manufacturing, and to assure that products of the best possible quality are offered for sale.

17. GLOSSARY

ball-mill
mill that uses steel or stone balls for pulverizing a material into very fine powder

beneficiation
processing of a mineral or ore to improve its quality

binder
material with cementing properties

bituminous
characteristic of coal; refers to degree of maturity

block and pillar mining
underground mining technique using rectangular grid patterns where pillars of ore rock are left to support the roof of mine tunnels

blunger
mixing tool used to achieve thorough mixing of clay slurries

brine
salt solution; also, trapped resevoirs of salt solutions

calcination (calcined)
burning of materials such as limestone or gypsum in order to expel gases or water and render the mineral usable

calcite
a calcium-carbonate material

chemical inertness
resistance to chemical changes. A chemical inert material will not react chemically with other materials under most circumstances.

efflorescence
(see evaporite)

ephemeral
(see evaporite)

evaporite
residual material left over from a solution after water is evaporated (usually under the sun's heat); also, efflorescence and ephemeral

exfoliate

"peeling" of rock due to changes in temperature resulting invariable expansion and contraction of different minerals in a given rock sample

filler

material added to a product to enhance its desirable qualities (for example, graphite added to paint to improve its easy spreading.)

fines

fraction of soil sample with small particles

fluvial

sediments deposited by wind-action

flux

additive to material that allows burning in kilns or smelting in furnaces to occur at lower temperatures

fossicking

digging through loosely consolidated soils and gravels using hoes, picks and shovels

fossil fuel

energy resources derived from organic matter buried and preserved for millions of years

foundry

factory where molten iron ore or steel is moulded

gneiss

metamorphic rock with bands or layers

grog

ceramic material that has been crushed, moulded and re-fired to increase its re-fractoriness

groundwater

water stored in the permeable parts of the earth; seperate from lakes, rivers or oceans

hacks

clay cuts, ready for placing in moulds

"horizon"

layer or bed in a soil or rock column

hydrothermal
intermixtures in hot solutions; geologically, a category of mineral resources deposited at the temperature of steam

igneous rock
rocks derived or crystallized from molten magma in the earth's interior

industrial minerals
generally, non-metallic minerals and mineral deposits, as defined in Section 1.2

in-situ
in place, (Latin)

insulator
material which has protective properties against heat, light, cold and/or electric current

jigger
tool used to shape ceramic-ware from clay

lacustrinal
deposited by lake water; of lake origin

laterite
an iron-rich tropical residual soil that hardens on exposure to the atmosphere

Mchinji Mining Technique
mining technique developed for mining of "dambo" glass sand in Mchinji District

mean head assay
average content of a chemical element (for example, carbon) from a bulk sample, before processing

metamorphic marble
limestone which has undergone metamorphism (i.e. altered under intense heat and pressure)

mica
a plate-like silicate mineral

micron (um)
one thousandth of a millimeter (1/1000 mm or 0.001 mm)

ndime
ground allotted for time piece work (Chichewa)

nsenjere
a tall and thick grass also known as "elephant" grass (Chichewa)

ore
payable mineral resource, if extracted and processed

overburden
soil or rock overlying a payable mineral resource

pediment
eroded and fairly flat surface on which sediments have been deposited

Precambian Period
geological period, 500 million years ago

quartz
silicon-oxide (SiO_2) mineral

refractory
material capable of resisting high temperatures (for example, ceramic clay enriched in alumina (Al_2O_3))

residual soils
soil resulting from the weathering (erosion) of rock which has not been transported (some material has been leached out)

smelter
factory where a mineral concentrate is melted and converted into a more readily usable metal

sovite
limestone of igneous origin, enriched in calcium carbonate

"sterilised" ground
ground overlying a mineral deposit upon which a man-made structure has been erected, rendering the mineral deposit inaccessible

stucco
a cement-based mortar used for plastering

terrazzo
mosaic masonry made by embedding small pieces of marble or decorative stones in mortar and polishing

travertine
limestone derived from percolating solutions, crystallised at about room temperature

tufa
porous carbonate rock

18. APPENDIX

APPENDIX A - 1

EXPLANATION OF MESH SIZE NOTATION

The 'mesh-size' notation used in this report is essentially British (see A-2 below).

Some size analysis data is presented as size ranges; for example as - 30 + 60 mesh. This notation may be explained as follows:

- there are 2 sieves, one of 30 mesh (openings of 0.5mm size) and the other of 60 mesh (0.25mm size). The smaller the openings a sieve has the greater the number of meshes it has in a unit area;
- when material is sieved through these sieves (the 30# above and the 60# below) the material that is coarser than 30# will be retained on the sieve - this is the +30# fraction. All the fine material will pass through the sieve, and this is the -30#. As some of the material that passes through the 30# sieve will also be finer than the 60#, it will also pass through the 60# sieve. Whatever is retained is the +60#. Hence we have a range of sizes established for the material: finer than the 30 mesh sieve but coarser than the 60 mesh, or in short -30+60 mesh' size fraction range.

APPENDIX A-2

COMPARISON OF U.S.A., TYLER, BRITISH, AND FRENCH STANDARD SIEVE SERIES

(only a selected range is presented)

U.S.A. (Standard)	TYLER (Mesh designation)	BRITISH (mesh number)	FRENCH (opening)
25.4 mm	1.0 inch		
16 "	0.624 inch		
8 "	2.5 mesh		
4 "	5 mesh		
2.0 "	9 mesh	8 mesh	2.0 mm
1.0 "	16 mesh	16 mesh	1.0 mm
500 microns	32 mesh	30 mesh	0.5 mm
250 "	60 mesh	60 mesh	0.25 mm
125 "	115 mesh	120 mesh	0.125 mm
63 "	250 mesh	240 mesh	0.063 mm
53 "	270 mesh	300 mesh	-
37 "	400 mesh		0.040 mm

— the term 'mesh' refers to the size of the nominal aperture (opening) in a sieve

— these sieve sizes and designations correspond to those proposed as an International (ISO) Standard. Most sieve analysis data for scientific and technical purposes are reported in these designations.

APPENDIX A-3

THE LEGAL FRAMEWORK OF THE MINERAL SECTOR FOR SMALL SCALE OPERATIONS

1. GENERAL

All minerals in Malawi are vested in the President on behalf of the people of Malawi.

For purposes of control, the Mines and Minerals Act of 1981 was enacted, repealing the 1937 Act. By this Act various licences are issued to prospectors and miners of all sizes i.e., small and large.

Applications for these licences are made to the Commissioner for Mines and Minerals who approves them in the case of Non-Exclusive Prospecting Licences (NEPLs), Mining Claims and Reserved Minerals License (RMI). Mineral Rights, i.e., the Reconnaissance Licence (RL), Exclusive Prospecting Licence (EPL) and the Mining Licence (ML) are approved by the Minister on behalf of the government of Malawi.

Prospecting, extraction, sales or export of mineral resources without a proper licence is not permitted. Illegal dealers can be sued in a court of law. However, the Act does not prohibit, except within limits of private land and other licenced areas, any Malawian from taking the purposes of his village life minerals which have been customarily taken by the community. this includes materials used for constructing houses and other earthenware items.

The Act classifies the minerals under three headings:

(i) Building and Industrial minerals - includes stone, sand limestone for lime and clay for brick making.

(ii) Precious and semi-precious stones - diamonds, gold, and all gemstones or other minerals designated under Reserved Minerals Regulations.

(iii) Other metallic and non-metallic minerals - the rest of the minerals including coal and petroleum.

The Commissioner for Mines and Minerals appoints officers to assist him with the administration of the Act. These officers have the right to enter without notice any areas operating under a Mineral Licence to check and inspect all activities. They can also request to have access to documents kept by the company. These officers are the Chief Mining Engineer and the Chief Geologist.

2. MINING TITLES

As already stated there are two sets of licences which are issued to both small and large scale operations.

2.1 SMALL SCALE MINING

These are mining operations undertaken by individuals or cooperatives which are fairly labor intensive utilising hand tool. Production methods are limited both by financial and technical expertise. These licences are as follows:

2.1.1 Minerals permits - issued to individuals for building and other construction materials by the District Commissioner of the area concerned. The interested person will approach the District Commissioner who will issue the permit for a special amount of mineral (the tonnage to be extracted). The fee will depend upon the tonnage requested. This fee varies per mineral and is as follows:

— clay or earth for bricks (per 1000 bricks)	10t
— raw limestone per tonne	20t
— building stone per tonne	5t

A mineral permit holder is not permitted to use explosives or any powered machinery in his operations. Underground excavations are also not allowed.

2.1.2. Non-Exclusive Prospecting Licence (NEPL) - this is suitable for individuals or firms who cannot afford large scale prospecting operations but they have the technical expertise. The interested parties will apply to the Commissioner for Mines and Minerals for an NEPL, which allows them to prospect in district (s) for specified minerals. The term for this licence is initially for one year but may be renewed for further one year periods. However, this licence *does not* allow any mining to be undertaken.

Only surface geological investigations, pitting and trenching is allowed. Fees for this licence are K20.00 per district for the initial term and K10.00 for any subsequent renewals.

Applicants for NEPLs should be Malawians or foreign nationals who reside in Malawi for not less than four years.

The prospector has to seek permission from the owners of the land before commencing his operations. When minerals of sufficient quality have been discovered, he should inform the Commissioner about the discovery. Lack of success should also be conveyed to the Commissioner. A prospecting report is expected at the end of the year from every prospector.

Once a mineral deposit has been discovered a claim should be pegged. Usually the Department of Mines assists prospectors in pegging claims. It is possible also for knowledgeable prospectors to do their own pegging or request the assistance of the agricultural extension officers in their areas. The maximum area to be pegged for each claim is two hectares or less and up to 3 claims can be pegged on one NEPL.

2.1.3 Mining Claim - these are issued only to holders of NEPLs after they have submitted their sketches and fees. When granted, the licence confers upon the holder the right to mine and sell his product. This licence is granted for one year periods which are renewable after submission of a satisfactory report every six months. All claims expire on the 31st of March each year and can be renewed effective the 1st of April. Fees payable are K35.00 and K20.00 for grant and renewal respectively.

It should be mentioned here that a claim does not preclude the use of land for grazing and farming by the landowners.

A mining claim may be cancelled when either the conditions are not being met or the mineral deposit can be exploited using large scale equipment.

2.2 LARGE SCALE OPERATIONS

Mineral Rights are granted to companies (or individuals) with financial resources and technical expertise to operate large capital intensive operations. A lot of planning is required to get the project off the ground. Once operational they operate for long periods and the corresponding revenues are higher.

Applicants for RLs and EPLs can be individuals, partnerships, companies or external operations. For MLs, all external corporations are required to register locally. Under section 10 of the Act, the Minister may sign an agreement to modify or complement any conditions stipulated in the Mineral Right Licence.

In general, the information required for the granting of a Mineral Right includes name(s) of director(s), their nationality, addresses, area and plans, required mineral(s), financial resources available to them, previous experience in the mining sector, and technical expertise. Above all they should be credible.

Applications are submitted to the Commissioner for the Minister's approval.

There are three kinds of licences required for large scale operations; Reconnaissance License, Exclusive Prospecting Licence, and Mining licence. Large scale operators should refer to the Minerals Act of 1981, and the Regulations, for specific information on how to apply for licences.

3. MISCELLANEOUS

3.1 ROYALTY

This is payable on all mining operations at 5% of the gross sales value for processed materials or 10% for the unprocessed material. In the case of gemstones these rates are for the cut and polished stones and rough and uncut stones respectively.

3.2 MINERAL EXPORTS

Those licence holders who wish to export mineral products should first apply to the Commissioner for an Export Permit before doing so. The fee for the permit is K5.00 in respect of all other minerals and K10.00 for gemstones.

3.3 RESERVED MINERALS LICENCE

This is issued to those people who wish to buy and sell gemstones. The fee is K300.00 for each application and the period is one year.

19. REFERENCES

Boynton, R.S. 1980. *Chemistry and Technology of Lime and Limestone.* John Wiley and Sons. New york. 2nd. Ed.

Charsley, T.J. 1972. The Limestone Resources of Malawi *Mem. Geol. Surv. Malawi.*

Chatupa, J.C. 1979. Limestone Reserves at chikoa and Livwezi in Kasungu. *Unpub. rep. Geol. Surv. Malawi,* T733.

Chatupa, J.C 1982. Glass sands Mining Trials at Mchinji. *Unpub rep. Geol. Surv.* Malawi.

Chatupa, J.C. 1977. Gemstone Occurrences in Mzimba. *Unpub. rep. Geol. Surv.* Malawi, T.685.

Chatupa, J.C. 1983. Preliminary Evaluation of Salt Resources in the Nchalo Area, Chikwawa. *Unpub. re. Geol. Surv. Malawi,* T.818.

Chatupa, J.C. 1988. Mineral Resources for Crop Production. *Unpub. rep. Geol. Surv. Malawi,* T959.

Garson, M.S. 1964. An Investigation of some Mica Pegmatites in the Mzimba District. *Rec. Geol. Surv. Malawi,* Vol. VI.

Habgood, F. 1962. An Account of the Recent investigation of Graphite Occurrences in the Central Region. *Rec. Geol. Surv. Malawi,* Vol. IV.

Kuzvart, M. 1984. *Industrial Minerals and Rocks.* Elsevier, Amsterdam.

Mndala, A.T. 1982. Glass Sands Reserves and resources in Mchinji. *Unpub. rep. Geol. Surv. Malawi,*

Phiri, F.R. 1982. The Refractory Clay of the Linthipe Area in Dedza District. *Unpub. Thesis for the Degree of Master of Science* - University of Hull, U.K.

Phiri, F.R. 1981. Exploration and Evaluation of the Brickclays Resources of Chadza Area, Lilongwe, *Unpub rep. Geol., Surv. Malawi,* T775.

Phiri, Y.R. December 1989. Legal Framework of the Mineral Sector. *Malawi Business,* pp.13-14.

Piper, D.P. 1982. The Kaolinitic Clay Resources of Linthipe Dedza District. *Unpub. rep. Geol. Surv. Malawi, T812*

Piper, D.P. 1986. An Assessment of the Flake Graphite at Katengoza, Dowa District. *Unpub. rep Geol Surv. Malawi*, T874.

Piper, D.P. 1982. The Resources of Clays Suitable for Brickmaking East of Bangwe, Blantyre. *Unpub. rep. Geol. Surv. Malawi*, T805.

Thatcher, E.C. and Wilderspin, K.E. 1968. The Geology of the Mchinji - Upper Bua Area. *Bull. Geol. Surv. Malawi*, 24, pp.56 - 64.

Thatcher, E.C. and Walter, M.J. 1968. The Geology of the South Lilongwe Plain and Dzalanyama Range. *Bull. Geol. Surv. Malawi*, 23, pp. 53 - 59.