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A Technical Discussion of Mining Operations in the Lime and Cement Industries of Zambia and Malawi

Volume I

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Thesis submitted to the University of Nottingham for the degree of Doctor of Philosophy

6th January 2000

ABSTRACT

This document constitutes a brief discussion of the total concept of mining limestone, particularly for lime and cement manufacture. Actual case studies in which the writer has participated have been used to demonstrate the methods used by the various operators and their attitude to matters such as the environment has been described.

The document has been written to be presented as suitable material for the Degree of Doctor of Philosophy, however, on reading several cotemporary theses which deal solely with the matter concerning the degree, the writer has chosen to produce a document that compiles material from a multitude of sources, including the writers own experience which he thinks may be of interest to mining students. The part of this document that complies with the requirement to "advance science" is in the use of explosives and the principles of rock breakage, this is the main area of the writers expertise and is to be found, in Chapters ten and eleven.

The method of blasting and the reasoning for its evident success, challenges some, and agrees with other, mathematical theorem that have been presented previously. Most mathematical theorem use either perfect models, or require so many variables that the accuracy of the maths becomes doubtful, because of this, their usefulness to the mining engineer is limited. Chapter eleven explains how explosives work in surface mining and identifies enhanced effects. The writer believes that these enhanced effects are the result of coincidences in the pulses of the shock waves.

The writer first noticed the effects of a shock wave on rock when designing huge blasts for strip mining of coal in Zambia, where the rock had to be totally shattered but remain in place, further experiments in the Falkland islands with spacing and timing, finally led to application in African limestone quarries. The blasting described at Chilanga has been designed to first shatter the rock then produce further breakage in the enhanced heaving process, in addition, the imperfect rock formation provides a perfect example of using explosives to blend the various grades of material.

Many photographs are included of the results of blasting and as the practice is still current, the readers are able to visit Zambia to examine the effects for themselves.

Jack Mills

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1.1.0 INTRODUCTION

1.1.1 Africa

Africa is the second largest continent, being smaller only than Asia and covering about one-fifth of the total land surface of the world. The continent is bounded on the west by the Atlantic Ocean, on the north by the Mediterranean Sea, on the east by the Red Sea and the Indian Ocean, and on the south by the Atlantic and Indian oceans. The total land area is approximately 30,365,000 square kilometres, and the continent measures about 8,000 kilometres from north to south and about 7,400 kilometres from east to west.

Figure 1-1 Map of Africa. Ref [55]

The continent is cut almost equally in two by the equator, so that most of Africa lies within the tropical region, bounded on the north by the tropic of Cancer and on the south by the tropic of Capricorn. Because of the bulge formed by western Africa, the greater part of Africa's territory lies north of the equator. Africa is crossed from north to south by the prime meridian, which passes a short distance to the east of Accra, Ghana.

In antiquity, the Greeks are said to have called the continent Libya and the Romans to have called it Africa, perhaps from the Latin aprica ("sunny") or the Greek aphrike ("without cold"). The name Africa, however, was chiefly applied to the northern coast of the continent, which was, in effect, regarded as a southern extension of Europe. The Romans, who for a time ruled the North African coast, are also said to have called the area south of their settlements Afriga, or the Land of the Afrigs which is the name of a Berber community south of Carthage.

Africa contains an enormous wealth of mineral resources, including some of the world's largest reserves of fossil fuels, metallic ores, gems and precious metals. This richness is matched by a great diversity of biological resources that includes the intensely lush equatorial rain forests of central Africa and the world-famous populations of wildlife of the eastern and southern portions of the continent. Although agriculture still dominates the economies of most African countries, the exploitation of these resources has become the most significant economic activity in Africa in the 20th century. Climatic and other factors have exerted considerable influence on the patterns of human settlement in Africa. While some areas appear to have been inhabited more or less continuously since the dawn of humanity, enormous regions, most notably the desert areas of northern and southwestern Africa have been largely unoccupied for prolonged periods of time. Because of this, although Africa is the second largest continent, it contains only about 10 percent of the world's population and can be said to be underpopulated. The greater part of the continent has long been inhabited by black peoples, but in historic times there also have occurred major immigrations from both Asia and Europe. Of all foreign settlements in Africa, that of the Arabs has made the greatest impact. The Islamic religion, which the Arabs carried with them, spread from North Africa into many areas south of the Sahara, so that many western African peoples are now largely Islam.

1.1.2 Overview of Malawi and Zambia

Malawi and Zambia share a common land border, the climates are similar, with the humidity in Malawi being raised slightly because of evaporation from the many lakes. Both countries speak the similar languages of Chichewa and Nyanga, this being the lingua franca in Lusaka, the area to which many migrants from Malawi have moved. Both countries have mixed tribes of the same Bantu heritage. Artisans of these lands often seek employment as guest workers in South Africa and in each others countries.

Economically, the differences between Malawi and Zambia were initially more striking than the similarities; Malawi was dependent on plantation agriculture, while Zambia depended on the export of copper. Both countries prospered in the first years after independence, but Zambia's economy declined dramatically with the collapse in the world price of copper. The weaknesses in Malawi's economy were only to become manifest a decade later. Banda and Kaunda differed most, however, in their relations with the liberation struggles in the rest of southern Africa. In the hope of gaining control of northern Mozambique, Banda negotiated with the Portuguese and withheld assistance from Mozambican nationalists, who during the 1960s were beginning their military campaign. He also established close ties with the white South African government, which supplied much of Malawi's direct aid. Malawi thus became the foundation of South Africa's "outward-looking" foreign policy in Africa.

Although initially Zambia was as tied economically to Rhodesia and the Lusophone colonies, Kaunda backed the resistance movements there and supported UN sanctions against the white government in Rhodesia. He paid a heavy price. The sanctions closed Zambia's major trade and transportation routes through Rhodesia, and although alternate routes were established through Angola and new east-west lines through Tanzania were constructed by the mid-1970s, subsequent armed incursions from Rhodesia and South Africa and continued warfare in Angola and Mozambique disrupted the costly new trade and transportation lines. Zambia's economy contracted by nearly half between 1974 and 1979, and its collapse was prevented only by intervention from the International Monetary Fund (IMF). By the end of the 1970s Zambia was one of the poorest countries in Africa. Poor peasants made their way to the towns, and this contributed to high levels of unemployment, social violence, and crime. Despite the end of the war in Rhodesia, which had been perceived as the main constraint on the economy, Zambia's economy deteriorated further in the 1980s. Elections were held in 1991, and the newly formed Movement for Multiparty Democracy under the leadership of the trade unionist Frederick Chiluba swept to victory.

During the late 1970s Malawi, long believed to have successful rural development policies, also faced economic crisis. The lean years of the 1980s saw a widening gap between rich and poor, which was worsened by Banda's support of the Mozambican insurgency movement, Resistance National Mozambique, better known by the abbreviation Renamo who fought against the Frilimo government and the influx of vast numbers of refugees from the civil war in Mozambique. The late nineteen-eighties were dominated by political unease, resulting from an unofficially led campaign against the dominance of northerners in the countries civil service and education. By the 1990s an ailing Banda was confronted by a rising tide of popular and external pressure and was forced to allow multiparty elections, which were held in 1994 and won by the opposition United Democratic Front.

Both of these rulers chose to dominate every aspect of running their respective countries have now lost their power and Zambia is entering a new era of development, whereas, Malawi, having a lower standard of education, is having a difficult time adapting to democracy and remains on a downward financial spiral. In 1989 the World Bank (officially, the International Bank for Reconstruction and Development, or IBRD) issued a landmark report titled Sub-Saharan Africa: From Crisis to Sustainable Growth. It warned that if Africa's slide into underdevelopment continued, some countries would soon find themselves in worse poverty than the most stricken Asian lands.

There are 160 countries on the United Nations' annual development index, a measure of comparative economic and political progress. Thirty-two of the lowest forty are in Africa. Since 1980, the external debt of sub-Saharan Africa has tripled to about $174 billion. Both populations merit better than they have, in Zambia this will soon happen, in Malawi there remains much work to do, especially in education.

According to World Bank projections, the population of sub-Saharan Africa's will rise from the current 548 million to 2.9 billion by the year 2050. The disease of Acquired Immune Deficiency Syndrome (AIDS) is devastating the populations. It has hit cosmopolitan educated elite as hard as the villagers. The direct and indirect costs of this disease to the community are causing extreme difficulties, this is especially true where a company needs a young skilled workforce, as it would seem that these are the group who are particularly affected by the disease. In the opinion of the writer, most of the people of Zambia remain as they always have been, welcoming and friendly, accepting foreigners as people who will help improve their country, while most of the people of Malawi, particularly the ones who have received education, are sullen and quick to resort to violence.

1.1.3 Geology of Africa

Africa is a massive crystalline platform of ancient granites, schists, and gneisses, the oldest of which are more than 3.2 billion years old. They contain rich and varied minerals, including copper, zinc, lead, gold, uranium, diamonds, limestones, coal and many other more rare metals. The working of limestone is a basic industry which is essential to economic, industrial and agricultural development of both the nations.

Present-day Africa was once part of the super-continent known as Gondwanaland, which also included Australia, Antarctica, South America, Madagascar, and the Indian subcontinent. During the Late Jurassic and Early Cretaceous periods these landmasses drifted apart, but compared with the other continents, Africa remained relatively stable. South America was separated from Africa approximately 80 million years ago and Arabia split off about 20 million years ago. As Gondwanaland fractured and drifted, Africa acquired its scarp-dominated coastline, interior seas that occupied shallow depressions emptied, and rivers carved steep gorges and formed new courses. Volcanic outpourings covered vast areas of east and southern Africa. As the Cretaceous Period came to an end, the sedimentary rocks of northwestern Africa were severely folded and uplifted in a series of orogenic phases to form the Atlas Mountains, which geologically are part of Europe's alpine system. Epi-continental seas extended across North Africa linking the present Mediterranean with the

Gulf of Guinea, which in their wake left extensive deposits of limestone and sandstone.

Gigantic meridian fractures occurred in the African shield producing the Great Rift Valley. As tensional forces wrenched the land apart, some land blocks sank while others rose and tilted, allowing volcanic materials to break the surface. Mount Kilimanjaro and Mount Cameroon were formed this way. During Gondwana's last 100 million years of existence, southern Africa was covered by the Dwyka ice field, which scoured the crystalline surface and deposited tillites hundreds of metres thick. Following the glacial age, southern Africa became progressively drier, and a lengthy period of sedimentary accumulation began in the Kalahari and Karroo basins. These sediments in turn were covered by outpourings of basalt as much as 7,600 metres thick.

Southern Africa has thousands of outcrops of limestone, these are of varying quality and many deposits have been altered by tectonic activity and metamorphosed into marble. Most of the limestones are dolomitic with pure calcitic deposits being relatively uncommon. Both Zambia and Malawi have massive deposits of both dolomitic and calcitic limestones. [ref 47, 55, 113]

1.2.0 THE REPUBLIC OF ZAMBIA

1.2.1 Geography

Zambia is totally landlocked and has a long land border on the west with Angola but is divided from its neighbours to the south by the Zambezi River. To the southwest is the thin projection of Namibian territory known as the Caprivi Strip, at the eastern end of which four countries (Zambia, Namibia, Botswana, and Zimbabwe) appear to meet at a point, but the precise location of the meeting is contested. Man-made Lake Kariba now forms part of the river border with Zimbabwe. Mozambique is Zambia's neighbour to the southeast, Malawi to the east, and Tanzania to the northeast. The long border with the Democratic Republic of Congo starts at Lake Tanganyika, crosses to Lake Mweru, and follows the Luapula River to the Pedicle, a wedge of Zairean territory that cuts deep into Zambia to give the country its distinctive butterfly shape. Westward from the Pedicle the frontier follows the Zambezi-Congo watershed to the Angolan border, passes by Zaire to the north, Tanzania and Malawi to the east, Mozambique, Zimbabwe, Botswana, and Namibia to the south and Angola to the west.

The country is divided into nine provinces: Lusaka, Luapula, Northern, Eastern, Western, Southern, North-Western, Central and Copperbelt. Lusaka is the capital city, (pop. 982,000), regional towns are Ndola (500,000), Kabwe (381,000), Kitwe (348,000), Chingola (161,000), Mufulira (146,999), Luanshya, Livingstone (population figures from 1992 census).

Climate

Although Zambia lies within the tropics, its climate is modified by its altitude and is generally favourable to human settlement and comfort. The marked seasonal pattern of rainfall is caused by the north and south movement of the inter-tropical convergence zone (ITCZ), following the apparent movement of the Sun. In January the ITCZ is in its southernmost position, and the rainy season is at its peak; by June it has moved north, and the weather is dry. Summer rains reduce the high temperatures that might be expected at this time.

Rainfall is concentrated in just five months and is highest over the Bangweulu basin with more than 1,500 millimetres per annum and along the Congo-Zambezi watershed, declining southward to the middle Zambezi valley, which averages less than 900 mm. The Luangwa valley is also drier than the surrounding plateau. Rainfall is less reliable in the drier regions, and failure of the rains in the south and southwest periodically brings famine to these areas.

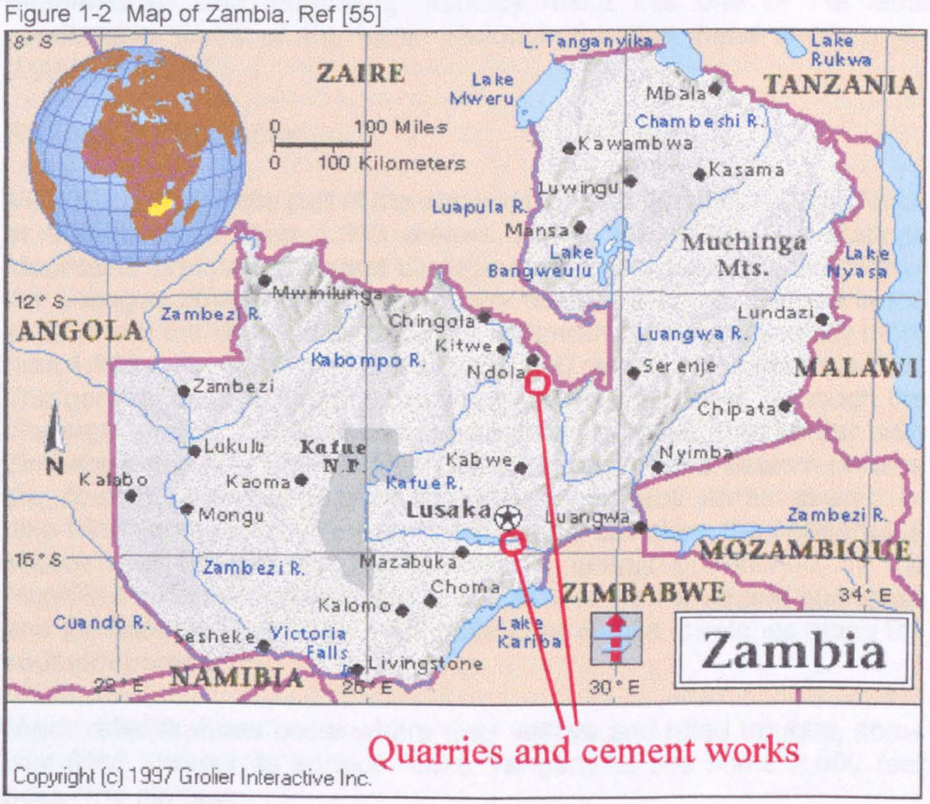
Temperature is modified by altitude, with mean daily maximum temperatures higher than 38 degrees occurring only in the Luangwa valley and the southwest. The coolest area is the high Nyika plateau on the border with Malawi. During the cold months of June and July, the area west of the country is coolest, with mean minimum temperatures mostly less than 7 degrees centigrade. Sesheke, in the southwest, has frost on an average of 10 days per year.

Average annual hours of sunshine range from more than 3,000 in the southwest to less than 2,600 on the eastern border. Winds are predominantly easterly-southeasterly, although in the rainy season winds blow from the northwest and north. Wind speeds are rarely strong enough to cause damage.

Although the major contrast is between the rainy season and the drier months, three seasons may be identified.

The warm wet season lasts from November until April. The movement into Zambia of the moist Congo air mass from the northwest heralds the start

Figure 1-2 Map of Zambia. Ref [55]



of the rains, in the north usually in early November and toward the end of the month around Lusaka. The change from dry to wet conditions is transitional rather than abrupt. December and January are the wettest months. Cloud cover lowers maximum temperatures but also limits radiative heat loss at night, so that minimum temperatures are kept comparatively high. Relative humidity values are high, typically 95 percent in early morning but declining to 60-70 percent by midafternoon. Sunshine is surprisingly frequent, Lusaka averaging six hours of sunshine per day in January. Rainfall declines rapidly in April with the northward movement of the ITCZ.

The cool dry season lasts from April until August. The sun is overhead in the Northern Hemisphere, so temperatures are low; July is usually the coldest month. Clear skies allow maximum radiation and result in especially low temperatures on calm nights, with occasional ground frost occurring in sheltered valleys.

The hot dry season lasts from August until November. This is a period of rapidly rising temperatures; just two months separate July, the coldest month, and October, usually the hottest, although if the rains are delayed November can be hotter. Usually by mid-October cooler oceanic air moves in, leading to increasing humidity and cloud formation. High temperatures and increasing humidity make this one of the least comfortable times of the year, although the first rains wash away dry-season dust.

Rivers and topography

Most of Zambia forms part of the wooded high plateau of this part of Africa at 900 to more than 1,500 metres above sea level; The Mafinga Mountains form part of a great escarpment running down the east side of the Luangwa River valley. The country rises to a higher plateau in the east, where the Nyika Plateau on the Malawian border is generally more than 1,800 metres, rising to more than 2,000 metres in the Mafinga Hills. The general slope of the plateau is toward the southwest, although the drainage of the Zambezi turns eastward to make the border with Zimbabwe and flow to the Indian Ocean. In central and eastern parts of the country, downwarping of the plateau surface forms swamp or lake-filled depressions. In the north are three great lakes, the Tanganyika, Mweru and Bangweulu. The country is deeply entrenched by the magnificent Zambezi River (and its tributaries, the Kafue and Luangwa) and the Luapala River. The man made Lake Kariba stretches along the southern border.

Major relief features occur where river valleys and rifted troughs, some lake-filled, dissect its surface. Lake Tanganyika lies some 2,000 feet below the plateau.

- In the north the major rivers are the Chambeshi and the Luapula, which rises in Lake Bangweulu. Both the Luapula which drains the

Bangweulu basin into Lake Mweru and Lake Tanganyika are tributary to the Congo.

- In the south lies within the Zambezi basin with the Zambezi River and its two main tributaries of the Kafue River which drains the Lukanga Swamp and Kafue Flats and the Luangwa River which being mostly confined within its rift trough feeds the Bangweulu Swamps and the Kafue Flats. Both of these are wetlands of international importance.

Flora and fauna

Flora: Forest, mostly savannah bushveld, covered 323,000 sq. km. (43% of the total land area) in 1990, decreasing at an average 1.1% pa. (1981-90). The high eastern plateau consists of open grassy plains with small trees and some marshland. The government is anxious to control use of wood and charcoal, still the main domestic fuels in both rural and urban areas, as seven million cubic metres of fuel wood are consumed each year, equivalent to felling 135,000 ha of indigenous forest.

Fauna: Zambia has a wealth of wildlife, including big mammals and numerous species of antelopes. There are 19 National Parks and 34 game management areas, about a third of the country's area. South Luangwa has one of Africa's largest elephant populations. Kafue National Park has the largest number of antelope species of any African park, including the rare red lechwe, an aquatic antelope; it is also a home of the fish eagle, Zambia's national emblem. Decline in animal numbers has been slowed by the government's commitment to wildlife conservation, and the enforcement of measures against poaching and weapon-carrying in the conservation areas.

People

Relative to the country's area of 752,614 square kilometres, Zambia's population at 9,300.000 (1995) is small with about a fifth of the population living in the Copperbelt and gives a population density of 12.3 people per square kilometre. Probably due to early growth of the copper mines, Zambia has one of Africa's largest urban populations at 43% (1993). The population growth rate is estimated at 3.3% per annum (1985-95) with an average 5.9 births per woman, or 45 per 1,000 (1996). Half of the population live in the four provinces along the Line of Rail. The movement of people from the rural areas into the towns was particularly marked after independence. Government efforts to reverse the flow have had only limited success.

Although most Zambians are of Bantu origin, the people are ethnically diverse, complex patterns of immigration have produced wide linguistic and cultural variety. Eighty different languages or dialects have been identified in Zambia; they can usefully be considered as comprising 14 groups, of which the Bemba group (including Bemba, Tonga, Malawi, Lozi of the west, and Lunda) is the most widespread, accounting for more than one-third of the population. Bemba are found mostly in the northeast and Copperbelt. Second in importance is the Nyanja group of Eastern Province and Lusaka (about 17 percent), while the Tonga group of Southern Province is about 15 percent. Some San and Twa are still to be found. The Luba and Lunda peoples came during the 14th-15th century, from what is now the Democratic Republic of Congo and Angola. The Bemba are descendants of the Luba and the Lozi of the Lunda. The Ngoni warrior tribe came north from South Africa to Eastern Zambia.

There are seven official vernacular languages: Bemba, Nyanja, Lozi, Tonga, Luvale, Lunda, and Kaonde, the latter three being languages of the North-Western Province. The official and commercial language is English, in which almost all of the population can at least to some degree converse. There are small minorities of Europeans and Asians.

Life expectancy is 49 years, 48 for men and 50 for women (1996). At independence in 1964, life expectancy was only 40 years. Infant mortality rates fell from 141 per 1,000 live births in 1965 to 109 in 1995. There was one doctor per 6,959 inhabitants in 1985. Four in five children are immunised against preventable diseases. However, malnutrition among mothers and children is high, for children averaging 27% (1985-93). Government programmes implemented in 1995 to prevent malnutrition included provision of Vitamin A supplements to lactating mothers and young children. The health service has suffered under cutbacks required by economic adjustment programmes. Malaria is the leading cause of hospital admissions. The incidence of tuberculosis is rising – from about 30,878 cases in 1994 to about 37,004 in 1995 – most new cases also proving HIV-positive. There were outbreaks of cholera in 1990-93 and 1996.

The disease of HIV is rampant and Zambia was one of the first countries to admit the severity of the AIDS pandemic with reports of up to 90% infection being reported and it is having a dramatic effect on the population. The government and industry are providing the public with free contraceptives and AIDS prevention, control and management programmes are given prominence in all health programmes.

Religion

Zambia is predominantly a Christian country (66%) this is often blended with traditional beliefs and few have totally abandoned all aspects of traditional belief systems. The Roman Catholic church is today the largest single denomination, but Anglicans, Baptists, Methodists, and others are well established. The new President is a profoundly intense, born again Christian, and perhaps because of this, the growth of American style fundamentalist churches has been particularly noticeable since independence. The Asian community is predominantly Hindu, the rest mainly Muslim. There are relatively few Muslims in the indigenous population.

Education

The adult literacy rate is relatively high, at 78% – male 86% and female 71% (1995), but the education system has difficulties in keeping pace with rapid population growth. In 1995 there were 4,000 primary schools, accommodating 1,808,560 pupils. Primary school enrolments increased by 4.3% in 1995, but only 55% of 7-year-olds were admitted to grade one, and 15% of the primary school age group were not enrolled in any school. Access to secondary education is being expanded by upgrading some primary schools into basic schools, which also provide secondary education. The University of Zambia was established in 1965, and the Copperbelt University in 1986. There is a shortage of lecturers at universities and technical training institutes.

Infrastructure

Road: The national road network reached 37,000km by 1984, 40% being all-weather roads, but road maintenance declined after 1980 and the network is currently being upgraded. Roads can be hazardous during the rainy season. The passenger transport system is privately operated, following the closure of the United Bus Company of Zambia in December 1994. To encourage the private sector, the government suspended duty on imported transport vehicles in 1994 and 1995; 115 new transport companies were registered in the first half of 1995. Rail routes run from Livingstone in Southern Province through Lusaka and Central Province up to Chililabombwe, the last town on the Copperbelt. The Beira railway line through Zimbabwe to Mozambican ports is in operation, but the Benguela Railway is closed because of the upheavals in Angola and the Democratic Republic of the Congo. The Tanzania-Zambia Railway (Tazara) has been troubled by delays on the line and security at the port of Dar es Salaam, and upgrading has been a priority for the Southern African Development Community. The railway authority was suffering financial difficulties in 1996.

Air: There are international airports at Lusaka, Livingstone, Ndola and Mfuwe, run by the National Airports Corporation Ltd, and 18 commercial airports. Zambia Airways was closed in 1994. Several international airlines call at Lusaka airport. Private airlines serving domestic and regional routes include Aero Zambia and Zambian Express.

Forestry and Fisheries

The old men say that the Southern Province can feed all of Zambia and

Zambia can feed the whole of Africa. Agriculture normally contributes some 20% to Zambia's GDP. Production varies, however, as the country is vulnerable to drought. Rains (and output) were poor in 1995, better in 1996. Zambia has the potential to grow a wide range of crops. Only about 20% of the 9m ha of workable arable land is planted, mainly with maize. Other crops are sorghum, cassava, millet, sunflower, groundnuts, cotton, tobacco, sugar cane, paddy rice, soybeans, vegetables. Agricultural development policies since 1989 have aimed to expand the area cultivated and introduce new crops, such as coffee and sugar. Production of maize, the main subsistence crop, has declined in the 1990s as commercial farmers switch to more export-oriented crops; traditional farming accounts for 70% of annual maize output. In poor years, domestic maize production is insufficient and maize is imported, mainly from South Africa and Zimbabwe. A fertiliser shortage caused maize production to fall by 40% in 1996/7. Groundnuts are exported on a small scale. Cotton production rose to nearly 60,000 tons in 1992/3; cotton is the main cash crop for small farmers. Soya beans are another important cash crop. Livestock production has been hit by drought and by an outbreak of African swine fever in 1993. Around 85% of the national herd is still held by traditional farmers.

Tourism

Zambia earns about US$20m p.a. from tourism, and the industry is developing rapidly. The country's attractions include some of the world's best game parks and the Victoria Falls, and efforts are being made to develop other areas, such as Lakes Kariba and Tanganyika. Private investment in Zambian tourism rose from ZK1.9bn in 1994 to ZK25.5bn in the first 10 months of 1995, representing a more than 15-fold annual increase. The Ministry of Tourism manages the Zambia National Tourist Board and National Hotels Development Corporation. A ZK190m investment programme aims to improve operation of the sector and to expand higher-quality tourist accommodation.

Energy

The development of hydroelectricity, based on the Kafue Gorge scheme, has allowed the country, when its systems are working, to become a net exporter of electricity to Botswana, the Congo and Zimbabwe. About 70% of non-household power is provided by electricity, 20% by oil and 10% by coal. Oil is imported, mainly from the Middle East, and supplied by the Indeni refinery, operated by Tazama Pipeline (two-thirds owned by the Zambian government, one third by Tanzania). Coal output has fallen since 1980 and domestic consumption of coal has declined. The copper industry is by far the largest consumer of energy. A rural electrification programme has been started and ten projects were completed in 1994.

Manufacturing

Early estimates of manufacturing output in 1997 indicate that the industry, which had been in decline, with businesses closing as tariffs against imports were removed, were recovering. Output had fallen by 4.5% to ZK525.8m in 1995, with the sharpest falls in paper and paper products, chemicals, rubber and plastics. Other manufactures include wood and wood products, fabricated metal products, food, beverages, tobacco, textiles and clothing, leather. Many clothing enterprises closed after the lowering of tariffs against imports. Manufacturing contributed 37% to GDP in 1995.

The Legal system

The Zambian legal system is based on English common law. The court system consists of the Supreme Court, the High Court, subordinate magistrate's courts, and local courts. Zambia is a signatory to several international treaties for the protection of foreign investment and the settlement of investment disputes. The law is enforced fairly and a foreigner can expect to be treated well, the police are well trained but very under-resourced.

Affiliations

Zambia is a founder member of the Southern African Development Community (SADC), which is working towards a regional common market among its member countries and includes the Southern African Transport and Communications Commission (SATCC), whose activities in upgrading rail transport are of vital importance to the Zambian economy. It participates in the Association of Southern African States (ASAS), a group within SADC, charged with handling peace and security issues. It is also a member of the Common Market for Eastern and Southern Africa (Comesa), the Organisation for African Unity (OAU), and the ACP group of country signatories to the Lomé Convention.

1.2.2 Political history

The Republic of Zambia is located in southern central Africa and was visited by the Portuguese in the late 18th century and by Livingstone in 1851. In 1924, as the then Northern Rhodesia, the country became a British protectorate and together with the former kingdom of Barotseland (now Western Province) was, at the request of its ruler, taken under British protection.

In 1953, the country together with Southern Rhodesia (now Zimbabwe) and Nyasaland (now Malawi) became part of the Federation of Rhodesia and Nyasaland. This federation was dissolved in 1963. Northern Rhodesia became in 1964 the independent Republic of Zambia with Dr Kenneth

Kaunda, leader of the United National Independence Party (UNIP), as its first president and remained within the Commonwealth.

By 1964, Zambia was, excluding South Africa, the richest country in Africa south of the Sahara. It had $1.1 billion in foreign reserves, and the world's second largest copper-mining industry. It also had emeralds, other gemstones and immense fertile areas. In 1970 President Kenneth Kaunda made the still unfulfilled promise, that every Zambian would receive a pint of milk and an egg a day. Between 1964 and 1972, when it was declared a one-party state, Zambia was troubled with frequent outbreaks of violence because of disputes within the governing party and conflicts among the country's more than 70 tribes.

In the early '70s OPEC multiplied the price of oil several fold, and world copper prices tumbled, a disaster for Zambia. As foreign debt began to mount, copper production dropped from the rate of 700,000 tonnes at independence to less than 450,000 tons today. Despite his imposition of strict economic policies, Kaunda was re-elected unopposed in 1983 and again in 1988, for a sixth consecutive term.

Within Zambia, there was political discontent. The government created a one-party state (lasting from 1973 until 1991) in an unsuccessful attempt to strengthen national unity. A coup plot in 1980 involved local business leaders and the Governor of the Bank of Zambia. Several trade union leaders, including Frederick Chiluba (then Chairman-General of the Zambia Congress of Trade Unions), were detained during a wave of strikes in 1981, unions now having become the main focus of opposition to UNIP. Popular discontent was fuelled by the effects of IMF-backed recovery programmes: riots on the Copperbelt followed the announcement in 1986 of the removal of maize meal subsidies.

In 1987, Zambia broke with the IMF, though domestically popular, this move brought strong international disapproval and a slowdown of aid. In 1989, the government devalued the currency by 50%. For three days, the country ceased trading, it closed the borders while introducing new currency notes and coins to counteract the black market, the population was presented with a very short time to change the old notes and limited to the number they could change, and after the time expired so did the old notes. It also reduced maize subsidies, removed price controls and raised interest rates, and a reconciliation with the IMF took place in March 1990.

From 1986, demonstrations, sometimes violent, against food price increases began to take a more political form, leading to demands for a more democratic system of government. In July 1990, the 17-year ban on organised opposition groups was lifted. Three days later, the Movement for Multi-Party Democracy (MMD) was founded. The MMD was formally registered as a political party in January 1991. The elections in October 1991 gave a substantial majority to the MMD and its presidential candidate, Frederick Chiluba, bringing to an end the 27-year leadership of Kaunda.

The 1991 constitution provides for a multiparty state. The state president was to be elected by universal suffrage for a five-year term, renewable only once, this has since changed. The president governs with an appointed cabinet and is advised by the House of Chiefs, consisting of chiefs from the country's nine provinces. There is a single-chamber, 150-member national assembly, also elected by universal suffrage for a five-year term.

1.2.3 Economy

The unit of currency is the kwacha (ZK) meaning rising sun or new beginning, introduced in 1968. Tied to the US$ until July 1976, it has lost value since then. The average exchange rate in 1993 was ZK452.76 to US$1; the rate on 5 December 1997 was ZK1,407:US$1. GNP: Zambia is now classified by the World Bank as a low income country (in the 1980s it rated as lower-middle income). Total GNP for 1995 was US$3,605m with GNP per capita of $400. In real terms, GNP per capita declined by an average 1.0% p.a. over the 1985-95 period. Real GDP is estimated to have expanded by 6.4% in 1996 to Zk4,979.7bn, after contracting in the five previous years.

Zambia has been an exporter of refined copper for more than 400 years. Copper being one of the benefits derived from the great mineral wealth of the central African plateau.

The plateau deposits include other metals such as gold, lead, zinc, tin, cobalt, iron and minor amounts of exotic and precious metals, gemstones such as amethyst, tourmaline, emeralds etc. and basic minerals such as coal and limestone. Copper, known as the "red metal" was, and still remains the principal source of foreign earnings (90%). With Zambia Consolidated Copper Mines (ZCCM) producing 8% of the worlds copper. ZCCM, recently privatised, was a 60% state owned corporation operating a fully integrated copper industry on the Zambian Copperbelt. Copper continues to dominate exports (almost 60% in 1996, US$568m), with cobalt also significant (19%, $193m). The country has almost all metals, most of which have been only marginally exploited, exports consist of, skilled people, copper, cobalt, zinc, emeralds, cement, sugar, flowers, some agricultural products and tobacco. Privatization of the state-owned economic structure is an integral part of the country's new policy. The government plans to continue in its policy to unbundle state-owned properties, price them realistically, and offer enhanced investment incentives, including guarantees allowing profits to be taken out of the country and protection against expropriation, although good in principle, by the end of 1998 this had still not been completed.

Crude oil is the largest single import; others are fertilisers and sometimes electricity. The main export partners are Japan, Saudi Arabia, Thailand, India and the main import partners are, South Africa, Britain, Zimbabwe, Japan. The trade balance maintained a small surplus between 1986 and 1995, but in 1996 exports were officially estimated to be $975m and imports $990m. There is a heavy trade imbalance with South Africa which has particularly hit Zambia's manufacturing sector. Notwithstanding its great mineral wealth, the economy remains totally dependent on the donor community, between 1980 and 1990, the country's average per-capita income declined by 4.9% a year. Of each $3.00 spent in the capital budget $1.00 is donor financed and of each $2.00 in the revenue budget $1.00 is donor financed. However, in 1995 the country finally earned the right to borrow again from the International Monetary Fund (IMF) and under an Enhanced Structural Adjustment Facility (ESAF), agreed between the government of Zambia and the IMF, Zambia will receive US$1.4bn in funding from a group of donors. This deal, and the IMF's praise for the government's recent economic policy, encouraged donors to pledge $300m for 1996, plus a similar amount in project and commodity support. The largest donor is Japan, followed by Britain, Germany and Norway. Zambia received US$718.6m in official development assistance in 1994.

In relation to its GNP, Zambia is rated by the international financial institutions as an HIPC (Heavily Indebted Poor Country). Total external debt was US$6.943bn in 1992 (equivalent to 242.5% of GNP). It fell slightly in 1993, was estimated to have risen again to more than $7bn in 1995. Of this, 38% was long-term debt to single-country donors. Zambia has been repaying debt arrears and benefiting from debt reschedules, as well as some cancelling of debt. In 1996 the Paris Club of creditor nations rescheduled its official bilateral debt.

Despite its adherence to IMF programmes, economic success continues to be elusive. Mining, agriculture and manufacturing performed indifferently in 1995 resulting in no change in gross domestic product (GDP). Improvements were expected after 1996 with a real growth of 5% per annum. Inflation is expected to gradually reduce from the average of 50%. In 1996, the budget contained public expenditure, but relaxed the customs and excise and VAT regimes to the benefit of the mining industry. Tourism receipts for international visitors in 1989 were $5 billion. Tourism is in an early stage of development, however, and considerable potential for foreign exchange earnings exists at the country's game parks (especially South Luangwa Valley) and at Victoria Falls.

The situation can be summarised by stating that; Zambia was one of the most prosperous countries in sub-Saharan Africa until its economy foundered with the slump in world copper prices in the mid-1970s. The country's transport network was also crucially disrupted by civil unrest in the neighbouring countries of Angola, Congo, Mozambique, Namibia, South Africa and Zimbabwe. The economy remains vulnerable to fluctuations in copper prices, and to drought. The early 1990s were a difficult period, the impact of a two-year drought being exacerbated by bank failures and poor revenue performance. The government launched an economic reform programme with substantial divestment of state enterprises in 1992: by October 1996, one third of the almost 300 companies had been sold off. The government operates a tight fiscal policy, which has brought inflation down sharply, despite several poor maize harvests. After reaching a peak of 187% in 1993, inflation fell to 53% in 1994 and 45% in 1996.

The government offers strong incentives to encourage inward investment. The 1991 Investment Code allows 100% retention of foreign exchange earnings for the first three years, and gives investors an attractive range of exemptions from tax and duties, as well as guarantees. The 1993 Investment Act made mining a priority and taxed new investors 15% on their profits. Despite severe economic difficulties, direct foreign investment increased through 1995, reflecting investor confidence in government policies. A 'one-stop' investment centre, introduced in 1992, has streamlined the investment process.

1.2.4 Mining

Copper is Zambia's main export product, valued at US$830m in 1993, falling to $568m in 1996. Copper production fell to a record low of 307,800 tonnes in 1995, a 14.6% decline from 1994, but recovered to 311,000 tonnes in 1996. Most mining takes place on the Copperbelt, along the border with the Democratic Republic of Congo. Zambia Consolidated Copper Mines (ZCCM) (partly government-owned) has been affected by breakdowns, lack of financial resources for maintenance, and power failures through drought affecting hydroelectric production.

The MMD government targeted ZCCM and its subsidiaries for privatisation by mid-1998, and aims to encourage local investors to become direct shareholders. The closure of Kabwe mine in 1994 halted production of zinc and lead, while the scaling down of some activities at Kasenshi mine contributed to large falls in output of gold, silver and selenium between 1994 and 1995. The Kabwe mine was sold to 300 workers in November 1996, although no date has yet been set for the restarting of production. Other mineral products include cobalt (a by-product of copper), emeralds, amethysts, beryl, aquamarine, tourmaline and limestone.

Cobalt is an important mineral, bringing in about US$75m a year in export sales. Output has fluctuated; following poor years in the early 1990s, it increased from 2,934 tons in 1994/5 to 3,577 tons in 1995/6, though considerably higher production is the aim. World prices are currently high and Zambia is believed to have the richest concentration of cobalt in the world. There are large emerald deposits on the Copperbelt; to curb widespread illegal mining and smuggling, the government has liberalised the marketing of gemstones, allowing miners to keep 100% of foreign exchange earnings. Output of all gemstones except beryl declined in 1995; beryl production rose by 123.5%.

Limestone mining in Zambia is mainly centred around Lusaka, with various marble, aggregate and cement quarries and in Ndola with quarries for aggregate, lime and cement production. The major quarry in the Lusaka area is at the Chilanga cement factory and several other quarries produce varies grades of limestone and dolomite aggregates, the market exists and the equipment is in place to produce cut marble. Two limestone quarries are located approximately five kilometres east of the town of Ndola, at, 12 degrees, fifty nine seconds south of the equator and twenty-eight degrees, forty two seconds east of Greenwich and close to Ndola international airport. One of the quarries is operated by Chilanga Cement Company and is known as the Ndola Works. The other quarry is operated by the Zambian Consolidated Copper Mines and is known as The Ndola Lime Company (NLC).

1.3.0 THE REPUBLIC OF MALAWI

1.3.1 Geography

The republic of Malawi was formerly named Nyasaland (Lakeland) and lies between nine and 17 degrees south of the equator and between thirty-three and 35 degrees east of Greenwich. It is approximately 855 kilometres long and from 10km to 250km wide, it has an area of 118,484 sq. km. To the south, southeast, and south-west lies Mozambique, to the west is Zambia and to the north and northeast is Tanzania. The country is completely landlocked, with the nearest port being Beira in Mozambique. While Malawi's landscape is highly varied, four basic regions can be identified: the Great Rift Valley, the central plateaus, the highlands, and the isolated mountains.

Figure 1-3 Map of Malawi ref [55]

The East African Rift Valley Rift System, a part of the enormous Great Rift Valley is by far the dominant feature of the country, it is a gigantic troughlike depression running through the country from north to south and containing Lake Malawi (north and central) and the Shire River valley (south). More than 35,000 sq. km of the country are fresh water, with lake Malawi, having a surface area of some 28,760 sq. km, it is fed by the North and South Rukuru, Dwangwa, Lilongwe, and Bua rivers. The lake stretches 568km along the spine of the country, with varying widths from 16km to 80km. Lake Malawi is the third largest in Africa. The Shire valley stretches some 250 miles from the southern end of Lake Malawi at Mangochi to Nsanje at the Mozambique border and contains Lake Malombe at its northern end. The Shire is the major river and is the lake's only outlet, which flows from the southern tip of Lake Malawi to join the Zambezi River in Mozambique. A second drainage system is that of Lake Chilwa, the rivers of which flow from the Lake Chilwa-Phalombe plain and the adjacent highlands. Malawi hosts the world's highest number of endemic fish species.

The plateaus of central Malawi rise to a general height of between 915m and 1220m and lie just west of the Lake, the plateaus cover about three-quarters of the total land area. The highland areas are mainly isolated tracts that rise as much as 2,500 m above sea level. They comprise the Nyika at 2,600 m, Viphya, and Dowa highlands reaching between 1524m and 2440m, the Dedza Kirk Mountain Range in the north and west and the Shire Highlands in the south.

The isolated massifs of Mulanje with its highest peak Sapitwa, at 3,050 m, being the highest point in the country, and Zomba at 2,134 m represent the fourth physical region. Surmounting the Shire Highlands, they descend rapidly in the east to the Lake Chilwa-Phalombe plain.

Soils

Composed primarily of red earths, with brown soils and yellow gritty clays on the plateaus, the rich soils are distributed in a complex pattern and are some of the most fertile in Africa. Alluvial soils occur on the lake shores and in the Shire valley, while other soil types include hydromorphic, excessively moist soils, black clays, and sandy dunes on the lakeshore.

Climate

Malawi has a tropical continental climate, with some maritime influence marked in the dry season by a light drizzle, locally known as *chiperoni* experienced in the Shire Highlands of southern Malawi.

Temperatures vary seasonally, and they tend to decrease on average with increasing altitude. Nsanje (Port Herald), in the Shire River valley, has a mean July temperature of 21degree centigrade and an October mean of

29 degrees, while Dedza, which lies at an altitude of more than 1,524 feet, has a July mean of 14 and an October mean of 21 degrees.

There are three seasons: the dry season, the cool and the wet season. The rainy season extends from November to April. The cool season is from May to July and the dry season runs from August to October. Temperatures and rainfall are greatly influenced by the lake and altitude, which varies from 37m (in the Lower Shire Valley) to 3050m (Mount Mulanje).

Mountain areas above 1068m are cool with annual temperatures ranging from 14.4 to 17.8 degrees. The highest temperatures are in the Rift Valley where they may reach as high as 37.8 degrees in the hottest months while in July it is quite common on the mountains of the Nyika Plateau and on the upper levels of the Mulanje Massif (above 1830m) to find frosts.

Annual rainfall is highest over parts of the northern highlands and on the Sapitwa peak of Mulanje Mountain, where it is about 2,300 millimetres; it is lowest in the lower Shire valley, where it ranges from 600 to 900 millimetres depending on attitude and position of the area to rain bearing winds. Although rainfall varies, most parts of the country receive sufficient rain for dry land farming (except of course during periods of droughts as has happened in the last several years). The wide range in the climate enables Malawi to grow both tropical and subtropical crops.

People

Nine major ethnic groups are historically associated with modern Malawi, these are, the Chewa, Nyanja, Lomwe, Yao, Tumbuka, Sena, Tonga, Ngoni, and Ngonde (Nkonde). At the time of the last census (1994) the population was estimated at between 9,732,409 and 11,484,000, these latter figures include almost one million Mozambicans who fled from their civil war, giving Malawi one of the world's highest ratios of refugees to indigenous people. Chewa, are the largest ethnic group, they are descended from the Maravi, a Bantu tribe that first entered the region about 600 years ago. Small minorities of British and Indians also live in Malawi. The population is growing at a rate well above average for sub-Saharan Africa. The birth rate is 50.42 births/1,000 population (1994 est.) one of the highest on the continent, but the death rate is also high, and life expectancy at, total population 39.73 years men male 38.93 years and women 40.55 years (1994 est.) is significantly below average for a southern African country. The total fertility rate is 7.43 children born per woman (1994 est.) And the infant mortality rate is 141.1 deaths/1,000 live births (1994 est.) With nearly one-half the population younger than age 15, high birth and population-growth rates should continue in the 21st century, however, the death rate is 23.19 deaths/1,000 population (1994 est.).

The disease HIV is having a dramatic effect on the population with levels as high as 50% being reported infected. The general public do not believe that HIV exists and are reluctant to accept its reality. Other common diseases include malaria, schistosomiasis, and trachoma. Malawi has the highest infant mortality rate in southern African.

The labour force is comprised of 428,000 wage earners which are employed in;

- agriculture 43%
- manufacturing 16%
- personal services 15%
- commerce 9%
- construction 7%
- miscellaneous services 4%
- other permanently employed 6% (1986)

Language

All the African languages spoken in Malawi belong to the Bantu group of people. Chichewa is the national language and English the official language, although English was understood by less than one-fifth of the population at independence. Chichewa is spoken by about two-thirds of the population. Other important languages are Chilomwe, Chiyao, and Chitumbuka. The previous President did not encourage education and the literacy rate of age 15 and over who can read and write (1966) total population 22%, male 34%, female 12%. Those who can afford to, send their children to Zimbabwe or South Africa for their education.

Religion

Some seventy-five percent of the population are Christian, of which more than half are members of various Protestant denominations and the remainder Roman Catholic. Muslims constitute almost one-fifth of the population, and traditional beliefs are adhered to by the remaining 5%. Muslim notions are being encouraged by cash donations from various Arab nations, because of this, it seems that more of the population will change to that religion.

Capital

Malawi is unusual in that the three principal functions of government and its main commercial centre exist in four separate locations. Since 1975 Lilongwe has been the official capital, it is located in central Malawi. Mzuzu, is the northern capital and is located in the north, Zomba, remains the seat of government and is located in the south. Blantyre, in the southern province is the largest city and commercial centre. More than half of the population are concentrated in the south.

The administrative divisions are;

Blantyre, Chikwawa, Chiradzulu, Chitipa, Dedza, Dowa, Karonga, Kasungu, Lilongwe, Machinga (Kasupe), Mangochi, Mchinji, Mulanje, Mwanza, Mzimba, Ntcheu, Nkhata Bay, Nkhotakota, Nsanje, Ntchisi, Rumphi, Salima, Thyolo, Zomba.

Exports and food crop

The most important agricultural export products are tobacco (61%), tea, sugar, and groundnuts. Tea is grown on plantations on the Shire Highlands by the largest proportion of the country's salaried labour force. Tobacco, by far the most important export, is raised largely on the central plateau on large estates. Maize is the principal food crop and is typically grown with beans, peas, and peanuts throughout the country by virtually all smallholders. Other important crops are cotton, cassava, coffee, and rice. Although the major share of commercial crop production and nearly one-fifth of all cultivated acreage is on large estates, most farms are small, averaging less than 1.2 hectares. Smallholder cash crops are purchased and marketed by the Agricultural Development and Marketing Corporation; a few cooperative societies purchase and market produce.

Land use:

arable land 25%
permanent crops 0%
meadows and pastures 20%
forest and woodland 50%
other 5%

Irrigated land:

200 sq km (1989 est.)

Environment:

The current issues are said to concern;

- deforestation land degradation
- water pollution from agricultural runoff
- sewage
- industrial wastes
- siltation of spawning grounds endangering the fish population
- energy depletion, more than 90% of the countries energy needs are met by wood burning, resulting in a rapid depletion in the countries forestry resource.

The environmental international agreements that Malawi is a party to are;

- Biodiversity
- Endangered species
- Environmental modification
- Marine life conservation
- Nuclear test ban
- Ozone layer protection

and signed, but not ratified;

- Climate change
- Law of the Sea

Natural resources are limestone, unexploited deposits of uranium, coal, corundum, and bauxite.

1.3.2 Politics

The Chief of state and head of government since 21 May 1994 is President Bakili MULUZI, leader of the United Democratic Front, the Cabinet is named by the president. Malawi's history since independence reflects the longtime leadership of Dr. Hastings Banda, the nationalist leader who became prime minister in 1963. In 1966 a new constitution abolished the post of prime minister and made Malawi a republic headed by a president, with the Malawi Congress party (MCP) as the sole legal political party.

One-party legislative elections were held in 1992, a year that saw the first significant domestic antigovernment protests in three decades. Western loans were withheld pending improvements in Malawi's human rights record. In June 1993 a referendum showed that 63% of those voting preferred a multiparty political system. An interim constitution adopted by the outgoing legislature on May 16, 1994, eliminated many of the absolute presidential powers Banda had enjoyed. Multiparty elections were held on May 17. Bakili Muluzi of the United Democratic Front became president of a coalition government after winning 42% of the vote to Banda's 33%.

The head of state and government remains Bakili Muluzi. Political parties include the Malawi Congress Party (MCP), multiracial, right-wing; United Democratic Front (UDF), left of centre; Alliance for Democracy (AFORD), left of centre. The Government has alliances with the following organisations;

ACP, AfDB, C, CCC, ECA, FAO, G-77, GATT, IBRD, ICAO, ICFTU, IDA, IFAD, IFC, ILO, IMF, IMO, INTELSAT, INTERPOL, IOC, ISO (correspondent), ITU, LORCS, NAM, OAU, SADC, UN, UNCTAD, UNESCO, UNIDO, UPU, WHO, WIPO, WMO, WTO

1.3.3 Economy

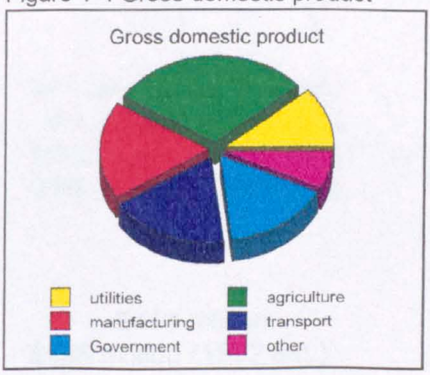
The national currency is the Kwacha, meaning in Malawi, rebirth or new rising, with one Malawian kwacha (MK) = 100 tambala. Exchange rates: Malawian kwacha (MK) per US$1 - 16 (1996) 4.4598 (November 1993), 3.6033 (1992), 2.8033 (1991), 2.7289 (1990), 2.7595 (1989). Malawi is harrowingly poor and occupies second place from the bottom in the list of the wealth of the world, with only Brazil being worse off. The debt of the country, in 1996 stood at US $1,800,000,000. With the currency dropping from 4.4 in 1993 to 16.0 to the US dollar and gross domestic product down by 12.4%.

The government promotes agriculture, which provides more than 90% of all exports, but its policies favour large holdings where cash crops are grown, the economy has been adversely affected by drought, floods, insect pests, overpopulation, and the civil war in Mozambique. Tourism should be popular with the Great Rift Valley; Nyika, Kasungu, and Lengare national parks, poor facilities and petty officialdom deter many potential visitors. Deforestation also discourages tourism, the cutting down of trees appears to be a national obsession, with the demise of forests continuing at an alarming rate. Soil erosion is a serious problem that has a significant impact on ground fertility, particularly as Malawi relies on subsistence farming to feed its population.

Until 1979, Malawi's rate of economic growth averaged 6%. Between 1980 and 1990 the gross national product increased at an average annual rate of 3.2%. Economic growth came from increased agricultural production, mainly from exported cash crops from government-favoured large estates. Before independence these estates were held by a few hundred white settlers. Since independence the estates have been controlled by the state or by high government officials and other influential individuals. By 1984, 86% of rural households farmed on fewer than five acres, and overcrowding had led to serious soil depletion. In 1993, agricultural production fell by 29.7% from $2,631,250 to $1,836,250, in 1987 the government was forced to import food. The drop in income is having an adverse effect on all areas of the economy. The debt, as of gross domestic product is more than 90%. Gross domestic product per capita is $180 and by sector is;

Agriculture	29.4%
Manufacturing	18.3%
Transport and distribution	17.8%
Government	15.9%
Utilities and construction	11.5%
Other	07.1%

Figure 1-4 Gross domestic product



Real Gross domestic product growth is less than 2%. In 1995, the national budget deficit rose from $106,812,000 against a forecast of $43,500,000. In 1995 inflation reached 79% per annum and was adversely affected by a 350% depreciation in the Kwacha, interest rates peaked at 55%. Industry employs only a small percentage of the labour force. The leading manufactures are processed foodstuffs, chemicals, textiles, and beverages. Despite a growing mineral inventory, mineral extraction remains extremely limited and relates mainly to the working of limestone, coal, and gemstones.

Historically, because of poor economic conditions, many Malawians have been forced to become migrant labourers in South Africa and Zimbabwe. In recent years they are finding less work in those countries. In 1992 the nation's economic difficulties were aggravated by severe drought. More than 80% of the population now live on a per capita income of less than $180.00 per year and partly because of this, one child in four is expected to die before reaching the age of five years and malnutrition is endemic. While internal reforms and an end to the long civil war in Mozambique should help Malawi's economy, the nation's long-term prospects for development also depends upon reducing its rapid rate of population growth and improving its relations with neighbouring black states. To address the economic problems the country has put in place a stringent set of reforms as part of the International Monetary Fund and World Bank Structural Economic Programme. The main aim of the reforms is to control expenditure and speed up private sector development. The economy depends on substantial inflows of economic assistance from the IMF, the World Bank, and individual donor nations.

National Accounts for 1992/1993

The economy is predominately agricultural, with about 90% of the population living in rural areas. Agriculture accounts for 40% of GDP and 90% of export revenues. After two years of weak performance, economic growth improved significantly in 1988-91 as a result of good weather and a broadly based economic adjustment effort by the government. Drought cut overall output sharply in 1992.

National product:

GDP - purchasing power equivalent	$6 billion	(1993 est.)
National product real growth rate:	-8%	(1992 est.)
National product per capita:	$600	(1993 est.)
Inflation rate (consumer prices):	21%	(1992 est.)

Budget:

revenues	$416 million
expenditures	$498 million (1992 est.)

Exports: with the main commodities being, tobacco, tea, sugar, coffee, peanuts and wood products. The main trading partners were; US, UK, Zambia and South Africa, Germany with a value of, $413 million (FOB. 1992)

Imports: with the main commodities being, food, petroleum products, semi manufactured goods, consumer goods, transportation equipment. The main trading partners were, South Africa, Japan, US, UK and Zimbabwe, with a value of, $737 million (CIF. 1992)

External debt in December 1991 was estimated to be $1.8 billion.

Industrial production was estimated in 1992 to have a growth rate of, 3.5% which accounts for about 15% of GDP.

The assumed statistics for generation of electricity are;

- capacity 190,000 kW
- production 620 million kWh
- consumption per capita 65 kWh (1992)

The capacity is assumed because the country is unable to generate any power for much of the time.

The main industries are; agricultural processing (tea, tobacco, sugar), sawmilling, and the production of cement. The main consumer goods are; agriculture which accounts for 40% of GDP; cash crops - tobacco, sugarcane, cotton, tea, and corn; subsistence crops - potatoes, cassava, sorghum, pulses; livestock - cattle, goats

The country is a gross recipient of economic aid with US commitments, including Ex-Im (FY70-89), $215 million; Western (non-US) countries, ODA and OOF bilateral commitments (1970-89), $2.15 billion. The fiscal year is from the 1st April to the 31st March.

Transport Facilities

The road network comprises 13,663 kilometres of which only 2,364 are metalled, the remaining are, unpaved gravel, crushed stone, stabilized earth 251 km; earth and improved earth 10,520 km. The main M1 highway which runs north/south from north of Mzuzu to south of Blantyre is a two-lane tarred road. Bus services are available throughout Malawi. Three times a day, the Stagecoach Coachline service provides facilities between Blantyre and Lilongwe, daily to Mzuzu.

Figure 1-5. [ref Mills] A derailed train which the writer put back on the tracks for the rail company.

Malawi has a commercially important rail network of 789 km with external connections only to Mozambique. The track is wide gauge at 1.067-metre, however, it is in poor condition and derailments are common. The railway is not geared for, nor is it safe for tourist travel. The majority of exports would normally go through Mozambique on the Beira, Nacala, and Limgogo railroads, but now most, because of insurgent activity, theft and damage to rail lines go by road through to South Africa.

The two main airports are at Lilongwe and Blantyre, the main international airport is Lilongwe International, situated 23km outside the city. It is regarded as one of the cleanest and efficient, unfortunately it is also the one with the most corrupt officials of Africa's airports. A departure tax is payable by visitors of US$20 (to be paid in US dollars) is levied on all international departures from Blantyre's and Lilongwe's international airports. Domestically, Air Malawi, the national carrier, flies to Karonga, Mzuzu, Lilongwe, Blantyre and the Lakeshore hotels. Major air links exist between Malawi and South Africa, Botswana, Zimbabwe, Zambia, Tanzania, Mocambique, Kenya, Uganda, Ethiopia, Dubai, the United Kingdom and the Netherlands. Air travel in and out of Malawi is made more exciting by the fact that the aeroplane may not arrive, may not depart, may do either of the above without you and the journey may not end up where you think it will.

A summary of airports shows a total of 47 of which 41 are usable.

- with permanent-surface runways 6
- with runways over 3,659 m 0
- with runways 2,440-3,659 m 1
- with runways 1,220-2,439 m 10

Inland waterways are the Lake Malawi and the Shire River, 144 km. Ports are Chipoka, Monkey Bay, Nkhata Bay, and Nkotakota - all on Lake Malawi.

The Legal system

The judiciary is based upon the English common law system prevailing in the British colonial era and Malawi traditional law. It consists of a Supreme Court of Appeal, a High Court, magistrates' courts, and traditional courts.

Since 1969, criminal cases involving witchcraft or local superstition, for which the death penalty can be imposed, have been tried in the traditional courts instead of the High Court. The minister of justice has the power to direct a particular case or group of cases to a particular court; cases tried in the traditional courts can be appealed to the National Traditional Court of Appeal.

Malawi is a signatory to several international treaties for the protection of foreign investment and the settlement of investment disputes. By the mid nineteen-nineties, the writer had found that the enforcement of law, from the policeman on the street to the high courts had virtually broken down.

1.3.3 Mining

Malawi contains a variety of mineral resources, primarily those associated with carbonatites. There is also coal apatite, monzonite and strontianite. There are also deposits of bauxite on the Mulanje syeno-granitic massif. Limestone is a very important mineral resource. The most significant limestone reserves to be commercially exploited have been worked since 1960 by the Portland Cement Company at the Changalume quarry near Zomba. Most of Malawi's mineral deposits are neither extensive enough for commercial exploitation nor easily accessible. Exploration and assessment studies continue on other minerals such as apatite, located south of Lake Chilwa; bauxite, on the Mulanje Massif; kyanite, on the Dedza-Kirk Range; vermiculite, south of Lake Malawi near Ntcheu; and rare-earth minerals, at Mount Kangankunde northwest of Zomba. Deposits of asbestos, uranium, and graphite are known to exist as well.

Except for the central and northwestern parts of the country, Malawi is well endowed with limestones, unfortunately, most of them are dolomitic and impure and hence have a limited usefulness. Only one major limestone deposit is being exploited, this being operated by the Portland Cement Company PLC at Changalume. Changalume quarry is located 15 degrees, twenty-three minutes south of the equator and 35 degrees, thirteen minutes east of Greenwich. The site is on the eastern escarpment of the Shire valley, approximately 20 kilometres west of Zomba. Access to the site can be made on good unpaved roads from the east and west through the village of Chingale, which is in the Shire valley (pronounced sheeri). A private railway line connects the cement factory to the main Malawi railway network.

Chapter Two

LIMESTONE

Geology

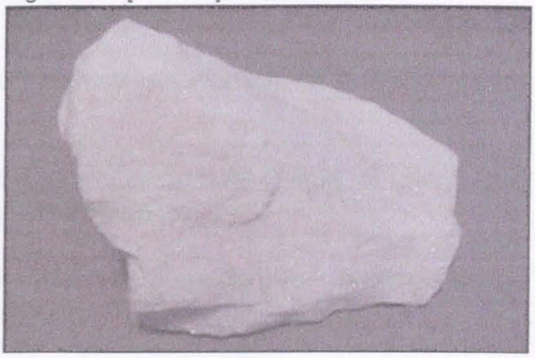
2.1.0 LIMESTONE

2.1.1 Description

Limestones and dolomites are collectively referred to as carbonates this, because they consist predominantly of the carbonate minerals calcite ($CaCO_3$) and dolomite ($CaMg[CO_3]_2$). Using compositional classification, the first half of the name will describe the dominant visible chemical content, such as; 'oo' 'bio', or intra. The name will end in micrite if it has a fine matrix and sparite if it has a crystalline cement. Micrite is found in Ndola and sparite is common at Chilanga and Changalume. Microcrystalline carbonate mud (micrite) and sparry carbonate cement (sparite) are collectively referred to as orthochemical carbonate

Composition and description

Figure 2-1. [ref Mills] Limestone from Carerra



Limestones occur throughout the world in every geological period, from the Cambrian onwards and make up approximately 15 percent of the Earth's sediments and sedimentary rocks and about 2 percent of the terrestrial crust. Ancient limestones and dolomites are composed of calcite and dolomite, respectively, other calcite group minerals such as magnesite ($MgCO_3$), rhodochrosite ($MnCO_3$), and siderite ($FeCO_3$) occur in limited amounts in restricted environments. Modern carbonate sediments are composed almost entirely of metastable aragonite ($CaCO_3$) and magnesium-rich calcite, both of which readily recrystallize during diagenesis to form calcite.

Figure 2.2 Limestone types. [Ref after Folk et al]

Principal allochems in limestone	Limestone types	
	Cemented by sparite	With a micrite matrix
Bioclasts	Biosparite	Biomicrite
Ooids	Oosparite	Oomicrite
Peloids	Pelsparite	Pelmicrite
Intraclasts	Intrasparite	Intramicrite
Limestones formed in situ	Biolithite	Fenestral limestone-dismicrite

Calcite is also the chief component of marls, travertines, calcite veins, most speleothems (cave deposits), many marbles and carbonatites, and some ore-bearing veins. William Henry Fitton, (1780-1861) laid down the correct succession of strata between oolite and chalk in 1824 -36.

Texture

Texture refers to the physical makeup of rock, that is; the size, shape, and arrangement (packing and orientation) of the discrete grains (for sedimentary rocks) or crystals (for igneous and metamorphic rocks). Also of importance are the rock's extent of homogeneity (*i.e.*, uniformity of composition throughout) and the degree of isotropy. The latter is the extent to which the bulk structure and composition are the same in all directions in the rock. Analysis of texture can yield information about the rock's source material, conditions and environment of deposition (for sedimentary rock) or crystallization and re-crystallization (for igneous and metamorphic rock, respectively), and subsequent geologic history and change.

The carbonate minerals present in ancient limestones and dolomites occur in one of three textural forms:

- discrete silt to sand to coarser carbonate grains, or allochems, such as oöids or skeletal fragments,
- mud-size interstitial calcium carbonate matrix called microcrystalline calcite or micrite,
- interlocking, 0.02 to 0.1 millimetre diameter crystals of clear interstitial calcium carbonate cement or spar.

The common textural terms used for sedimentary rocks with respect to the size of the grains or crystals, are derived from the Udden-Wentworth scale. The broad categories of sediment size are coarse (greater than 2 millimetres), medium (between 2 and 1/16 millimetres), and fine (under 1/16 millimetre). The latter includes silt and clay, which both have a size indistinguishable by the human eye and are also termed dust.

Grain size

The size of particulate materials that make up sediments and sedimentary rocks are measured by weighing the proportions that accumulate in a series of wire mesh screen sieves, by visually counting grains with a petrographic microscope, or by determining the rate at which particles of varying diameter accumulate in a water-filled glass cylinder (known as a settling tube). The millimetre and phi unit grade scales are the standard ones used for sediments and sedimentary rocks. In the millimetre scale, each size grade differs from its predecessor by the constant ratio of 1:2;

each size class has a specific class name used to refer to the particles included within it. This millimetre, or Udden Wentworth, scale is a geometric grade scale since there is a constant ratio between class limits. Such a scheme is well suited for the description of sediments because it gives equal significance to size ratios, whether they relate to gravel, sand, silt, or clay. The phi scale is a useful, logarithmic-based modification of the Udden-Wentworth scale. Grain-size diameters in millimetres can be converted to phi units. Phi values for grains coarser than one millimetre are negative, while those for grains finer than one millimetre are positive. After the grain-size distribution for a given sediment or sedimentary rock has been determined by sieving, microscopic analysis, or use of a settling tube, it can be characterized using standard statistical measures in either of two ways:

- visual inspection of various types of graphs that plot overall percent abundance versus grain-size diameter (*e.g.*, histograms or bar diagrams, size frequency and cumulative size frequency curves, and probability curves that compare the actual grain-size distribution to a normal straight-line Gaussian distribution) or

- arithmetic calculations made using diameter values in either millimetres or phi units that are read off the graphic plots and inserted into standard formulas.

For siliciclastic sedimentary rocks, the following standard statistical measures are conventionally described for grain-size distributions:

- mode, the most frequently occurring particle size or size class,
- median, the midpoint size of any grain-size distribution,
- mean, an estimate of the arithmetic average particle size,
- sorting or standard deviation, a measure of the range, scatter, or variation in grain size,
- skewness, the degree of symmetry or asymmetry of the grain-size distribution, which is in turn a function of the coincidence or noncoincidence of mean, median, and mode, and
- kurtosis (peakedness) of a grain-size distribution, which compares sorting in the central portion of the population with that in the tails.

Analysis of grain-size distribution is conducted with the disputed assumption that particular transporting agents and depositional settings (*e.g.*, river delta deposits versus shallow marine longshore-bar sands) impose a distinctive textural "fingerprint" on the sediments they produce.

Constituents

Limestones vary enormously in their complexity and contain both allochemical and orthochemical constituents being commonly, one or more of the following;

- Allochems

Consisting of fossils and or shell fragments, if abundant enough they may justify a specific name, for example coral or reef limestone or foraminiferous limestone. Common fossils include brachiopods, bivalves, gastropods, crinoids and corals.

Oööids (also known as oöölites or oööliths) are spherical to sub-spherical carbonate mud concentrically laminated aggregates cemented together about some sort of nucleus grain. They have a structure of less than 2 mm and build around a nucleus which is usually of quartz. Formation can be by chemical precipitation, usually in shallow agitated waters with $CaCO_3$ saturated water conditions. The surface texture of oöölites is rather like that of fish roe. Particles larger than 2 mm are known as pisolite.

Introclasts consist of fragments or flakes of limestone particles bound together by a microcrystalline cement. The fragments originate from a local area, probably a mud flat and are deposited following erosion which is normally approximately contemporaneous.

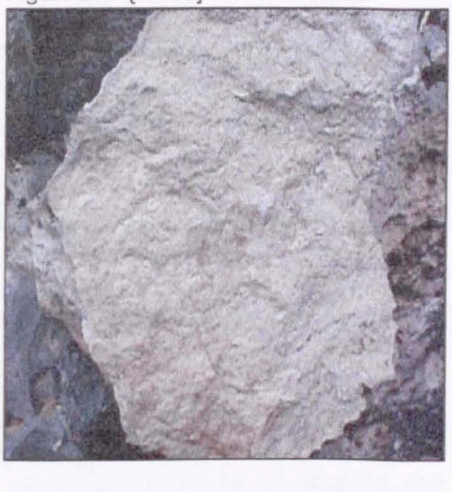
Peloids are spherical or ovoid particles of 250 to 500 micron which have been excreted by molluscs or other organisms, because of their formation, they are referred to as pellets.

- Orthochems

Microcrystalline carbonate mud (micrite) and sparry carbonate cement (sparite) are collectively referred to as orthochemical carbonate because, in contrast to allochems, neither exhibits a history of transport and deposition as clastic material.

Micrite is formed in a microcrystalline calcitic ooze or mud and usually deposited in very low energy conditions. It is fine grained (less than 4 micron) and often has a dark matrix. The texture is clay like (see Ndola Lime Company L3).

Figure 2-3. {ref 89] Miocene micrite



Sparite, consists of sparry calcite cements with clear calcite grains of more than 0,01 mm. It is crystalline in nature and may be indicative of diagenetic process. The purest grades of limestone are calcite and aragonite. Calcite crystallizes hexagonally, and aragonite is rhombic. The specific gravity of calcite can be as high as 2.7 and araganite, 2.95.

Limestone has a predominantly fine to coarse grained structure with a hardness, ranging on Mohs' scale from 1.8 to 3.0.

The three main types of limestone are;

- Sparry allochemical

Figure 2-4. [ref 86] Calcite crystals.

Shelly and ooolitic types which indicate a higher energy environment where micrite is not deposited. Coarser sparry calcite can be contemporaneous or diagenetic. Most of the coarser and clearer crystals of sparry calcite that fill interstitial pores as cement represent either recrystallized micrite or essentially a direct inorganic precipitate.

- Microcrystalline allochemical

Biomicrite is the most common of this type with the micrite suggesting low energy conditions or rapid burial.

Microcrystalline oozes

Micrites form in the absence of allochemical supply, which indicates a deep sea environment of depths greater than 2,000 m/6,600 ft. Micrite is the limestone equivalent of mudstone ooze.

Several kinds of limestone ooze exist, with each being named after its major constituents, the main two are;

Siliceous ooze is composed of the silica shells of tiny marine plants (diatoms) and animals (radiolarians).

Calcareous ooze is formed from the calcite shells of microscopic animals (foraminifera) and floating algae (coccoliths).

2.1.2 Categories

Diagenesis is the name given to the process of forming sedimentary rock by compaction and natural cementation of grains, or crystallization from water or solutions, or recrystallization. The conversion of sediment to rock is termed lithification

Limestone origins are often divided into two basic categories;

Primary limestones, which were formed in deep sea conditions by either-

- Chemical origin

The presence of carbon dioxide in sea water increases the amount of calcium carbonate that can be dissolved into the water. Simply, if the upper layers of sea water are saturated with calcium carbonate, a loss of carbon dioxide or a rise in temperature will result in some of the calcium carbonate precipitating out of the water to settle on the sea bed.

or

- Organic origin

Some sea creatures and other organisms have the ability to extract calcium carbonate from sea water and use it to build bones, shells and coral. When the organisms die, their skeletal remains fall to the sea bed.

The above is sometimes described as the shallow marine carbonate platform, whereby the additional presence of H_2CO_3 in sea water originating from rain and river water, under certain circumstances, allows the formation of $CaCO_3$. The formation is governed by a complex system of chemical reactions.

Evaporites are mainly chemical sediments which precipitate on evaporation of warm, shallow sea water, the most common salts are deposited in a definite sequence: calcite (calcium carbonate), gypsum (hydrous calcium sulphate, $CaSO_4.2H_2O$), halite (sodium chloride, NaCl), and finally salts of potassium and magnesium. Calcite precipitates when seawater is reduced to half its original volume and the concentration of $CaCO_3$ is close to saturation. The degree of saturation depends largely on the level of H_2CO_3 which dissolves calcite when in high concentrations and stimulates the precipitation of $CaCO_3$ when present in low concentrations.

Gypsum precipitates when the seawater body is reduced to one-fifth, and halite when the volume is reduced to one-tenth. Thus the natural occurrence of chemically precipitated calcium carbonate is common and gypsum fairly common. In deep sea conditions of, typically 4000 metres depth, only fine sediments will be deposited and then, at a very low accumulation rate.

Secondary limestones are formed on land by the solution and re-precipitation of primary limestones, usually the calcium precipitation will form around a nucleus of a foreign particle and coalesce to form cemented nodular limestone. As with sea water, lakes contain calcium carbonate, this usually originates from slightly acidic ground water dissolving a primary limestone deposit, followed by redisposition of the material into a lake. Evaporation or other loss of water in the lake will cause the water to become super saturated. When this happens the calcium carbonate will precipitate to the lake bed.

Calcrete (UK) or caliche (USA) can form layers of hard cemented soils and gravel above a limestone deposit. The most mature stage is reached when the calcrete forms a solid bank of massive secondary limestone.

Deposits of calcite by spring and river water are named as tufa and travertine, tufa has a structure similar to sponge while travertine is banded and dense. The difference is mainly due to the speed of the water at deposition. The $MgCO_3$ which causes limestone to become dolomitic limestone can tolerate a lower level of CO_2 in water, it therefore stays in solution longer. This often results in a significant decrease in $MgCO_3$ content in the calcrete relative to the source rock, a typical example is Chilanga RP3 reserve. Because of this, cement grade limestone can sometimes be derived from a source rock which is generally unsuitable.

Figure 2-5. [ref 85] Crystalized rock from Changalume, the inclusions are iron pyrites

Earth movement can cause limestone to be moved or displaced a considerable distance from the source rock (telescopic or flow deposit), the deposit at Changalume, Malawi has been identified as a flow deposit possibly due to migration from a deep metamorphic zone (Cooper 1955)

2.1.3 Marble

Marble is a rock formed by the metamorphism of limestone or dolomite, sedimentary rocks that are predominantly composed of carbonate minerals such as calcite or dolomite. The main result of metamorphism is an increase in grain size and because of this, marble tends to be coarser grained than the rock from which it was derived. Calcite marbles have a mosaic texture, whereas dolomite marbles are granular. During metamorphism, impurities, such as clays and quartz in the original rock, react with the calcite and dolomite to form other minerals such as garnet, talc, and olivine. Marble may be uniform in colour, or it may have streaks and swirls of other colours. The presence of other minerals gives marble its many colours: iron oxide produces red; chlorite and epidote, green; and graphite, blue.

Figure 2-6. [ref 86] Chilanga marble, the colours are caused by iron minerals.

2.2.0 CHILANGA WORKS

2.2.1 Physiography

The geology of Zambia is made up of the most ancient crystalline rocks, consisting of sediments, lavas and intrusives, all intensely altered by repeated folding and metamorphism, dynamic, thermal and regional. Zambia constitutes part of the Central African plateau with an average elevation of 1,300 metres above mean sea level. The plateau is thought to be part of the great Miocene (25,000,000 years old) peneplain. Overall, the plateau is gently undulating, broken only occasionally by ranges of hills composed of rocks with a greater resistance to weathering than the norm. The highest parts of the plateau lie in the extreme north and north west where the elevation rises to 1,800 metres. In the south and south east the plateau is interrupted by a series of deep trough like valleys. These are of tectonic origin and are thought to be part of the great rift valley system.

Metamorphism, dynamic, thermal and regional, together with folding have so altered the original character of the materials that accurate interpretation of the sequences is not always possible. To the south west, which is the area dominant to Chilanga, younger groups of sedimentary rocks unconformably overlie the older igneous granites. Three divisions are found, the oldest and most extensive is the Katanga system, which is divided into smaller lithostratigraphic units. The lowermost part of the Katanga system is known as the Lusaka series.

Table 2-7. [ref 104] Superposition sequence of the Lusaka series is;

Lusaka granite,	Coarse grained granite; probably post Katanga
Lusaka dolomite,	Dolomite and limestone with intermediate types
Major structural break and possible unconformity	
Cheta Formation,	Quartz-muscovite schist, phyllite and micaceous shale
	Grey-white and banded limestones and dolomites
	Quartz-muscovite and muscovite-chlorite schists and shales
	Grey, white and grey banded limestones and dolomites
Chumga Formation,	Quartz-muscovite-biotite-garnet, schists, micaceous quartzite
	Thin impure limestones and calc-schists
	Black banded, current-bedded quartzites
Unconformity	
Basement Complex	Interbanded pure quartzites, micaceous quartzites, limestones, calc-silicate rocks, biotite paragneiss and sheared gneiss

The structural complexity shortage of drill information and lack of exposures have made it impossible to establish a detailed chronological sequence.

2.2.2 Regional geology

The Chilanga area is generally underlain by Precambrian metasediments intruded by granitic and basic bodies. These metasediments can be divided into the Basement Complex, which consists mainly of granitised rocks, and an unconformable Katanga sequence, which has been regionally metamorphosed.

The limestones and metasiltstones of the Cheta formation are overlain by the Lusaka dolomite and underlain by the lower Katanga schists and quartzites. Regional dip of the area is northwards, with the result of the Lusaka dolomite occurring in the extreme north and northwest of the area, with the lower Katanga beds underlying the southern and southeastern sectors. Ten kilometres southwest of Chilanga, the Katanga beds fall beneath the alluvial cover of the Kafue flats. The limestone facies of the Cheta formation has been designated the Mampompo limestone and is described as dominant calcareous (containing lime), but including dolomite facies. The limestone forms a broad belt running west to northwest along the Kafue escarpment. It appears from beneath an alluvial cover at the eastern end of the Kafue flats where it includes inlayers of metasiltstones and quartzite's. Eastwards, it swings to the northwest with Chilanga lying on a narrow strike that is possibly a fold limb.

The Katanga beds have been folded along east-west axes. These folds have been affected in the east and southeast by the Mpande dome of basement gneiss, which lies to the southeast of Chilanga. The effect of this dome has been to superimpose folding along northeast and southwest axes. Although considerable areas within the vicinity of Chilanga are underlain by carbonate rocks. Generally, they are believed to contain too high a percentage of magnesia to be suitable for cement production. The low magnesia limestones form relatively thin bands. These are usually of blue-grey coloured stones found within the low grade limestones and dolomites. It is only where such a band is thicker than usual and has been concentrated by tectonic activity that a deposit of reasonable quantity and quality exists. Because of this, any deposit of high grade limestone found in the Chilanga area will generally occur as a complicated fold core and can be considered a rarity.

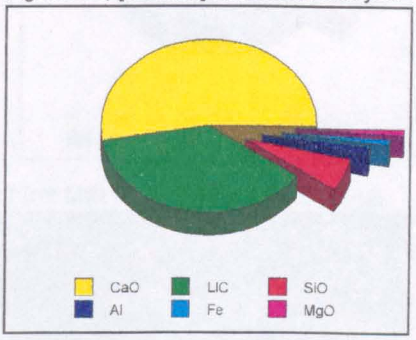
2.2.3 Structural geology

Around Chilanga, the limestones are part of a general formation evidenced as outcrops that extend from Kafue to Lusaka. The limestone deposits have been subjected to upwards pressure. This has caused extensive faulting and folding. The formation has an undulating character, representing anticlines and synclines, with the anticlines emerging as outcrops, the synclines are mostly at considerable depth.

2.2.4 Geology of RP3

The limestone deposit at RP3 is a tight synform that has probably been thrust to the surface. The synform is both striking and dipping to the south. In the north it is well developed and relatively simple, it has steeply dipping limbs in the northern sector. The structure of the deposit becomes more complicated towards the south where, because of east-west cross folding, the synformal axis is not easily distinguished and is probably obliterated. At the extreme north of the deposit, local movement has caused the limestone to be brecciated. The eastern limb of the synform is thought to reduce in thickness and swing to the east, while the western limb becomes intermixed with dolomites and swings to the west. At the southern flank, the deposit is tectonically truncated against a fine grained mica schist. The limestone at the mine has undergone moderate to high grade metamorphism. The material beneath the new haul road was found to be dolomitic limestone, which is underlain in parts by a medium grade limestone. Northeast of the mine, contact is made with, country rock of micaceous shale, a lamprophyre dyke, dolomitic limestone and limestone.

Figure 2-8, [ref Mills] Limestone analysis



Analysis of the limestone in the northern area is;

SiO_2 -	9.0%
Al -	2.0%
Fe -	2.0%
CaO -	49.0%
MgO -	1.0%
LOI -	37.0%

Average calcium carbonate 85.0%

Figure 2-9. [ref Mills] Lamprophyre dyke at Chilanga

Upon entering the mine at the 84-metre bench level the haul road encounters a large lamprophyre dyke, this feature is easily identified by its green to blue colour. The oval shaped dyke strikes in a northwest to southeast direction. At this level it can be seen to be 110 metres long and at its greatest is 38 metres wide. The vertical extent of the dyke is not known. The southwest end of the haul road shows a contact between the dolomite, limestone, country rock and the dyke of lamprophyre. The country rock at the north

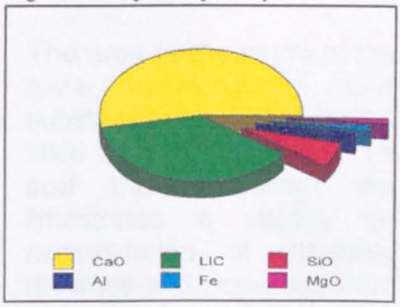
Figure 2-10 {ref Mills} Blast, of quality limestone

of the quarry is mica-shale which is formed from sediments such as, shale and clay and composed of muscovite and biotite with a variable amount of quartz. The material at the 84-metre bench level is an incompetent, re-crystallised, dark grey coarsely grained and vertically loose-bedded limestone. Some faces show conglomerite and breccia.

Typical analysis of the breccia is;

SiO_2 - 6.0%
Al - 1.5%
Fe - 1.0%
CaO - 53.0%
MgO - 1.0%
LOI - 37.5%
Average calcium carbonate 89.0%

Figure 2-11 [ref 86] Analysis



Calcitic crystals are common throughout the area and small amounts of Graphite (carbon) and chalcopyrite (copper sulphate) has also been found. A convenient demarcation of the mine can be made by dividing the area along its northeast / southwest axis. The area to the north of the axis, is a developed bench of light grey, medium quality, competent limestone.

Figure 2-12 [ref Mills] View of the working face

Typical analysis of this limestone is;

SiO_2 - 5.82%
Al - 2.13%
Fe - 1.85%
CaO - 48.92%
MgO - 0.72%
LOI - 38.7%
Average calcium carbonates 84.35%

Figure 2-13 [ref 86] Analysis

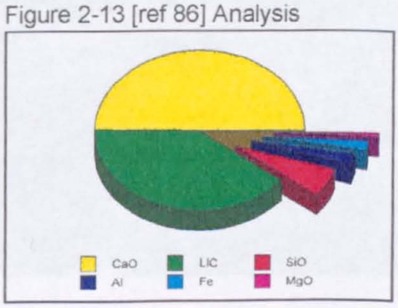


Figure 2-14 [ref 86] Karstic material.

Figure 2-15 [ref 89] Voids and plugs.

The area to the south of the axis is karstic and substantially covered and in-filled by a lateritic soil. The soil that develops on limestones is usually an accumulation of insoluble residues and impurities from the dissolved rock, often these are iron-rich and give the soil its red colour and name of terra-rossa (Latin for red earth). At the time of writing, 100,000 cubic metres of lateritic overburden had been removed from the karstic area, to be tipped in a selected site to the south of the deposit. Beneath the overburden, the surface of the limestone is extremely varied and modified by chemical weathering. The spaces and plugs formed in the limestone have been filled by a lateritic soil. It is believed, though not proven, that the lateritic infill reaches to a depth of more than 20 metres. All this heavily contaminated material must be removed before good quality limestone is exposed. Beneath the overburden, the limestone has been found to be of

Figure 2-16 [ref 89] Weathering in limestone.

medium quality and suitable for cement production. A significant deposit of grit-stone of unknown depth has been exposed in the south east of the mine.

2.2.5 Lithology

Limestone

Limestones in consist essentially of a grey or grey and white banded crystalline calcium carbonate (sparite). Often some magnesium carbonate and siliceous matter such as quartz grains will be found within the rock. The highest grade limestones with a $CaCO_3$ content of more than 85% and $MgCO_3$ of less than 2% are usually;

- pale grey and coarse grained
- lightly banded, dark grey and medium grained

The lower grade limestones with a $CaCO_3$ content of between seventy-five and 85% and higher in $MgCo_3$ are usually;

- dark grey and finely banded
- medium grey and variously banded

The most common composition in the limestones range from 83% $CaCO_3$ upwards and 2 to 4% $MgCO_3$.

Figure 2.17 [ref 86] Typical physical analyses of the RP3 limestone.

Bulk density (kg/m^3)	Specific density (kg/m^3)	Porosity (%)	Relative density (%)
2.632	2.714	3.00	97.00
2.632	2.718	3.15	96.85

Figure 2.18 [ref 86] Typical chemical analyses of the RP3 limestone.

CaO	MgO	SiO2	AL2O3	Fe2O3	Ms	Ma
45.73	1.49	6.55	2.06	1.66	1.76	1.24
46.14	1.26	5.76	1.93	1.71	1.58	1.13
43.68	1.42	6.27	2.08	1.32	1.84	1.58

Tremolite, phlogopite, scapolite and pyrites have been found in the limestone;

Limestone breccia

The crushed rock fragments are larger than 10 mm in diameter and can be seen to contain quartz (SiO_2), and haematite (Fe_2O_3). Closer examination will show muscovite and pyrite. The breccia has undergone a low grade metamorphism and typically, shows much calcitic crystallisation. Bands of muscovite and pyrite crystals can be found.

Dolomitic limestone

Dolomitic-limestones underly the limestone on all sides of the mine, except the southern area. This rock contains inclusions of, biotite and iron pyrite, accessory minerals are, muscovite, plagioclase, chlorite and rutile.

Lamprophyre

Dykes and lenses of lamprophyre are found intruding into various areas of the deposit. The largest of these dykes has been exposed to the north at the 84-metre level. The composition consists of varying amounts of the extremely chemically complicated, hydrous silicate amphibole groups of phlogopite and sphene. With lesser amounts of quartz, magnetite and unspecified pyrite and apatite.

Figure 2.19 [ref 86] Lamprophyre

Summary

The reserve at Chilanga is extremely varied both physically and chemically, it is only because of the lack of calcium carbonate limestones in the southern province that the deposit is worth considering for quarrying.

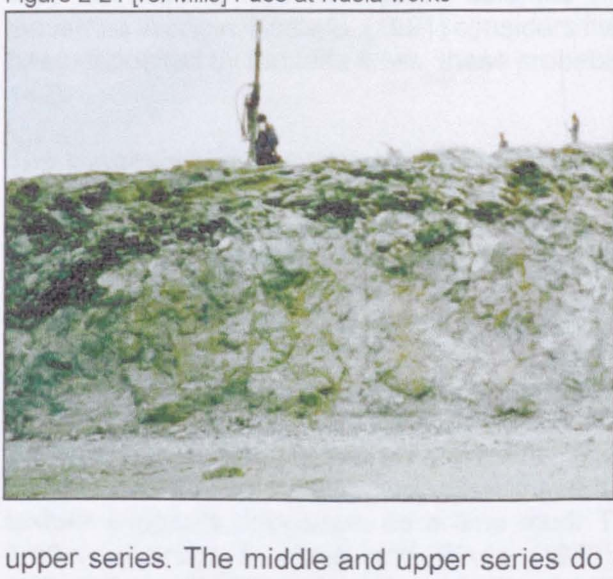
2.3.0 NDOLA

2.3.1 Regional geology

Figure 2-20 [ref Mills] NLC quarry

Ndola Lime Company (NLC) and Ndola works are both located on the north east limb of the Kafue anticline that is east of the Ndola Dome and to the north is the Mufulira syncline. The basement rocks consist of gneiss, foliated granite and minor quartz mica schist, they form the core of the anticline and the dome. Unconformably overlying the basement is the Proterozoic Katanga system. This system is divided into two series. The base being the mine series and above that is the Kundelungu series.

Figure 2-21 [ref Mills] Face at Ndola works



The mine series represents a marine transgression and consists of the Lower Roan, Upper Roan and Mwashia group. The Lower Roan is predominantly argillites and arenites. The Upper Roan is dolomites and argillites. The Mwashia group is carbonaceous shales. The Kundelungu series is represented by lower, middle and upper series. The middle and upper series do not outcrop in the Ndola area and are therefore not relevant to this study. The lower Kundelungu series has a base of marine deposited mud flows or tillites, this is known as the Great Conglomerate. The upper part of the lower Kundelungu series is known as the Kakontwe limestone, a dolomitic base overlain by limestone. [ref104]

2.3.2 Local geology

The geology of the Ndola area is complex, consisting of superimposed structural deformations. It is typified by normal and reverse faulting within synclinal and anticlinal features. The NLC mine is found on an outcrop of the Kakontwe limestone with dolomite forming the footwall. A transition zone of high magnesian limestone occurs below the footwall. The dolomite is typically fine grained, white to light grey with little banding or laminations. The hanging wall outcrops along the length of the deposit where it displays as calcareous shale with changes to limonitic and pyritic shale. The general strike of the area is north west to south east. The Ndola dome together with the Chiwala anticline and syncline have modified the local strike to east-west. The deposit dips about 30 degrees to the north.

2.3.3 Sedimentology

Moore (1967) states that the lithologies and chemical compositions of the Katontwe Limestone are related, suggesting that the composition is an original feature. However, no attempt was made to place the deposits in a sedimentary environment. Binda and Van Eden (1971) conclude that the underlying Great Conglomerate is a clacio-marine deposit, deposited mostly by mud flows and turbidtes. They infer that the deposits of finely bedded argillites, are of lacustrine origin and above the conglomerate, they identified a layered argillitic dolomite that they also suggest is lacustrine in origin. Katonto, (1991) considers the Ndola limestone to have been deposited by turbidite flows, these probably off a limestone reef. [ref 142]

The suggested sedimentary framework for the limestones is;

- dolomite
- massive limestone
- breccia
- laminated limestone

No evidence has been found of evaporites within the Katontwe limestone and the conclusion is that the dolomite was formed from limestones deposited in a near shore environment. The carbonaceous, pyritic, massive limestone indicates deposition in a reducing environment and its texture suggests deposition as a lime mud. The origin of the organic matter is probably algae and Binda (1972) states that the black carbonates contain an abundance of micro-fossils, it is speculated that the pyrite has replaced the algae. A shelf margin is considered to be a possible origin for the limestone with a deposition of algal mud in an environment shallow enough to be slightly affected by wave motion. [ref 142]

Limestone and dolomite breccias occur commonly and the large size of the clasts suggest the source to be near, with the limestone breccias grading into micrites, suggesting deposition by turbides. The calcarious shales are rich in organic matter and pyrite and show no internal structure apart from layering. The origin is probably a low energy reducing environment such as deep water and the source is probably wind blown material. [ref 142]

Summary of regional geology

The top of the Great Conglomerate was deposited in glacio-marine, followed by a brief regression, marking the base of the Katontwe Limestone. A marine transgression followed, allowing deposition of limestone in shallow water as a shelf deposit, possibly with localised development of reefs. As the water deepened, the lime mud was deposited from pelagic algae and occasional storms produced ripple pavements. Deposition was interrupted by occasional turbidite flows or series of flows. The turbidite flows thinned and the amount of lime mud deposition decreased as the water depth continued to increase. At the top of the deposit sequence, the sea reached a depth where pelagic sediment dominated over material brought in. Finally the sea level fell with the deposition of limestone resuming. Dolomitisation of the limestone at the base of the Katontwe Limestone was diagenetic. [ref 142]

2.3.4 <u>Structure</u>

Folding

Moore (1967) recognised two generations of folding events, with each generation having two fold styles affecting the Katangan in the Ndola area. The first was generation associated with the Lufilian Orogeny and the second being post Lufilian. The first generation of folds is more important to the area west of the quarry site, and may be seen at the Bwana Mkubwa (Lord Copper) mine where the folds are recumbent and overturned, generally plunging to the WNW with occasional folds plunging to the NNE. The second style of first generation folds, that Moore identified at the quarry are symmetrical, plunging WNW at a shallow angle, with occasional plunge reversals. They decrease in intensity to the east. The first style of second generation folds plunge at approximately 30^0 to the NW and have axial planes dipping steeply to the NE. This folding is associated with the formation of the Kafue Anticline, the Ndola Dome and the Mufulira Syncline. The second generation of folds are gentle broad domes. [ref 142]

Faulting is not of major structural importance at the quarries.

2.3.5 Hydrogeology

Figure 2.22 [ref Mills] Aquifer at Ndola works quarry

No specific hydro geologic studies of the Ndola area are available, however, in an untitled 1967 report, subsurface dolomites and limestones of the Kakontwe formations were, with rainfall ranges from 600 mm to more than 2000 mm, identified as the major water producing zones in the Ndola area by virtue of their high permeability. This permeability results from the enhanced secondary porosity as enlarged fissures following joint planes. Where the saturated sections of these limestones and dolomites crop out, surface water features such as the Itawa (changing to the Kafue River) is formed.

2.3.6 Seismicity

Laying close to the great rift valley system, the seismicity of Zambia has been studied in detail. Generally the country can be divided into four zones. Chilanga lies between Zones two and three and Ndola is in zone four. Zone number one (the Kariba zone) has the highest seismicity, this being due to filling of the Kariba dam, with the weight of the water resulting in the reactivation of an established NW-SW faulting zone. Zone number four, is of diffuse seismicity, it includes part of the Copperbelt where some of the seismic activity is due to mining activity. The level of seismicity in all of the zones is relatively small. [ref 104]

2.3.7 Lithology

The chemical and physical characteristics of the deposit vary both along the succession and throughout the dip and strike. This causes massive problems to production, the main problem being that, the vertical kiln by nature of its operation is far more cost effective to operate than the rotary kiln, to operate successfully, the vertical kiln can only use a rock that has good physical properties, particularly with subjected to thermal shock. The deposit only contains a small percentage of this rock, and it is generally found within undefined areas of unsuitable rock. To define the variations in the limestone, NLC has given the different rock types identification of L1 through to L10 and the following designations and descriptions have been modified by the writer.

L1 Kilnstone; This is the rock that is most suitable for production from the vertical kiln, it is a dark, fine grained, massive, very hard rock. It is suitable for lime production from both kilns and has good physical and chemical properties. With experience it can be identified by eye, mainly by its colour and its retention of sharp edges after breaking.

Figure 2.23 [ref Mills] L1 limestone from the NLC deposit

L2 Laminated magnesian limestone; black to grey laminae, fine to medium grained, hard, impure. Has high silica, iron and alumina, fuses in both kilns and causes clinker in the vertical kiln. Physical properties are fair to poor.

L3 Semi sugar stone; dark to medium grey, fine to medium grained, slightly friable. Has good chemical property. Fair to good physical properties make it suitable for the rotary kiln and poor for the vertical kiln, it can be used in cement manufacture.

L4 Sugar stone; medium to light grey, fine to coarse grained, poorly cemented, generally friable. Has excellent chemical properties. Fair to poor physical properties make it suitable for use only in the rotary kiln. This material is mined at Ndola works for cement manufacture and any waste produced at NLC is usually sold to Chilanga Ndola works.

L5 Breccia; calcareous sub angular fragments in a mineralogically similar matrix. Is often excessively high in magnesia. Fair to good but inconsistent physical properties make it suitable for use in the rotary kiln in preference to the vertical kiln.

L6 Limestone with calcitic segregations; white calcitic lenses and beds within other limestones. Has good chemical property. Poor to fair physical properties make it unsuitable for use in either kiln, it can be used for cement production.

L7 Dolomitic limestone; grey to pinkish grey to white, fine to medium grained. Has excessive magnesia content. Not used in lime or cement manufacture.

L8 Siliceous limestone; lenses and beds of dark grey, fine to medium grained, hard silica rich limestone. Poor to fair physical properties. High in magnesia. Not very suitable for lime manufacture and causes clinker in the vertical kiln, it is not suitable for cement production.

L9 Calcareous shale black to grey when fresh weathers to yellow, carbonaceous shale grades into shale limestone, contains pyrite. Very poor physical properties and high in silica and alumina. Unsuitable for lime or cement manufacture and causes clinker in the kilns.

L10 Calcitic veins; white to transparent, coarsely crystalline calcite veins. Chemically good. Very poor physical properties make it unsuitable for use for lime manufacture in either kiln, but can be used for cement production. [ref 143]

Summary

All the above grades can be used as aggregate and for general construction purposes. From a commercial viewpoint, the deposits available to Chilanga Ndola works are close to ideal, whereas the deposits available to Ndola Lime Company are difficult to work. Due to the problems of separating the various grades of limestone, NLC are being forced to operate the less cost effective rotary kiln, as there is no viable alternative, the cost of lime and therefore the cost of producing copper will increase, perhaps making copper uneconomical in the world market.

2.4.0 CHANGALUME MALAWI

2.4.1 Country geology

The geological history of Malawi is that of a Precambrian "mobile belt", overlain by Permo-Triassic sediments, cut by Mesozoic igneous intrusions, and disrupted by Cenozoic rift faulting. Most of Malawi is underlain by this early Precambrian to early Palaeozoic sequence of metamorphic rocks of sedimentary and igneous origin. The complex can be divided to the north and south.

To the north, biotite and hornblende gneisses dominate.

To the south, a Charnockitic suite dominates, being comprised mainly of pyroxene bearing granulites and gneisses, intruded by syenites and granites. At various areas, the basement complex is overlain by sedimentary and subordinate volcanic rocks ranging in age from Permo-Triassic to Quaternary. The most extensive of these is the Karroo System, a Permo-Triassic sequence of sedimentary rocks, this system is the placement of the various coal deposits found throughout the Great Rift Valley.

In the north, Mesozoic intrusive activity includes Kimberlitic breccias cutting Karroo sedimentary rocks, with numerous doleritic dykes, diorite and pyroxenite intrusions.

In the south, Mezozoic igneous activity is dominated by this early Jurassic to late Cretaceous intrusive event and two large massifs are found.

Superficial Tertiary and Quaternary lacustrine and alluvial deposits occur in the north, close to the shore of Lake Malawi and the Zambian border. These deposits commonly mask the bedrock over large sections of the country. The most dominant feature of the geological history is the complex Lower Tertiary faulting associated with the development of the Great Rift Valley. The topography of the country is controlled by this linear trough. A complicated network of major faults, tilted blocks and small Horsts and Grabens have been created. Pre Tertiary faults have been reactivated, but the recent scarps formed by new Cenozoic faults define the escarpments. The Great Rift Valley where it passes through Malawi is largely non-volcanic with a sedimentary covering of up to 3000 metres, the area remains seismically active.

2.4.2 Regional geology

The surrounding areas consist predominantly of metamorphic and crystalline rocks of Precambrian to Lower Cretaceous age which forms three major morpho-tectonic areas.

- Zomba mountains in the north and northeast with a maximum elevation of 2087 metres.

- Shire Highlands, extending south of the Zomba mountains at elevations between 840 and 1390 metres. The Changalume deposit is located in these highlands.

- Chingale step and the Shire plain extending westwards of the Zomba mountains and the Shire Highlands at elevations between 475 and 685 metres.

The Zomba mountains consist mainly of syenites and granites which intruded during Jurassic times. The Shire Highlands are formed of Charnockitic granulites and migmatic gneisses of Precambrian age. The migmatic gneisses consist predominantly of migmatitic pyroxene-hornblende-biotite gneisses and garnetiferous biotite gneisses. These silicate rocks are associated with thick bands of marble of which the Changalume deposit is the most important, they have been strongly folded along NE to NW axis and their limbs have high to moderate dips. The Chingale step and the Shire Plain consist mainly of rocks of the Precambrian basement complex but are covered by recent colluvial and alluvial sediments.

The Chingale Step and the Shire Plains have been displaced from the Zomba mountains and the Shire Highlands by a massive north east trending fault which forms the eastern side of the Great Rift Valley, this being the dominant structural feature of the area. A throw of 1100 metres is documented.

2.4.3 Local geology

Charnockitic migmatic gneiss and granulites make up 90% of the rocks in the Changalume area. A uniform strike of NNE is found with minor variations, with a regional dip of between 60 and 90 degrees. The gneiss is frequently intruded by pegmatitic veins mainly composed of quartz and feldspar. Pegmatitic charnockitic granulites form a prominent NNE trending range of hills with a maximum elevation of 1175 metres. There is a transition from one rock type to another.

Hornblende biotite gneisses form the rocks in the rift valley where it is mostly covered by a reddish brown sandy soil. Foliation of the rock is in the NNE-SSW direction with nearly vertical dips to the east. These rocks are separated from the above rocks by the rift valley faulting system.

2.4.4 Changalume deposit

The origin of the deposit has not been confirmed, suffice to say that the deposit is extremely complex and unlikely to be of purely sedimentary origin. Furthermore the form of the deposit, attenuating at both ends, and the wedge shape does not lend credence to such an origin.

Figure 2-24 [ref Mills] View to the south of Changalume

An alternative theory, is that the carbonate may have been mobilised and introduced subsequent to host rock deposition and metamorphism, an epigenetic or allocthanous type deposit structurally controlled by shearing or fracturing, possibly related to Rift Valley faulting. The carbonate rock could be a flow limestone originating elsewhere and emplaced as a result of regional metamorphism, or of metasomatic origin related to magmatism or metamorphism, or both. The main body forming Changalume Hill consists of irregularly layered, spatially discontinuous lenses, bands and zones of crystalline limestone intercalated with biotite or hornblende gneiss, granulite or granulite gneiss and their associated rocks. The whole mass constituting a very heterogeneous assemblage developed over a strike length of more than one kilometre. Individual limestone layers range from a few centimetres to many metres in width. Little or no correlation exists between the limestone widths along a general strike or plane. The main material required from the deposit is a medium grained, white to light grey calcitic limestone of holocrystalline rhomboedric structure, with crystals sizes of between two and ten millimetres.

Figure 2-25. [ref Mills] View south from the north west

Figure 2-26. [ref Mills] View showing various rock types

Graphite is a common accessory mineral which is usually found in flakes distributed throughout the limestone. The sizes of the flakes reach a length of seven and a thickness of two millimetres. Graphite is not harmful to cement production as it burns off in the kiln. Areas where calcite crystals alternate with bands of graphite give the rock a gneissose appearance and only where this gneissic texture is developed does the rock possess a certain plane of cleavage. Other accessory minerals found in the limestone, close to xenolith inclusions of gneiss and syenite are a wide range of calcsilicate minerals such as, diopsite, tremolite, wollastonite, scapolite and garnet. Furthermore, quartz, phlogopite, forsterite, brucite, blue apatite and pyrite occur. A very coarse grained, white limestone with crystals of up to 80 mm is found inter-grown with the medium grained limestone described above.

A major characteristic feature of the deposit is the occurrence of xenoliths (inclusions) which range from a few centimetres to thirty metres diameter. The xenoliths consist of;

- pegmatite veins of migmatitic feldspar-hornblende-gneisses, dark grey, with disseminated pyrite mineralisation
- biotite gneisses, dark grey or green
- holocrystalline porphyric syenitic rocks, light grey

Pegmatite veins as large as two metres thickness are a widespread intrusive.

The syenitic rocks are generally associated or intrusive throughout the limestone but more predominantly along the eastern and western body of the rock. They have an irregular dyke or lense like configuration and show a strong variation in shape, length and thickness, ranging from 500 mm to twenty metres in length and 500 mm to three metres in thickness. The xenoliths are irregularly distributed throughout the limestone and no distinct distribution pattern regarding size and enrichment in layers can be distinguished.

The most recent rock forming event in the Changalume calender resulted in the implacement of dark to light grey volcanic dykes of doleritic, phonolitic and lamprophiric composition cutting both country rocks and limestones by;

- perpendicular to the general strike in east to west or north east to south west directions with almost vertical dips

- as sills dipping 20 to 40 degrees to the south east

The thickness of the dykes and sills ranges from 100 mm to 1.5 metres. Massive chert or cryptocrystalline silica widths ranging from a few millimetres to 200 mm are associated with the limestone. Their origin is uncertain, whereby they may be of magmatic derivation and intrusive in nature or have formed as a result of pervasive replacement from metasomatism. [ref 1. 2. 26. 85]

Summary

This deposit has been worked in a parasitic manner, that is; with the best and easiest material being removed first and with little, if any heed being paid to future development, the lower benches have been removed and various turrets of poor quality limestone rise to heights of over one hundred metres. The deposit was covered on all surfaces by a covering of igneous material, this being weathered and worn from the top of the hill and thickening down the sides, this material should have been removed as development progressed, unfortunately, it was not considered cost effective to move material that did not have a direct revenue. By 1999 only a few select areas of the site were available for quarrying and the nature or the rock proved to by a serious handicap to development. It is only because of the lack of suitable limestone in the region that this deposit is operated. It is the opinion of the writer that quarrying this deposit is a challenge that is hardly worth the effort. In late 1999 the 200 metre peak that is shown in the picture on page 55, collapsed and destroyed the crushing plant. By this time the writer was no longer associated with the site.

Chapter Three

LIMESTONE PRODUCTS

3.1.0 DESCRIPTION

3.1.1 Limestone

Limestone is a relatively commonly occurring rock, covering about 10% of the worlds surface, and is dominated by the presence of calcite. It is probably the most useful and widely used common rock type on earth, and thus in terms of bulk, represents the largest mining operation in the world with estimated annual tonnages mined being between 4,000 and 5,000 million tonnes. While the majority of limestone mining is for aggregate production, other uses are, cement, lime, flux in metallurgical processes and as a major feedstock in the chemical industry.

Cement has been known as a building medium for more than ten thousand years. It is in the massive masonry constructions of the Egyptians that the present day system of uniting blocks and slabs with mortar is first found. The binding agent was lime or calcium oxide (CaO). The oldest type of cement would seem to be, burned gypsum. With quick lime (burned "unslaked" lime containing an average of 87% CaO) being almost as old. Being usually the first to adapt items to war, the British in the Middle Ages used quicklime to burn the faces of their opponents at war. The source of lime was gypsum, a hydrated calcium sulphate mineral with a chemical composition of $CaSO_4$ $2H_2O$ rather than limestone ($CaCO_3$), this despite the fact that gypsum was scarce compared to limestone. The reason for using gypsum instead of limestone is that gypsum requires a lower temperature and, therefore, less energy than limestone for its calcination and at the time of use, there was a scarcity of fuel. In due course the burning of gypsum became the prime source of lime, with the Greeks copying the Egyptians and the Romans copying the Greeks. Both the Greeks and the Romans were aware of the fact that finely ground material from volcanic deposits, when mixed with lime and sand yielded a mortar of superior strength that also had the ability to resist the action of water.

The Greeks mixed lime with sand of volcanic origin from the island of Thera, now Santorin and the Romans mixed lime with pozzolana, a red or purple material derived from volcanic tuffs found close to the town of Puteoli (modern Pozzuoli), near Naples that was particularly rich in essential aluminosilicate minerals and is located in an area near to Mount Vesuvius. To this day the term pozzolana, or pozzolan, refers either to the cement itself or to any finely divided aluminosilicate that reacts with lime in water to form cement. The word "cement" originated in early Roman times and was used to describe a material consisting of lime and sand mixed with crushed and sieved pottery. During the 3rd century BC, the Romans used pozzolana instead of sand with an aggregate of broken tuff, travertine, brick, or marble, the material contributed to the evolution of new architectural forms in such monumental constructions as the Pantheon and the Baths of Caracalla at Rome.

Construction using this material was known as opus caementitium. Later, the term cementum was used to identify admixtures which on being added to the lime gave it the power to set and harden under moist conditions. The advantage of using materials of volcanic origin was that the product would harden under water, thereby attaining a hydraulic product with properties based on the formation of lime-silica-hydrates, like Portland cement.

After Roman times and particularly during the ninth, tenth and eleventh centuries the art of burning lime was almost completely lost. From the twelfth century, things improved and in the fourteenth century Trevisa wrote, "whyle lyme is colde in handlyng it conteyneth prevely wythin fyre and grete hete", and excellent mortars were being produced. Joseph Black (1728 1799) in his investigations of the heating of magnesium carbonate, anticipated Lavoisier and modern chemistry by indicating the existence of carbon dioxide. Black's account of his studies, published in 1756 as *Experiments Upon Magnesia Alba, Quicklime, and Some Other Alcaline Substances,* proved that the mild carbonates become more alkaline when they lose carbon dioxide and that absorption of this gas converts the caustic alkalies again to mild ones, this gave the first technical explanation of the calcification process. This was improved on by Lavoisier and in 1766 De Ramecourt published an account of limestone mining and lime burning.

John Smeaton, (1724 -1792) was born at Austhorpe, near Leeds in Yorkshire and qualified as a Lawyer, he became England's first civil engineer and rediscovered high-quality cement, the secret of which had been lost after the fourteenth century. In the year 1796, Joseph Parker discovered that by burning nodules of limestone and clay which he found on the beach at the Isle of Sheppy England, and grinding the resultant vitrified material to a powder, a binder was produced which was superior to any other being used at that time and thus he was the first to recognize what constitutes a hydraulic lime. The material was known as Septaria. By the year 1800 the material was patented by Parker as Roman Cement

Production of the first material known as Portland cement was attributed in 1824 to Joseph Aspdin, a bricklayer originating from the Leeds area of England. He obtained a British patent for both the product and the name. He named the material 'Portland cement' from the similarity of the colour of the new product, once set, to stone quarried from the Isle of Portland. In 1825 he opened the first Portland Cement Factory to operate on a commercial basis. Aspdin's product may well have been too lightly burned to be a true Portland cement. The first true Portland cement, was produced in 1843 by William Aspdin the son of Joseph Aspdin. He, by using higher temperatures to burn the clay and lime than his father, caused a partial fusion of the material (sintering) to produce clinker, which when ground to powder showed good hydraulic properties. Within two years Isaac Charles Johnson had made the same discovery (although later in his 101 years of age he claimed to have discovered Portland Cement) and in 1851 he, together with his employers (White and Sons) set up a cement works and later took control over one of Aspdin's abandoned cement works. Aspdin's cement company had eventually failed, this was said to be due to it having a high free lime content. The first cement factory in Africa was opened in 1892 at Daspoort near Pretoria, South Africa by Edward Lippert and in 1904 the first rotary kiln was installed.

Portland cement is produced by using the five most common elements on the surface of the earth, ie; oxygen, silicon, aluminium, iron and calcium. A modern definition of cement is; a finely ground hydraulic binding medium consisting substantially of compounds of calcium oxide with silicon dioxide, aluminium oxide and ferric oxide formed by fusion. When mixed with water, the anhydrous calcium silicates and other constituents in the cement react chemically with the water, combining with it (hydration) and decomposing in it (hydrolysis) and hardening and developing strength. [ref 26. 47.99]

3.2.0 MANUFACTURE OF CEMENT

3.2.1 Description

Appendix G gives a more detailed description of cement manufacture.

Cement is a synthetic chemical product that, when mixed with water and allowed to hydrate, forms a strong binding material. Often, it is used to cement aggregates together to form concrete. The term concrete is derived from the Latin concretus which signifies growing together. Manufacture is by, intimately mixing finely ground limestone and argillaceous materials in the correct proportions and burning the mixture at a temperature of between 1,300 and 1,500 degrees centigrade at which time partial fusion occurs and nodules of clinker are produced. The clinker is then rapidly cooled, and together with a small percentage (usually about 5%) of gypsum finely ground to make cement. The gypsum is used to delay the reaction time of the cement it may be partly replaced by other forms of calcium sulphate.

Composition of the finished cement has to fall within a narrow range to give a cement of the required performance. The ratios of the active components are defined by certain factors laid down as internationally used standards. Usually Portland cement contains CaO 60-65%, SiO_2 20-25% with 2% Fe_2O_2 and Al_2O_3. Strict limits are set in most standards for the maximum content of certain harmful impurities, for example, British Standards set 4% as the maximum content of magnesia. The theoretical energy requirement for producing cement clinker is 420 kcal/kg. [ref 42]

3.2.2 Grades of material for cement production

An ideal material for cement manufacture is a rock that in its natural state already contains the correct proportions to produce a cement clinker of the desired composition. Raw materials usually consist of some kind of calcitic limestone and clay or shale. They should be, low in magnesia (less than 3%), low in sulphur (less than 1.5%) and low in phosphate (less than 1.0%). Limestone for Portland Cement manufacture, generally falls into two main types of material;

- Pure limestones which are mixed with argillaceous (clay or silt) materials
- Argillaceous limestones and unconsolidated marls, which conform to the basic material without the need for any additions. This is known as natural cement rock.

Natural cement rock of a suitable composition for the manufacture of Portland cement should contain approximately 75 to 77% calcium carbonate with the remainder being clay, shale or lateritic type materials. Because of the varying chemical composition limestone deposits it is normal practice to extensively blend the material at several stages of the process. [ref 73]

Figure 3-1 [ref 47] List of Elements

Typical percentages of elements in the earth, lithosphere and cement				
Element		Earth	Lithosphere	Portland Cement
Oxygen	O	22.0%	46.6%	37.0%
Silicon	Si	11.0%	27.7%	09.5%
Aluminium	Al	00.6%	08.1%	03.2%
Iron	Fe	50.0%	05.0%	02.0%
Calcium	Ca	01.0%	03.6%	45.3%
Magnesium	Mg	09.0%	02.1%	01.2%
Potassium	K	--------	02.6%	00.5%
Sodium	Na	---------	02.8%	00.1%

Figure 3-2 [ref 86] Composition of Portland cement

Composition of Portland cement	
Component	Percentage and symbols
Tricalcium silicate	45% $(CaO)_3SiO_2$
Dicalcium silicate	27% $(CaO)_2\ SiO_2$
Tricalcium aluminate	11% $(CaO)_3\ Al_2\ O_3$
Tetracalcium alumino-ferrite	8% $(CaO)_4\ (Al_2\ O_3)\ (Fe_2\ O_3)$
Calcium sulfate	2.5% $CaSO_4$

Investigation has shown that at Chilanga, according to their chemical composition it is possible to distinguish five types of carbonates and that the deposit consists of various grades of limestone with total calcium carbonates of between 70 and 95%. Multicoloured crystalline limestone (sparite) occupies the centre of the RP3 deposit and is the main source of feed to the processing plant. The deposit at Ndola is consistent in calcium carbonate content and because of this requires little blending.

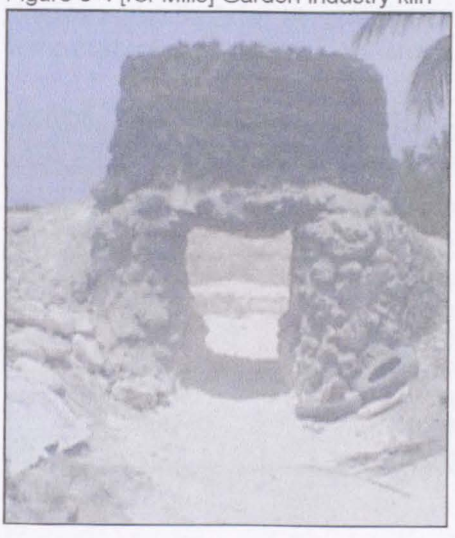
3.3.0 LIME PRODUCTION

3.3.1 Description

Lime production was originated by the ancient Egyptians. Often their kilns were of stone construction with large stones forming an arch at the bottom. The kiln was charged cold and a wood fire was lit beneath the stone arch. After four or five days the fire would be extinguished and after cooling, the carbon would have been released as carbon dioxide gas (calcined)and the lime would be extracted. Calcination, refers to the reaction wherein the limestone is heated to less than its melting point (approx. 1,100 degrees C), in order to drive off matter that evaporates easily, in this case, carbon oxides. Traditionally in Southern Africa, lime production has been, and in some areas still is, achieved by use of an intermittent batch process, with layers of limestone being burned using wood in covered heaps (reducing environment) in a single operation. Further production involves completely recharging the kiln. Kilns of this type would yield about one and a half tonnes of product per burn. A burn took 48 hours and 24 hours was needed for cooling. Various forms of these kilns are still being used, depending on local circumstances and

Figure 3-3 [ref Mills] Vertical kiln at Ndola

Figure 3-4 [ref Mills] Garden industry kiln



traditions. The kilns may be rectangular or round structures in brick or stone. They may be hollowed out river banks, ant hills or the sides of hills.

Wood was the preferred fuel, mainly because of its availability and its low burning temperature, making it difficult to overburn or hard burn the lime, also the long flames give good transfer of heat throughout the kiln. More recently, kilns have been built of greater height and capacity, featuring a refractory lining and operated in a continuous process. Alternate layers of stone and fuel were charged into the top of the kiln and as each layer was calcined it would be removed from the bottom to allow a further load to be charged at the top. The first rotary kilns were operated in the early 1900's with a typical output of thirty tonnes per day. Today, both rotary and vertical kilns (annular shaft kiln) are used in a continuous process. Typical temperatures found in a lime kiln are between 1150 and 1250 degrees centigrade. In order to be reactive, good lime requires not only to have a low CO_2 level but also the correct pore structure. When heating the limestone, it first expands and as calcination starts the pore volume increases with the actual volume remaining the same. At the moment when the calcination of the limestone is complete (total evolution of CO_2) the pore volume is at maximum. With further exposure to heat and time, crystal growth occurs and sintering begins, both pore volume and actual volume decreases. Consequently there is an increase in apparent density. The apparent density is therefore a measure of the degree of burning. The size and hardness of the limestone being burned will dictate the residence time required in the kiln. [ref 99]

3.3.2 Quicklime

The definition of quicklime, is "burned unslaked lime containing at least 87% CaO". Production is by heating limestone ($CaCO_3$), to temperatures at which the partial pressure of the CO_2 in the stone reaches atmospheric pressure. This is known as the dissociation temperature and is 900 degrees centigrade at sea level. The stone must be kept at this temperature until all the CO_2 is burned off.

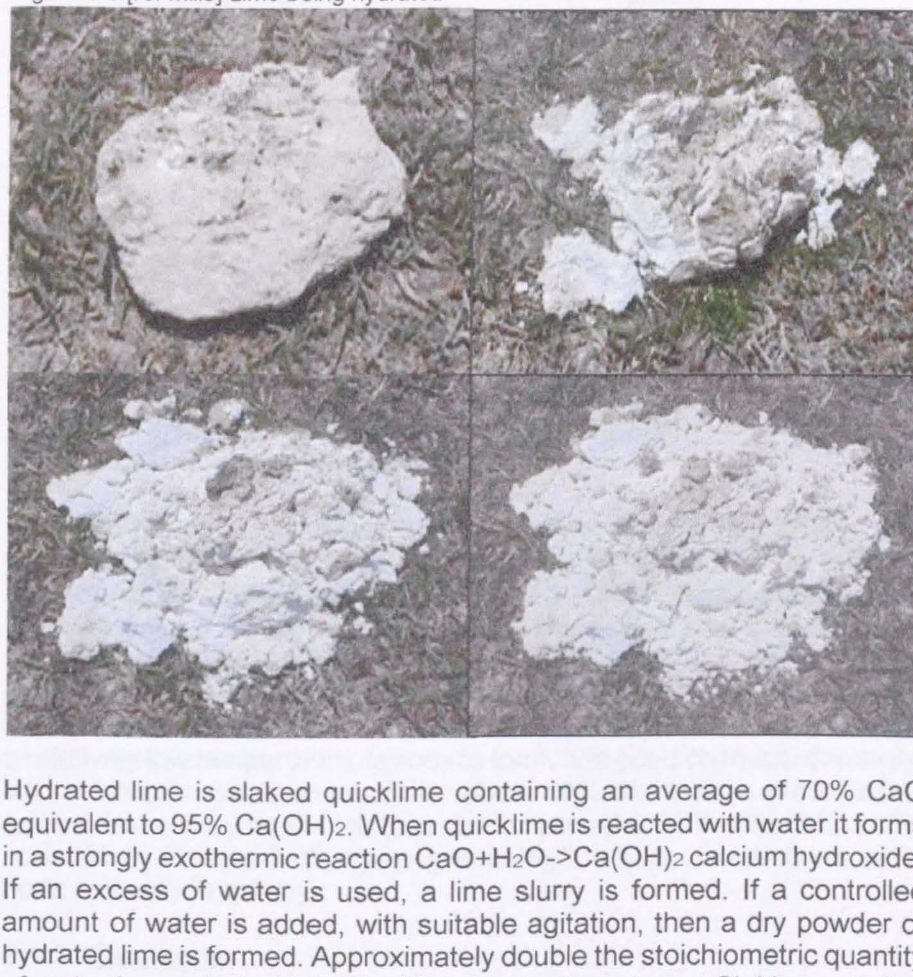
Figure 3-5 [ref Anon]

Chemical composition of quicklime		
Component	High calcium quicklime Range in %	Dolomitic quicklime Range in %
CaO	93.25 - 98.00	55.50 - 57.50
MgO	0.30 - 2.50	37.60 - 40.80
SiO_2	0.20 - 1.50	0.10 - 1.50
Fe_2O_3	0.10 - 0.40	0.05 - 0.40
Al_2O_3	0.10 - 0.50	0.05 - 0.50
H_2O	0.10 - 0.90	0.10 - 0.90
CO_2	0.40 - 1.50	0.40 - 1.50

3.3.3 Hydrated Lime

Hydration is the combining of calcium oxide with water in a reversible reaction to form calcium hydroxide. The pictures show a piece of lime being slaked and its reaction.

Figure 3-6 [ref Mills] Lime being hydrated



Hydrated lime is slaked quicklime containing an average of 70% CaO equivalent to 95% $Ca(OH)_2$. When quicklime is reacted with water it forms in a strongly exothermic reaction $CaO+H_2O->Ca(OH)_2$ calcium hydroxide. If an excess of water is used, a lime slurry is formed. If a controlled amount of water is added, with suitable agitation, then a dry powder of hydrated lime is formed. Approximately double the stoichiometric quantity of water is needed with 50% of it being lost as steam. Slaking satisfies quicklimes affinity to moisture, although it still retains a strong affinity for CO_2. Slaked or hydrated lime is mostly used to reduce soil acidity and as a cheap alkali in many industrial processes. [ref 63]

3.4.0 USES OF LIME

3.4.1 General

While the original use of lime has been for the construction and building industries, the most important use of lime in the modern world is for other uses as shown below ;

- Metallurgical industries 35%
- Environmental uses such as water treatment 24%
- Chemical industries 19%
- Construction 10%
- Paper and wood pulp 7%
- Sugar refining 4%
- Agriculture 1% [ref 26]

3.4.2 Glass

Common glass is essentially a solidified melt of sodium, calcium, magnesium silicate and is formed from, silica sand, limestone and alkalis, where each component has a specific task in the glass making process. Limestone acts as a stabiliser, giving hardness, lustre and insolubility in water. To be of use, the limestone needs to be reasonably pure, for example;

Fe_2O_3

less than 0.03% for fine quality glass
less than 0.20% for average quality, clear glass
less than 0.50% for bottle glass

Sulphur and phosphorus less than 1.0%, and organic matter less than 0.3%. Limestone makes up approximately 11% of a typical glass mix, with the remainder being 66% silica sand and 23% soda or potash. Lime earthenware can contain up to 50% lime, this can be introduced as marl, the carbonates will decompose in the kiln to produce anorthite and diopside. A substantial glass industry exists in Zambia at Kapiri Mposhi, located 160 kilometres south of Ndola. Soda-lime glass can be melted at a relatively low temperature, is easy to form, has good chemical durability, and is inexpensive, it accounts for about 90% of all glass produced. A typical commercial soda-lime glass is composed of 72% silica SiO_2, 15% soda Na_2O, 5% lime CaO, 4% magnesia MgO, 2% alumina Al_2O_3, and 1% boric oxide B_2O_3. [ref 47]

3.4.3 Flux stone

Limestones and dolomites are used to smelt various metals to supply basic CaCO and MgO which can combine with the undesirable acid components, such as sand, ash, or dirt. The flux forms a liquid mass, or slag, which can be drawn off from the surface of the molten metal. The basic requirement for a good flux, is for a material which is low in acid constituents and therefore, should not contain any acid content. The use of dolomite as a flux has increased, especially since environmental contamination has become a widely heeded consideration, this is because the resulting slag can be employed for such things as lightweight aggregate, whereas that formed when limestone is used cannot. Such is the case because dolomite-based slag does not slake (disintegrate in water), but limestone-based slag does. For use at ZCCM, the stone should be 97% $CaCO_3$, crushed and screened to produce sizes of less than 10 mm.

3.4.4 Agricultural lime

Various grades of lime are used within the agricultural industry, and agricultural lime is a term used to describe any lime product that can be used as a fertiliser or for Ph control of soil. A 93% $CaCO_3$ content is reasonable. Calcium and magnesium are both necessary to improve local soil conditions, which they achieve in a variety of ways. Their functions include the neutralisation of soil acids, improving the texture of clay soils by flocculating colloidal matter and therefore, making heavy soils more granular, the conversion of potash minerals to a form in which the potash is available for plant nutrition and providing a suitable environment for soil bacteria to break down vegetable matter into humus. As lime products are removed each year in harvested crops, they are replaced by the addition of lime as a fertiliser. Limestone and liming often improve the efficiency of other fertilisers. Agricultural limestone is often a by product, of fine dust from crushing and recovered fines from cement and air filters. [ref 106]

3.4.5 Aggregate

An area of industry that could be considered and possibly developed to subsidise the operation of the various cement and lime factories is the production and sale of aggregate. The dolomitic material which borders both the Chilanga and Ndola deposits should be removed, thereby making more of the high grade limestone available for processing to cement and lime. Mining the margins of the deposits will provide a ready source of material for blending. This will, without doubt, extend the life of the reserves and enable the maximum extraction of limestone. The borders of the deposits are known to consist primarily of dolomitic limestone. It is however, entirely possible that excavation of these areas will expose further deposits of high grade limestone. Should development of the areas mentioned above proceed it would be in the interest of Chilanga to process the material for sale as general purpose aggregate, much as is carried out at Ndola Lime Company. Indeed retailing crushed stone at current prices suggest that the project could be highly lucrative. A good aggregate for road stone or concrete has high toughness (resistance to fracture under impact), high hardness (resistance to grinding action), resistance to wear, and good cementing value, it should conform to BS 882. Sedimentary limestones, excluding dolomites, generally display, poor toughness, poor resistance to wear and good cementing value.

Bitumen carries a negative electrical charge and is attracted to the positive charge of certain rocks, including dolomites. This electrical attraction helps to create a good binding of the bitumen and the rock. Their good cementing value of limestones, means that they are often a favoured aggregate for road construction. In such cases, a hard wearing aggregate is often used as a thin surface layer (topping).Because of its high value as a decorative stone, poor toughness, hardness and low cementing value marble is rarely used as an aggregate. A particular use for which calcareous aggregates are preferred is in the manufacture of pipes being used in conditions favourable for corrosion by sewage. This is because the acid in the sewerage is neutralized to a certain degree by contact with the alkaline limestone. Dolomitic limestone, or dolomite marble, being harder than calcitic limestone is suitable for use in concrete, asphalt, rail ballast and any other purpose for which crushed stone is used. A secondary use for the crushing plant would be mechanically to sort the good quality limestone from the lateritic overburden. Aggregate is already produced from the combined Ndola quarries. The most important use of this product is as flux stone for use in the production of copper and as a slow release Ph correction material.

3.4.6 Soil stabilization

When a soil is treated to improve its bearing capacity and resistance to change, it is said to be stabilized, this is usually carried out with the addition of small amounts of lime or cement and is a common practice in road construction. Generally the addition of lime may be preferred to the addition of cement when the soil has a plasticity index of more than 20. The average addition is about 5%, or when used together with cement about 2% lime to 8% cement. In 1993 the Chinese company Sietco was the main customer of Ndola Lima Company for lime hydrate, they used the material for soil stabilisation in Tanzania.

3.4.7 Building and decorative stone

Marble is formed by metamorphosis of sedimentary limestone, it takes and retains a good polish. In its pure form it is white and consists almost entirely of calcite, $CaCO_3$. Because of its decorative appearance and strength, marble has long been prized for use in architecture and statuary. A premium-priced product that can be produced from selected areas of Chilanga RP3 and Ndola quarries, is cut and polished terrazzo flooring and facing stone. Much of the upper levels of the northern part of the deposit is covered with a particularly attractive dolomitic marble. The marble is highly decorative, with

Figure 3-7 [ref Mills] Marble from Chilanga

impurities producing pink and yellow varieties of pleasing appearance could be is used in building and perhaps sculpture.

Figure 3-8 [ref Mills] Carrara marble

As the dolomite is currently regarded as overburden to be blasted and hauled to the tip, it would serve the two purposes of clearing overburden and producing a high value product if this area were to be developed. For a modest investment in equipment, a profitable export business of cut and polished stone could probably be developed. One of the most famous quarries, that of Carrara in the Italian Apennines, has supplied fine white marble for centuries. The Apollo Belvedere (Vatican Museum, Rome), the Arch of Constantine (AD 315, Rome), and the Theatre of Marcellus (13 BC, Rome) are all are made from Carrara marble. In 1498, Michelangelo chose Carrara marble for his Pieta (Saint Peter's Basilica, Rome). [ref 47]

Dolomite

Dolomite is used as a source of magnesium metal and of magnesia (MgO), which is a constituent of refractory bricks. Dolomite is often used instead of limestone as an aggregate for both cement and bitumen mixes and also as a flux in blast furnaces. The use of dolomite as a flux has increased, especially since environmental contamination has become a widely heeded consideration, because the resulting slag can be employed for such things as lightweight aggregate, whereas that formed when limestone is used cannot. Such is the case because dolomite-based slag does not slake (disintegrate in water), but limestone-based slag does.

3.4.8 <u>Sugar</u>

Sugar is produced extensively both in Malawi (Sugar Corporation of Malawi) and more so in the huge growing fields of Mazabuka, Zambia (Zambia Sugar Company). The production of sugar requires lime for the refining and purification processes. In the Steffen process, quicklime reacts with the crude sugar juice to form calcium sucrate which is then filtered to remove undesirable materials. Hydrated lime is used in some other processes where it acts to precipitate impurities from the sugar solutions.

3.4.9 Paper manufacture

Pigments or dyes are added to paper pulp at the beating stage, along with filler materials that help to preserve the paper or give it a better opacity and finish. The most common fillers are white chalks (limestone), clays, and titanium dioxide.

3.4.10 Other uses

There are almost too many uses made of lime stone to quantify. The main ones include;

- fillers in asphalt, toothpaste etc.
- lime sands
- whiting such as in ceramics, chewing gum, foods, putty and plastics
- mineral food
- acid neutralisation
- electronics
- insecticides
- paints
- rubber processing
- cotton processing
- sewer neutralisation

Summary

Zambia has excellent limestone deposits, unfortunately, either they are not being exploited or they are being wasted, for example, by crushing high quality marble for aggregate and sand. Malawi has vast limestone resources, but most are of poor quality and in small deposits. It is likely that with the increasing costs of transport and the difficulties involved in crossing the borders from southern Africa, the development of this basic resource will progress and Zambia will become a major supplier of limestone products to south central Africa.

Chapter Four

FINANCIAL CONSIDERATIONS

and

Marketing

4.1.0 ASSOCIATED ECONOMICS

4.1.1 Introduction

The purpose of this chapter is to provide an indication of the fundamental processes involved in a simple quarry operation. As the three case studies indicate, limestone is excavated to provide a basic material for further processing, therefore, the cost of quarrying may not necessarily effect the market price of the final product.

Investment costs

For investment purposes, quarrying is considered a high risk industry and the development of new quarries is often described as a speculative venture and funding is usually regarded as risk capital. The way to reduce the risk, is to amass as much information about the project as possible and in as much detail as can be handled. A well researched and realistic feasibility study will enable the financial experts to evaluate and possibly modify the project before large amounts of money are committed. The crucial factor in deciding whether to develop a limestone reserve is a consideration of costs. A producer will only start to produce if it expects that total revenue will be sufficient to cover

- The cost of replacing fixed factors; called fixed costs
- the cost of variable factors such as, labour, raw materials; called variable costs
- normal profit.

Fixed costs are those costs which do not vary in direct proportion to the quarry output. They are the cost of indivisible factors, such as, buildings, plant, machinery and vehicles. Even where there is no output, fixed costs will be incurred, but for a time as output expands they remain constant.

Variable costs, are those costs that are directly linked to output. They are the costs of the changeable factors such as, operative labour, raw materials, fuel and machinery operating costs. Where there is no output variable costs are nil. The distinction between fixed and variable costs is principally useful in two ways;

- Variable costs can be changed to allow supply to respond to a change in demand
- the ratio between revenue and fixed to variable costs can determine the long term future of the quarry.

At the feasibility stage of the work studies featured in this document, the writer considered the revenue to cost ratio and it is estimated that the quarrying costs element of the overall product has a 10:1 element of revenue to cost factor. This is not a suitable reason for inefficient operation and any costs saved in extraction are of benefit to the overall profitability of the operation. The methods used to value a quarry are essentially the same whatever the purpose of the quarry or the material to be won.

Most quarrying costs reduce with economies of scale, this has given rise in the UK to the so-called super quarries, where, in a given area most of the small operations have given way to a more cost effective, large central quarry which serves a substantial geographical area.

Experience has shown the writer that it is the financial viability of operating the site that will determine its success, not the ease or difficulty of quarrying it and while technically, there will always be a way to exploit a deposit, basic economics may dictate that quarrying it will not be a cost effective operation. Before any consideration can be given to either opening a green field site or developing an existing quarry, the viability of it must be assessed, for this will dictate every aspect of its development.

The information to be collated is;

- the technical reserve
- expected cost of quarrying and therefore the economic reserve
- cost of processing, marketing and other overheads
- capacity and duration of the market
- expected selling price
- restoration and environmental considerations
- royalties and land ownership
- the possibility of sales contracts
- capital and operating costs, with cost of supplies
- life of project including restoration and rehabilitation costs

Financial details will concern;

- cash flow
- financial structuring
- preparation of bankable documents
- number and type of financial agencies
- possibility for due diligence surveys carried out by the bank
- debt servicing
- the extent and cost of a bond, supplied for environmental reconstruction

Evaluation of the above information will provide a general indication to the viability of a project. Probably, the most important external input will come from a market survey, with three vital pieces of information;

- What is the total size of the market.
- What is the annual market.

- What is the selling price, computed with expected annual increases.

Economies of scale

A quarry is generally set up to provide a certain output, to be efficient this should be about 80% of maximum capacity with the plant and equipment being matched to this end. Therefore, to achieve 100% capacity requires that the working hours be extended. In this instance the fixed cost have remained the same, giving a 20% advantage, however the variable cost have increased, probably by a similar amount. Should a further increase in production be required, it no longer becomes cost effective to operate the same equipment and larger plant is required. If there are several units involved, the production can be centralised and economies of scale will occur and the cost per unit will fall as a result of the advantages of large scale production. These are often referred to as internal economies and have given rise to the expression "superquarries".

The rate of extraction is of major importance when calculating Quarrying costs, whereby;

- A small operation will require less capital expenditure, involve less manpower and generally require a minimum of infrastructure, for example, hired equipment and on site management.

- A large operation will involve high capital equipment costs, involve slightly more manpower and require a substantial investment in infrastructure, for example, workshops, fuel distribution, stores and multilevel management.

In larger quarries, other economies of scale can be introduced;

- Financial economies, where in raising finance the larger producers are in a more favourable position with regard to risk. The established producer can, for instance offer enhanced securitisation measures to the finance houses.

- Commercial economies, where, if a bulk order can be place for materials and components the producer is likely to be quoted at a lower cost per unit. This is not always the case and in first world countries, to reduce cash in stock, daily replacement systems are often employed, in other instances, the producer may have sufficient influence to persuade the supplier to provide consignment stock. Economies can be achieved by selling the product itself, where, if sales staff are not being worked to capacity, the additional sales output can be marketed at little extra cost. Similarly advertisement costs can be spread.

- Technical economies, where in manufacturing a product increased output permits more division of labour, greater specialisation of machines and the economy of larger machines. The trend in producing limestone products is to close the smaller plants of perhaps 1,000 tonnes per day output and operate units of 10,000 tonnes per day, usually, the benefits in fuel alone make this process more cost effective.

- Risk bearing economies, where several elements of risk are distinguished

  - Risks that can be insured against, third party and employers risks.
  - Risks to plant and equipment.
  - Self insurance, where the producer accepts some of the risk.
  - Risk arising from changes in demand of product or its supply.

[ref for all above 117]

4.1.2 Marketing

Marketing can be defined as the supplying of goods and services to consumers. Assuming that the market is free, and without any external intervention, marketing will play an increasingly larger role in the determination of company policies, this by, influencing product development, pricing, methods of distribution, advertising, and promotion techniques. Altogether more than thirty countries across the African continent have recently embarked on radical programs of economic reforms and structural adjustment. Under economic reforms particular countries are opening up and exposing domestic markets to foreign competition. At the same time local producers are more aggressively looking for business opportunities. A market survey will provide the information required to enable the industry to grow, less corporate ownership will allow competition to develop. Effective marketing will often require a Market Research to be carried out this will usually consist of an examination of the following;

- domestic product demand and supply
- production costs and projected trends
- imports
- pricing policies of local and imported product
- potential growth rate
- comparison of self retailing or using external retailers
- transport facilities
- prospects for exporting for example; cross border tariff arrangements

To succeed in business, a company must adopt a marketing strategy in order to promote a product and often, a long-term marketing campaign is required to sustain the customers loyalty and interest in the product. A marketing campaign may use a mixture of marketing techniques such as money-back offers, BOGOF (buy one get one free), free samples, advertising, and leafleting.

The following elements help a company to sell its products, they are normally distinguished as;

- Realistic pricing strategy to meet demand for the product
- ensuring that the promotion in terms of advertising and marketing for the product is aimed at customer preference
- providing a marketing mix with different products offered at a range of prices
- ensuring that the product is distributed to the most convenient place for customers to buy it.

Only through successful marketing can the financial income equate to the forecasts and this is vital if the company is to develop in the way in which it was planned. Too often, this critical aspect of the company business is left to develop itself. It is of paramount importance that the marketing staff are fully trained in their business. In recent years, the emphasis on training has shifted from pure selling to include the study of such issues as environmental policy, corporate responsibility, business ethics, and internationalism.

A strong logo will help identify the company with the product, in the case studies, an elephant is used to represent the strength and longevity of the product. The logo should be designed to present a positive image of the company to others and be part of the marketing strategy of the organization.

Expressions such as green consumerism can be used with regard to base limestone industries, particularly when selling to consumers who are becoming increasingly concerned about the environment. Labels such as `eco-friendly' have become a common marketing tool as companies attempt to show that their goods had no negative effect on the environment. This is particularly important when dealing with mined products.

The Commonwealth Development Corporation (CDC) own the only cement producing plants in both Zambia and Malawi and due to the difficulty of importing cement from Zimbabwe these plant hold a virtual monopoly, similarly the nearest plant in Tanzania is also owned by CDC. This domination of the geographical market places a strong responsibility on CDC not to exploit the market and to keep the prices of the products realistic.

Pricing

Under perfect competition there are many sellers, each producing a very small amount of the total supply of product. Both cement and its related products are a basic commodity that is needed throughout on a worldwide basis, regardless of the level of development of that particular market. Perhaps, because of the large amount of initial investment required to build a cement or lime plant, control of the market is restricted to a small number of producers and it is common for these producers to invest in each others operations. This form of cooperation can result in the formation of a financial cartel, where all the individual producers are responsible for selling the product. A typical example of cooperation between rivals is found, where one producer will sell their product using packaging from an apparent competitor. This situation where a few producers control the pricing policy in the market is known as an oligopoly.

In an oligopolistic situation, pricing and output policy does not conform to given market principles. The oligopolistic producer reasons that should there be a price reduction, to avoid losing customers its competitors will follow suit, whereas if the producer raises its price, its rivals will also raise its price. Only if costs change significantly would the producer consider risking the loss of customers by raising its price or risk a price war by lowering its price. In practice, as the producer is unwilling to change its prices other policies are pursued, such as;

- to agree a price strategy, this, in order to achieve joint profit maximisation. Often this takes the form of following the price set by the largest producer. The extent to which collusion is possible depends on the ability to exclude new investors, particularly as production, to be cost effective, has to be carried out on a large scale.
- None price competition is prevalent through extensive advertising discounts and marketing.

In a perfect market, price is determined by the interaction of supply and demand. When demand for a product rises, the inevitable result, is that prices escalate. Eventually, the producer reacts by expanding supply, this usually results in a fall in price and the market stabilises. The market can simply be defined as "all those buyers and sellers of a good who influence its price". Within the market there is a tendency for the same price allowing for the cost of transport to be established for the same commodity. Notwithstanding this principal, there are instances where intervention in the market causes a distortion of prices over and above an oligopolistic situation. This can occur where the product has a strategic value to a government, or the public require the material regardless of cost, or it has an artificial value due to government introducing price controls. Where such price differences exist, these markets are said to be imperfect. Limestone products are a commodity that are highly prized by governments as essential requirements to the construction, chemical, mining and agricultural industries. In Zambia and Malawi, with typical third world economies, such industries are central to their national development. As such, limestone operations can sometimes be vulnerable to varying levels of government control, this will have an impact on an investors profitability and ultimate viability. To override this, and so as not to incur financial penalties, the product should be priced realistically, other benefits to the community can mitigate adverse public opinion. These may include, financing health projects, housing, road construction, failure to adopt these measure may result in the government attempting to control prices. Measures to avoid this may include;

- local employment
- community facilities
- healthy food regimes in a works canteen
- health clinics, health education and vaccination programmes
- schools and other educational facilities
- balanced regional development
- acceptable rates of growth with restrained inflation

Most of the above measure were successfully implemented in both Zambia and Malawi.

4.1.3 Simple Spreadsheet

Reasonably simple calculations, using the above information will enable the total aggregate planned income and expenditure and therefore the earning potential of the deposit to be calculated. In a lime or cement business, unless it is intended that the kiln will be replaced or another one added, the total project should be considered to have a life of not less than thirty and not more than forty years. Providing the market is known and the type and capacity of the kiln is available it is easy to calculate the total requirement from the mine, for example;

With a modern kiln producing around 2,000 tonnes of cement per day and operating for 300 days per year, the yearly extraction from the quarry, and depending on the raw meal mix, could be 1,200,000 tonnes (with 50% of the limestone being lost on ignition). Therefore, the total extraction taken over a thirty year period will be 36,000,000 tonnes.

The typical cost for mined rock in central Africa (1998) is reasonably high at say,$10,00 per tonne. Therefore at the rate of production shown above, the cost of Quarrying in 1998 will be 1,200,000 x 10 = 12,000,000 or twelve million US dollars. Add to this the cost of inflation and the life of thirty years and the mine will have a dollar value of 12,000,000 x 30 = 360,000,000 or three-hundred and sixty million dollars plus inflation.

When supplying rock from its own mine to a cement or lime factory, the cost of the quarrying will be internal, an exception to this, is if aggregate is sold from the quarry, in this case, the quarry will have an external earning potential and may become an external cost centre and in effect, sell rock to the factory. All of the usual costs such as fuel, electricity, transport, drilling, explosives, labour, royalties and restoration can easily be established to assist in producing a financial model. Assuming a thirty year operating period, the loading and drilling equipment will have been replaced six times and the trucks three times. For an output of 4,000 tonnes a day the quarry will probably operate

- one excavator ($600,000)
- one loader ($600,000)
- one drilling rig ($100,000)
- one compressor ($60,000)

With a value (1998) of about $1,360,000 and two trucks with a combined value of $1,200,000, giving a total plant value of $2,560,000. Once all the data has been collated, a spreadsheet can be produced to show the cash flow forecast and with the possibility to adjust the figures, identify and quantify the sensitivities, a very basic example is shown below; Where

- income of the quarry
- cost of capital equipment
- fuel, electricity and maintenance of plant @ 30% of income
- 160 tonnes of explosives and accessories per year @ 10% of income
- labour, administration and marketing @ 25% of income
- royalty, lease and environment @ 15% of income.

The financial model should be accurate for the whole life of the quarry and must take into account as many variables as possible to highlight both risks and opportunities. The model will dictate the most favourable rate of extraction and assist the quarrying engineer in the choice of suitable mine equipment. Usually the model will be something of a circular argument with a dispute between the accountants and the engineers, hopefully a reasonable compromise will be reached.

Figure 4-1 [Mills] Simple spread sheet

Year	Value of sales	Capital plant purchase	Maintenance fuel and electricity	Explosives and accessories	Labour administration and marketing	Royalty, lease and environment
1998	12,000,000.00	2,560,000.00	3,600,000.00	1,200,000.00	3,000,000.00	1,800,000.00
1999	12,600,000.00		3,780,000.00	1,260,000.00	3,150,000.00	1,890,000.00
2000	13,230,000.00		3,969,000.00	1,323,000.00	3,307,500.00	1,984,500.00
2001	13,891,500.00		4,167,450.00	1,389,150.00	3,472,875.00	2,083,725.00
2002	14,586,075.00		4,375,822.50	1,458,607.50	3,646,518.75	2,187,911.25
2003	15,315,378.75	1,700,000.00	4,594,613.63	1,531,537.88	3,828,844.69	2,297,306.81
2004	16,081,147.69		4,824,344.31	1,608,114.77	4,020,286.92	2,412,172.15
2005	16,885,205.07		5,065,561.52	1,688,520.51	4,221,301.27	2,532,780.76
2006	17,729,465.33		5,318,839.60	1,772,946.53	4,432,366.33	2,659,419.80
2007	18,615,938.59		5,584,781.58	1,861,593.86	4,653,984.65	2,792,390.79
2008	19,546,735.52	3,840,000.00	5,864,020.66	1,954,673.55	4,886,683.88	2,932,010.33
2009	20,524,072.30		6,157,221.69	2,052,407.23	5,131,018.07	3,078,610.84
2010	21,550,275.91		6,465,082.77	2,155,027.59	5,387,568.98	3,232,541.39
2011	22,627,789.71		6,788,336.91	2,262,778.97	5,656,947.43	3,394,168.46
2012	23,759,179.19		7,127,753.76	2,375,917.92	5,939,794.80	3,563,876.88
2013	24,947,138.15	2,550,000.00	7,484,141.45	2,494,713.82	6,236,784.54	3,742,070.72
2014	26,194,495.06		7,858,348.52	2,619,449.51	6,548,623.77	3,929,174.26
2015	27,504,219.81		8,251,265.94	2,750,421.98	6,876,054.95	4,125,632.97
2016	28,879,430.80		8,663,829.24	2,887,943.08	7,219,857.70	4,331,914.62
2017	30,323,402.34		9,097,020.70	3,032,340.23	7,580,850.59	4,548,510.35
2018	31,839,572.46	5,760,000.00	9,551,871.74	3,183,957.25	7,959,893.12	4,775,935.87
2019	33,431,551.08		10,029,465.33	3,343,155.11	8,357,887.77	5,014,732.66
2020	35,103,128.64		10,530,938.59	3,510,312.86	8,775,782.16	5,265,469.30
2021	36,858,285.07		11,057,485.52	3,685,828.51	9,214,571.27	5,528,742.76
2022	38,701,199.32		11,610,359.80	3,870,119.93	9,675,299.83	5,805,179.90
2023	40,636,259.29	3,825,000.00	12,190,877.79	4,063,625.93	10,159,064.82	6,095,438.89
2024	42,668,072.26		12,800,421.68	4,266,807.23	10,667,018.06	6,400,210.84
2025	44,801,475.87		13,440,442.76	4,480,147.59	11,200,368.97	6,720,221.38
2026	47,041,549.66		14,112,464.90	4,704,154.97	11,760,387.42	7,056,232.45
2027	49,393,627.14		14,818,088.14	4,939,362.71	12,348,406.79	7,409,044.07
2028	51,863,308.50		15,558,992.55	5,186,330.85	12,965,827.13	7,779,496.28
	849,129,478.54	20,235,000.00	254,738,843.56	84,912,947.85	211,453,480.50	127,369,421.78

4.2.0 NDOLA LIME COMPANY

The following is an extract from a business plan that was produced in 1996 by the writer and others, in order to make a bid for the purchase of Ndola Lime Company, in fact, the bid was not accepted, and by 1999, despite the plant being put on the market again in 1998 it had still not been sold. Possibly, the main reason for it not being sold was its strategic value, for without lime, copper cannot be produced and the economy of Zambia depends on copper. To protect CDC, sensitive areas of the document have been edited out. Nevertheless, the paper gives a good demonstration of the type of information that is required to invest in and operate a modern lime plant and quarrying process.

4.2.1 Introduction

The Ndola Lime Company Limited (NLC) is a wholly owned subsidiary of Zambia Consolidated Copper Mines Limited (ZCCM). The company's core business is to produce quicklime for its major customer ZCCM for use in the processing of copper, although it also manufactures hydrated lime, primarily for the export market as well as limestone aggregate and agricultural lime for local consumption. NLC's quarrying and production facilities are situated approximately 4.5 km east of Ndola in the Zambian Copperbelt, adjacent to the Ndola Works of Chilanga Cement plc.

The Government of Zambia has recently instructed the Zambian Privatisation Agency (ZPA) to privatise the Ndola Lime Company by selling a majority of the equity of the company by competitive bid and transferring the remainder to the Zambia Privatisation Trust Fund for eventual sale to the Zambian Public. NLC is expected to be formally offered for sale to interested parties in May 1996. A CDC planning team, led by Business Development and including two lime consultants from Rugby Cement Plc and a Senior Mining Engineer from CDC visited NLC in February 1996.

The purpose of this document, prepared following the visit to NLC, is to examine the case for CDC to submit a bid to acquire and rehabilitate NLC. The report assesses the company's current business situation, evaluates future options and proposes a business plan for a preferred strategy within the context of CDC's existing role in Chilanga Cement, its geographical neighbour with whom it shares clear opportunities for synergy in terms of raw material, process technology and managerial skills.

4.2.2 Company History

The Ndola Lime Company was originally founded in 1931 as the Northern Rhodesia Lime Company Limited, pursuant to an agreement between the Rhokana Corporation Limited and Ndola engineer, Mr John Owen Wallen, to supply lime to the copper mines.

Initial lime burning trials in 1931 at Misundu, 16 km north of Ndola close to the Zaire border, were conducted in wood fired, hollowed-out anthills where encouraging results led to the establishment of a quarry to extract limestone, followed a few years later by the construction of underground pot kilns. In 1962 the company moved to its present location at Mwatesi near Ndola where by the following decade it operated four small vertical kilns. However, in the quest for more cost efficient production and in response to the increasing demand for quicklime these kilns have gradually been replaced, first in 1973 by the commissioning of a new rotary kiln and crushing plant and later, in 1986 by the installation of an annular shaft vertical kiln. Today these two production lines give NLC a combined theoretical quicklime production capacity of approximately 1000 tonnes/day.

From April 1986 ZCCM's interests in NLC were transferred to Mulungushi Investments Limited (MIL), a ZCCM subsidiary holding company, and it remained dormant, operating as a division of MIL until the end of 1991 when as part of the restructuring of the ZCCM group of companies it was decided that NLC should revert to its original status and operate as a direct subsidiary of the parent with effect from January 1st 1992.

ZCCM is a 60.3% state owned corporation operating a fully integrated copper industry on the Zambian Copperbelt. 27.3% of its shares are held by Zambia Copper Investments Ltd, a company controlled by Anglo American Group. In addition to copper, ZCCM produces cobalt, lead, zinc and minor amounts of precious metals. It is by far the most important company in the Zambian economy and mineral exports by ZCCM account for over 90% of Zambia's total foreign exchange earnings.

ZCCM's copper production is divided into five operating divisions which operate underground mines and an open pit mine. Of the five operating divisions, two produce cobalt, as a by-product. The company smelts and refines the copper concentrate from the five divisions at Nkana and Mufulira. Nkana Division treats cobalt concentrates and also produces sulphuric acid. Nchanga Division operates a tailings leach plant, producing copper leach cathodes from tailings. These divisions are supplied with all their lime and lime rock requirements from NLC. The relationship between the two companies is symbiotic; one cannot function without the other.

4.2.3. Business Description

This section provides a brief description of the mineral reserves, plant and operations of Ndola Lime Company. Ndola Lime Company is situated adjacent to the Ndola works of Chilanga Cement Plc. Although the two companies operate different quarries they are both mining the same limestone deposit. Chilanga Cement has one quarry and Ndola Lime three (Mwatesi, Foxcut and New Foxcut). Two of the Ndola Lime quarries are no longer worked due to the absence of limestone of a suitable quality

(Mwatesi and Foxcut). All four quarries are flooded. A collection of huge waste tips dominates the area between the quarries and the plant. Although geologically complex, the reserve does not present any particular difficulties for quarrying except water management. Nevertheless, at NLC the reserve has been mined without a mining plan and abstraction has deteriorated to an operation of opportunistic mining where any area that is readily accessible is being worked.

Quarry-reserve

A drilling programme was carried out from 1986 to 1987 and in 1988 a report was published by DeVente and Haldane which estimated reserves to a depth of 50 metres as 8 million tonnes, sufficient for 7 years at the current consumption rate. Further drilling was carried out in 1990 and data entered onto a Lynx computer modelling system. Another report was compiled in 1993 titled "A Reassessment of the Ndola Lime Company Geology and Reserves". By reinterpreting the data using the computer model and incorporating the results of the 1990 drilling programme the reserve was re-estimated as 33 million tonnes, considered sufficient for 28 years at current rates of consumption.

The 1993 report has been reviewed by Jack Mills, CDC Senior Mining Engineer. Certain assumptions in the report were considered unrealistic or inaccurate. In particular the density of stone and wastage rates used in calculations were over optimistic. By revising these assumptions the reserve has been re-estimated as 17.3 million tonnes, sufficient for 22 years at current rates of consumption. The limited extent of drilling means that the information provided by the computer model may not be accurate. Further supplies of suitable quality limestone exist at the Chilanga quarry. However, no drilling has been carried out and therefore it is not possible to quantify these additional reserves which have been excluded from the above calculations. A full consideration of the limestone reserves of NLC is given in Jack Mills' report dated February 1996.

Mobile Plant

The current mobile plant fleet consists principally of:

- 2 electric rope shovels
- 4 front end loaders
- 7 dump trucks
- Misc drill rigs, compressors, dozers and others.

Many items of mobile plant have recently been transferred to ZCCM and Ndola Lime is now operating with a bare minimum of equipment. The electric rope shovels are used at the rock face in conjunction with the front end loaders to load the dump trucks with stone. The shovels are the largest and most expensive items of mobile plant.

Condition of Plant

Both the rope shovels are old (21 years and 27 years) and one has not been operational for two years. Although they could give many years further service, the cost and availability of spares suggests that purchase of replacement plant is preferable. A 75 to 100 tonne hydraulic excavator would be a suitable replacement. Much of the remainder of the mobile plant is also very old and costly to maintain. This business plan proposes replacing many of the items over the next 2 to 3 years at a total estimated cost of $3.7 million.

Crushing Equipment

Stone won from the quarry is selected for its physical suitability for the two kilns and conveyed by dumper to the crushing plant. It is first crushed in an obsolete 300 tonnes per hour (tph) primary crusher, then screened and crushed again in secondary and tertiary crushers to provide feedstone for the vertical kiln (size 35 to 75 mm), rotary kiln (size 19 to 35 mm) and aggregate (less than 19mm). This plant was supplied, erected and commissioned when the rotary kiln was installed in 1973 with further additions when the vertical kiln was installed in 1986.

Condition of Plant

The equipment is generally in reasonable condition. With the exception of the primary crusher and possibly the dust collection equipment it should not require significant rehabilitation work. Major remedial works have recently been carried out on the primary crusher. It is not yet clear whether these have been successful. If not, a new primary crusher may be required at a cost in the region of $1 million. Dust collection equipment on the crushing plant is not functional but it is hoped that simple maintenance work will rectify the problem. If not this will need to be replaced

Kiln Equipment•rotary Kiln

There are two kilns. The first is an FLS rotary kiln supplied in 1973 and rated at 550 tonnes per day (tpd) of quicklime. It is fitted with planetary coolers to cool the quicklime at the outlet. Heating is by heavy fuel oil which is preheated to assist atomisation. An electrostatic precipitator dust collector is fitted. Although rated at 55Otpd this kiln should be capable of producing 65Otpd if fitted with reasonable internal heat exchange fittings. Over the past two years daily outputs have averaged 46Otpd.

Condition of kiln

The girth gear which rotates the kiln is badly worn and will require changing. This is planned for the next annual shut down. The electrostatic precipitator is not operational and has not been since approximately three months after commissioning of the kiln when an explosion seriously damaged one of its two banks. Although $350,000 has been provided for rehabilitation of the electrostatic precipitator in the 1996 maintenance budget it is unclear whether this will actually take place. Rugby Cement estimate that $350k to $750k will be required for full rehabilitation. Until this has been done high dust emissions will continue.

Kiln Equipment. Vertical Kiln

The vertical kiln was supplied by Warmestelle Steine and Erde WG of Germany in 1986 and is rated at 500tpd although outputs of 37Otpd are currently being achieved. It is approximately 8 metres in diameter and 45 metres high and fitted with a gravel bed dust collection filter. Performance of the vertical kiln is more sensitive to the physical qualities of the limestone than the rotary kiln. Feedstone must be sufficiently strong to withstand the crushing forces at the bottom of the kiln. Stone which decrepitates on heating will be crushed to a powder causing gas flow blockages. This is a probable cause of the low production levels. The vertical kiln is fired by heavy fuel oil and is significantly more fuel efficient than the rotary kiln, consuming 45% less fuel per tonne of quicklime.

Condition of kiln

Apart from the exhaust fan and the gravel bed filter the vertical kiln appears to be in reasonable condition. Unfortunately it was not operational at the time of our visit as there were insufficient supplies of limestone due to failure of the primary crusher. The gravel bed filter has never been operational since installation, apparently because it was prone to blocking. By removing the gravel beds and inserting bag filters it may be possible to reduce significantly the current emissions though possibly not to European standards.

Lime Hydration

The lime hydration plant has a nominal capacity of 4tph and was installed in 1961. It consists of a mill to crush the quicklime and seven horizontal cylinders where the crushed quicklime is mixed with water. The hydrated product, a white powder is bagged in a 2 spout 6tph Haver and Bocker bagging machine.

Condition of Hydration Plant

Although the final product is of good quality, and the output, estimated at roughly 3.5 tonnes per hour, not far off nominal capacity, the plant is in a poor state of repair and losing significant amounts of dust to the atmosphere. There are strong environmental arguments for replacing the plant with newer cleaner equipment. This option has been considered by Ndola Lime several times in the last 10 years.

4.2.4. Operating Performance

Quicklime production levels for the last 5 years are as follows:

Figure 4-2 [ref 87] Production levels

Production levels for years 1992 until 1996			
Year to March	rotary kiln 000's tonnes per annum	vertical kiln 000's tonnes per annum	total 000's tonnes per annum
1992	111	91	202
1993	82	104	186
1994	149	61	210
1995	78	113	191
1996	127	81	188

In the past production has been geared to meet demand from ZCCM. The combined output capacity of the two kilns should normally be ample to achieve this. As the vertical kiln is significantly more fuel efficient than the horizontal kiln, production from this has been maximised whilst production from the horizontal kiln has been minimised.

Vertical Kiln

Average daily production for the vertical kiln over the last 9 years (excluding days of zero production) has been nearly 4SOtpd. It should be possible to achieve a run factor of 94% for 330 days i.e 140,000tpa. (0.94x330x450). The vertical kiln has therefore been operating at between 40% to 80% of achievable capacity. The cause of this poor performance is not clear but is likely to be attributable to:

- stone with unsuitable physical characteristics (size, strength)
- poor airflow arising from unsuitable stone and insufficient suction
- excessive mechanical and electrical breakdown

Fuel cost savings in the region of $800,000 pa ($16 per tonne of quicklime) could be achieved if the vertical kiln output was increased to 140,000tpa from the current average of circa 90,000tpa.

Rotary Kiln

The rated capacity of the rotary kiln is 55Otpd and it has been shown to be capable of producing 546 i.e. 169,000tpa (0.94x330x546). The rotary kiln is less sensitive to changes in stone quality and easier to operate than the vertical kiln and this explains why it has been operated more than the vertical kiln over the last 5 years.

4.2.5. Financial Performance

Figure 4-3 [ref 87] Plant revenue

Revenue in US $000's						
	1991	3 months to 31/3/92	1992/93	1993/94	1994/95	1995/96
Turnover	19,391	4,243	7,577	14,711	11,984	14,092
Production costs and overheads	(16,324)	(4,799)	(7,443)	(14,372)	(11,564)	(14,910)
Interest payable and receivables	25	117	134	(10)	265	209
Profit before tax	3,092	(438)	268	329	685	(609)
Profit after tax	3,204	(438)	128	203	495	(704)
Average exchange rate ZK/US$	38	85	275	565	722	939
Total production quicklime 000's pa	185	202	186	210	191	188

Pricing Policy

Towards the end of each year a budget is prepared for the following year and a selling price calculated which will recover fully all costs incurred. The budget and proposed price are then submitted to ZCCM for approval. If ZCCM approve, the new price is implemented at the start of the next financial year. A premium is charged for sales to non ZCCM customers. As a result of the above policy, if budgeted performance is achieved NLC should approximately break even each year. The objective is not to make a profit but simply to satisfy ZCCM's requirements for quicklime and limestone aggregate. The anticipated loss in 95/96 is due to several months downtime on the vertical kiln causing a switch in production to the rotary kiln which is more expensive to operate.

Production Costs

Average production costs per tonne for the 9 months to 31 December 1995 were as shown below. Quick lime and hydrated lime costs shown are for production from the (fuel efficient) vertical kiln. The final column shows the additional costs incurred, per tonne of quicklime, for production from the rotary kiln. Approximately 45% of production has been from the vertical kiln over the last 5 years.

Figure 4-4 [ref 87] Production costs

Breakdown of production costs in US $				
	Limestone	Quicklime	Hydrated lime	Rotary kiln additional costs
Variable costs				
Heavy fuel oil	0.0	19.0	16.2	15.9
Diesel	0.7	2.4	2.1	0.4
Repairs and maintenance	0.3	1.2	1.0	(0.5)
Power	0.4	1.5	2.3	
Paper sacks	0.0	0.0	10.5	
Other	0.3	0.7	0.9	
Total variable costs	1.7	24.8	33.0	15.8
Fixed costs				
Labour	1.6	7.0	10.6	
Other production costs	1.5	4.7	5.8	
Other non production costs	0.7	5.2	7.1	
Total fixed costs	3.8	16.9	23.5	
Total fixed and variable	5.5	41.7	56.5	15.8

The cost of fuel per tonne of hydrated lime is lower than the cost per tonne of quicklime because one tonne of quicklime produces approximately 1.2 tonnes of hydrated lime on hydration. No fuel is consumed during the hydration process. The analysis above excludes depreciation and finance costs. For comparison, the selling prices at February 1995 were as follows (for sales to ZCCM):

Limestone	ZK 4,400
Quicklime	ZK 39,500
Hydrated Lime	ZK 50,000

4.2.6. Market

The products sold by Ndola Lime can be categorised under the following headings:

1. Quicklime
2. Limestone
3. Hydrated Lime
4. Agricultural Lime

In addition the company manufactures 6" and 8" concrete blocks using limestone aggregate and cement, but sales from this essentially cottage industry are both tiny and highly localised and for the purposes o. market analysis can be discounted.

Quicklime is burned "unslaked" lime containing an average of 87% CaO It is sold almost exclusively to ZCCM, in bulk for use in the copper production process.

Limestone is crushed rock from the quarry of 98% CaCo3. It is primarily sold in bulk, as kiln stone (l0mm-75mm) for use in the construction industry or in its finer form (0-10mm) as fluxstone, to ZCCM's copper smelters.

Hydrated lime is slaked quicklime containing an average of 70% Ca(equivalent to 95% Ca(OH)2. It is mostly sold in 25 kg bags for use in the building industry, sugar industry, water treatment, tanneries and chemical industries.

Agricultural Lime is a fine powder dust obtained from the dust collector at the plant. Highly alkaline with approximately 93% CaCo3, it is mainly used as agricultural fertiliser and by the glass industry.

Quality problems identified by ZCCM's own testing regime which regular] examines minimum CaO contents and reactivity of both limestone an quicklime, are remarkably few.

Prices

Traditionally prices for lime products to ZCCM have been a "transfer arrangement, sufficient to cover NLC's costs of production without allowing the subsidiary company to make a profit. Currently the pricing structure is split into 3 groups for ZCCM, local and export markets according to the following formula:

for ZCCM, full absorbed costs only;

for local customers', full absorbed costs + 10% + Capex

for 'export', full absorbed costs + 10% + 10% + Capex

Capex Note: The agreed annual budget for capital expenditure is divided by the annual budget tonnage of all products except limestone.

Figure 4-5 [ref 87] Cost of lime

The 1996/97 fob prices per tonne			
	Limestone	Quicklime	Hydrated Lime
ZCCM	ZK 6,710	ZK 54,000	ZK 68,440
Local	ZK 7,500	ZK 62,300	ZK 76,500
Export		US$70	US$80

Promotion

The promotional budget is small, limited to approximately $75,000 per annum and is targeted primarily at increasing export sales of hydrated lime. Activities include publishing company documentation and brochures, seminars/workshops, foreign trade missions and local trade fairs as well as a small amount of advertising via trade journals.

Distribution

To Zccm

ZCCM's annual budget of product requirements is presented to Ndola Lime about 4 months before a new financial year commences giving the subsidiary ample time to formulate its own production budget. Orders from each ZCCM Division are sent to a central order/production office for collation before being passed to Ndola Lime. This office, part of ZCCM's Power Division, monitors receipts and stock in transit (SIT), to ensure that each plant retains optimum stocks. The stocking provision at each site varies considerably, but is approximately proportional to usage and in total equates to a healthy 11,820 tonnes of capacity for quicklime and 31,200 tonnes of limestone. Delivery to ZCCM plants of both quicklime and limestone is mostly by rail. Zambian Railways are not efficient and it often takes up to 7 days to deliver 60 miles. In the wet season truck tarpaulins are frequently stolen to provide shelter, and deliveries have to be made by road. This is when the SIT system is reported to work extremely well. ZCCM hydrated lime requirements are delivered solely by road, since experiments to utilise the rail network resulted in high levels of theft and bag damage during transit.

To the Local Market

By virtue of its low cost to weight ratio, both limestone and agricultural lime are currently only sold within the Copperbelt and is either distributed via company vehicles, or more usually, collected by the customer on his own transport for cash.

To the Export Market

Only negligible amounts of quicklime are exported. In contrast nearly three quarters of the total hydrated lime output is sold abroad, predominantly to Zimbabwe and South Africa but also to Malawi, Namibia and Zaire. Distribution is primarily by road, as the railway is unreliable and transport to the nearest accessible port at Dar es Salaam for onward distribution by sea is not a realistic, commercial option. Most hydrated lime sales are on a collected only basis. The road network is adequate rather than good and distances are long. The transport rates charged by the transporters for similar destinations (See Appendix 9) vary considerably. These charges reflect operators own margins but most importantly the distances needed to travel unladen. Where backloading is possible, costs can be halved.

Market Size, Historical Development and Future Potential

Figure 4-6 [ref 87] Sales summary

Five year product sales summary by market sector in tonnes						
	1990/91	1991/92	1992/93	1993/94	1994/95	1995/96
Quicklime						
ZCCM	171,097	173,995	186,091	200,120	168,590	167,275
Others	1	90	558	559	-	
Exports	-	24	5,312	3,715	13	138
Limestone						
ZCCM	175,642	162,989	183,477	230,007	185,583	156,151
Others	96,028	92,439	96,937	85,885	98,044	77,662
Hydrated lime						
ZCCM	2,995	2,988	3.425	3,051	1,748	1,078
Others	4,798	2,988	4,267	4,567	3,375	4,045
Exports	4,826	9,016	10,767	15,565	8,912	14,960
Agricultural Lime						
ZCCM	-	49	327	60	332	3.230
Others	6,451	6,003	4,964	4,231	5,069	6,846

Quicklime

The dominating influence of ZCCM on NLC's sales performance is evident. Over the last 5 years ZCCM has accounted for 99% of all quicklime sales, 66% of all limestone sales and about 18% of all hydrated sales. As discussed above quicklime sales have remained relatively constant in spite of declining production levels of finished copper. The potential for the quicklime market is obviously heavily reliant on ZCCM's budget. Historically these figures have been accurate and they remain stable for 1996/97.Over half of the quicklime produced is sold to the Nchanga Division and the stable operation of the Tailings Leach Plant is clearly fundamental to the future success of NLC. Discussion with management at Nchanga in February 1996 suggested that the plant had not been achieving expected outputs and that they were looking to increase production by 25% by April 1996. It was estimated that there wifi then be at least 15 years of tailings left to process at this rate of usage. Furthermore it is possible that when the Nchanga Mine closes in six years time the tailings from the new deep mine at Konkola could be pumped to Nchanga for processing; in any case the Konkola tailings will be leached and consequently more lime and limestone will be used.

The other main users of lime within ZCCM are the Cobalt Plants. Officials at Kitwe Headquarters confirmed that local cobalt extraction is planned for the next 5 years, that there are sufficient raw materials for 10 years and no reasons why extraction should not continue until the reserves are exhausted. It is thus reasonable to assume, particularly as more cobalt extraction is planned at other sites and more reserves are being identified, that there is well in excess of 10 years' assured need for lime and limestone into the industry. In addition there is the possibility of sales of exported quicklime resuming to the Zaire Copper Industry. Previously no more than a bad debt risk, the mines have now been taken over by the South Africans and Belgians and negotiations for a potential 24,000 tpa supply to Gecamines have recently begun.

Limestone

Over the last five years limestone sales have fallen slightly due to ZCCM's reduced offtake. This year total sales to ZCCM and others will be 96.7% of budget and next year the budget anticipates a 3% volume increase, which given the accuracy of previous budgets and the continuing need for neutralising in the leaching process suggests an optimistic long term future. Local sales, which have remained remarkably stable considering the construction recession of the last 3 years, should recover from the low estimated figure for 1995/96 (brought about by the serious crusher breakdown when all the available stone went for lime burning and fluxstone to ZCCM) as more local dealerships are developed and the expected economic upturn takes hold.

Hydrated Lime

Sales of hydrated lime peaked in 1993/94 at 23,123 tonnes which is probably close to the maximum output of the hydrating plant in its present condition.

Sales to ZCCM have been reducing and are lagging behind budget making it probable that approximately 1,000 tonnes will be sold in 1996/97. Most hydrate appears to be being used for water purification rather than copper separation.

Sales of local hydrate have remained fairly constant over the past six years. The product is sold nationwide but it is anticipated that volumes would increase if the number of retail outlets selling the product could be expanded; closer co-operation with Chilanga Cement in the event of a successful bid could achieve this aim. Potential for the future will rely on widening the customer base and broadening the uses for lime, for example in soil stabilisation, asphalt anti-strip, water/sewerage treatment and perhaps, gas desulfurization.

Sales of hydrated lime to the export market provide a vital source of foreign currency and represent a major opportunity. The Sales and Marketing department have estimated the total available export demand to the region as 113,600 tonnes which given an estimated sales level in 1995/96 of 14,960 tonnes suggests a penetration level of only 13% and the potential for considerable improvement.

Figure 4-7 [ref 87] Export sales

Hydrated Lime. Export Sales. Tonnes						
	1990/91	1991/92	1992/93	1993/94	1994/95	1995/96
Malawi	2,303	3,859	2,238	3,971	1,626	984
Zimbabwe	1,743	1,721	1,274	1,921	2,218	5,070
Zaire	780	296	210	108	226	260
RSA	-	2,989	6,745	7,720	4,564	8,509
Tanzania	-	-	-	1,515	30	36
Burundi	-	150	300	330	238	-
Namibia	-	-	-	-	-	101
Total	4,826	9,016	10,767	15,565	8,912	14,960

Although not proven, it is likely that total sales of hydrated lime are in practice capped at about 23,000 tpa due to the poor condition of the plant. Further restrictions to trade include the primitive and manual loading and handling facilities, the distance to and hence the cost of getting the product to regional markets by road and the political stability of neighbouring countries like Burundi and Rwanda. However on the plus side, despite being disadvantaged in each country NLC exports to, by between US$14 and US$68 a tonne, the company is still able to sell increasing quantities of lime by virtue of its premium quality. There are no other limes produced in Southern Africa of equal quality. The lime produced by PPC Lime at their Limeacres plant for example is said to look grey - like cement, and is reported, like other competitors products produced with dolomitic lime, to give brown solutions and residues when used in such processes as water purification. In contrast, NLC's hydrated lime is pure white owing to the high calcium content of the raw materials and/or the consistency of manufacturing control of the product. This competitive advantage, coupled with the establishment of agents in Zimbabwe and more recently Namibia, with sole product distribution rights should give added impetus to future sales, providing that transport costs do not escalate.

Agricultural Lime

Over the last six years agriculture lime sales reduced but in 95/96 have recovered to above their 1990/91 levels. This reflects the amount of lime used by local farmers and in glass manufacture. However the amount sold to ZCCM in 1995/96 increased ten times as Nchanga Division experimented with its use in their tailings plant and found it a successful and cheaper replacement for limestone. If CDC were to win the bid for NLC it would be prudent to price the dust at an acceptable level for ZCCM that would give a marginal benefit over limestone, because when the electrostatic precipitator is repaired a lot more dust will be available for sale. An assumed 8% dust loss on clinker production levels of 150,000 tonnes/annum for example, would give a potential volume of 12,000 tpa of dust, which if 1996/97 sales to other customers remained static at around 6,000 tonnes would leave a similar amount available for ZCCM.

4.2.7. Future Potential: Summary

Figure 4-8 [ref 87] Sales forecast

Sales Forecast to 2000 in 000's Tonnes				
	1996/97	1997/98	1998/99	1999/2000
Quicklime				
ZCCM	176	202	224	229
Others	-	2	2	2
Exports	-	-	-	-
Limestone				
ZCCM	177	200	200	200
Others	72	100	100	100
Hydrated lime				
ZCCM	1	2	2	2
Others	5	5	10	1-
Exports	18	20	25	30
Agricultural Lime				
ZCCM	4,000	6,000	6,000	6,000
Others	6,000	6,000	6,000	6,000

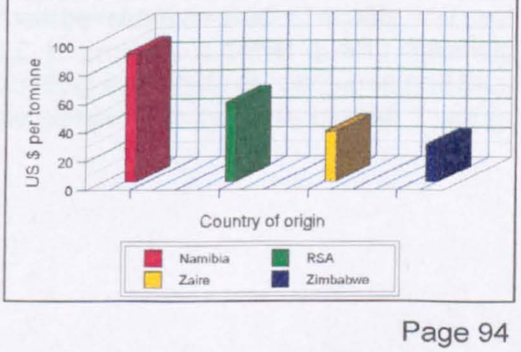
As discussed previously, the absence of a direct linear relationship between quicklime consumption and finished copper production makes forecasting difficult, but the figures above, derived from ZCCM's Corporate Planning Dept and taken in conjunction with the company's outstanding tailings dams and anticipated increased cobalt production, underpin the logic of the longer term projections. The anticipated sales of hydrated lime put forward by NLC's Marketing Dept, pre-supposes the installation of new capacity at the hydrating plant from around 1997/98 onwards, while the agricultural lime figures are dependent upon the re-instatement of the electrostatic precipitator.

Competition

There are two significant barriers to entry for competitive supply of lime products:

Transport costs

Figure 4-9 [ref 87] Transport costs per tonne



Lime products have a relatively low value per kg and therefore transport costs can be significant. The graph shown opposite, has been prepared assuming that transport costs for imports are similar to those for exports, and shows the lowest price quoted for each country (excluding Zambia Railways due to low reliability).

Capital Costs - for a green field site

There are numerous limestone deposits in Zambia which could be used by a new lime plant. The Rugby cement consultants have estimated that a new greenfield lime plant with a capacity of 300,000 tonnes per annum (similar to NLC) and including a hydrator, quarry plant etc. would cost in the region of $33 million to build. This does not include any cost for the acquisition of a limestone reserve. As long as NLC can be purchased and rehabilitated at a significantly lower cost than $33 million then it will enjoy a competitive advantage over newcomers arising from lower finance costs. This business plan proposes a total acquisition and rehabilitation cost of $15,823.

Competition Alternative Suppliers

Quicklime

The import or export of quicklime is difficult as deterioration during transit is a problem and access to good roads or reliable rail links is limited. The nearest producer of quicklime is Zaire Lime, but this plant produces a lower quality lime than Ndola and current negotiations with Gecamines suggest that the future product flow may well be to Zaire rather than from it. Information relating to a proposed greenfield site in Northern Namibia suggests a potential threat, but although detail is scant, distance to the Copperbelt is likely to add a conservative extra $90/tonne to the delivered price of quicklime, while the availability of sufficient bulk tankers to ship it is by no means guaranteed.

Limestone

Current limestone competitors within Zambia include Hume (Z) Ltd, Crushed Stones and Torstone Products. Distribution costs together with the intrinsically low value of the product make competition from further afield unlikely. In 1995/96 ZCCM accounted for 67% of limestone sales. It is therefore advisable that a long term contract is made with ZCCM prior to its privatisation to retain current economies of scale. If this is accomplished then NLC should be able to produce stone at a lower price than competitors and competition will be reliant on product quality and cost of transport. It is possible for NLC to produce a better quality dolomitic stone from the quarry for use as building aggregate or roadstone and thus there are real opportunities for the company to increase market share in this sector.

Hydrated Lime

The main competitors to NLC's hydrated lime sales are as follows -

South Africa	PPC Lime
	Anglo Alpha
Zimbabwe	G&W Mineral
	Blue Circle
Zaire	Zaire Lime
Namibia	Rumoured new Greenfield Site

For a variety of reasons discussed in section 6, namely inferior product quality, the high cost of transport, distance to market, a poor road network and the captive ZCCM market, there are currently no known hydrated lime imports into Zambia. In 1995/96 sales to the main export markets of Zimbabwe and South Africa representing 90% of the total were at an all time high and reflected year on year growth of 128% and 86% respectively. If the Namibian plant is built and proves capable of producing an equivalent quality, lime, both these markets could come under increased competitive pressure and this would adversely affect the decision to build a new hydrating plant at Ndola.

Agricultural Lime

Agricultural lime is a low value product unlikely to be affected by imports and with no known internal competition. If current ZCCM trials at Nchanga Division confirm its suitability as a replacement for limestone in the tailings and leachings process then it should form part of any long term contract.

Long Term Supply Contract

Consideration should be given during the appraisal to the issue of whether or not some form of agreed long term contract with ZCCM and/or their successors covering the supply of limestone/fluxstone, quicklime, hydrated lime and agriculture lime, is desirable, prior to submitting a bid for NLC. There are currently two schools of thought.

Against

(1) NLC has significant natural protection from competition by virtue of its location and the high cost of building another plant in Zambia.

(2) Having a contract with ZCCM could become unworkable very quickly as its main mining assets are all up for sale and are likely to be taken over by at least two new joint venture consortia in the next two years; Anglo American taking over the Konkola Division and Anglovaal JCDC purchasing the Nkana and Nchanga Divisions. Within a 5 year time horizon a further three new mining operations using heap

leaching techniques (the Chingola Refractory Ore Project, promoted by Cyprus Amax, the Western Province Oxide Caps, promoted by Phelps Dodge and the Bwana Mkobwa tailings recovery projected, promoted by an Australian Group), may also come on stream. These developments together with the possibility of lime becoming a component along with cement in the backfill mix being used in the new mining methods proposed for both Konkola and Nkana, could result in a significant increase in the demand for lime. Under these circumstances a long term agreement could limit the potential upside of the project.

(3) The practicalities of negotiating a meaningful bid with ZCCM prior to its own privatisation is difficult. Rothschilds and the ZPA will have to approve any long term agreements entered into by ZCCM and Ndola Lime and are unlikely to agree to anything that will restrict the freedom of potential bidders in what is already a complex process.

For

(1) NLC has effectively got one customer, ZCCM that accounts for 85% of its Sale Revenue. It is unlikely that other markets, however they are developed, will grow sufficiently for NLC to ever be independent of ZCCM and/or its successors. Any significant loss of volume would render NLC unviable.

(2) An agreement on supply and pricing issues over a 15 year period for example, (a common practice within the industry) would provide significant comfort to CDC and NLC as well as prospective ZCCM bidders during the potentially disruptive period of ZCCM's privatisation.

(3) Critically, an agreement would discourage potential competitors from importing lime themselves or establishing new production capacity in Zambia, either independently or in co-operation with other lime manufacturers, possibly using cheap second hand plant. The more fragmentary the break-up of ZCCM, the greater is the risk of this occurring.

(4) An agreed pricing formula giving CDC a fair but not excessive return, will be an important step in effecting the transition from the current transfer pricing arrangement to an acceptable market rate.

(5) Projections suggesting an excess of demand over supply based on possible projects five years hence are conjecture.

(6) The practical difficulties associated with securing a long term agreement acceptable to ZPA and Rothschild have not been tested.

The authors are of the opinion that the purchase of NLC with a long term agreement in place, is preferable to the purchase of the company without such an arrangement. If such an agreement were possible it should include the following:

Price and Variation

A series of dates at agreed intervals needs to be established so that prices can be regularly adjusted according to an agreed formula. The formula should be kept as simple as possible but could include factors such as the cost of fuel, inflation, quality and an index to take into account capital expenditure.

A suggested formula would be ; [ref 87]

$$AP = OP\ K + Ki \quad \frac{PFP}{OFP} + K_2 \quad \frac{PROJ}{OROI}$$

Where

AP = Adjusted price of lime product to apply for next period.
OP = Old Price of lime product in last period.
PFP = Present fuel price determined in last period.
OFP = Old fuel price determined from period before last.
PROJ = Current inflation factor determined from last period.
OROI = Old inflation factor determined from period before last.
K, Ki ,K2 are constants that together add up to one.

Consideration should be given to the suitable frequency of recalculating prices as well as to the consequences of changing the fuel source of the rotary kiln to coal. If this were to go ahead the formula should include the cost of all fuels including electricity in conjunction with a weighting factor.

Purchase and Sale of Lime Products

The agreement should state that ZCCM and successors will purchase all their lime products from NLC and that the pattern of lime deliveries will be as evenly distributed as possible throughout each contract year.

Term

Date of commencement, length of contract, review dates, negotiating procedures etc.

Storage and Delivery

Details of storage requirements at NLC and ZCCM sites should be provided together with an agreement to hold certain levels of stock, provide non binding offtake forecasts and co-operate on scheduled kiln stops. Responsibility for organising transport should be clearly defined.

Risks and Property

Risk should be arranged to pass to the purchaser once the lime is loaded into trucks at the works. Particular attention needs to be paid to quality sampling before despatch, shared samples, arbitration through a third party and subsequent damage by rain.

Weighing Procedures

The current system of relying on ZCCM's weighing facilities at the mines to monitor tonnages will not be commercially acceptable post privatisation. Weigh bridges will need to be installed at NLC and a workable method of reconciliation adopted.

Sampling and Testing

The contract should include agreed quality requirements for all lime products as well as sampling procedures incorporating NLC, ZCCM and an independent testing house. Monthly exchanges of sample results should be arranged between the parties.

Force Majeure

As the supply of lime is critical to the production of copper, consideration should be given to ZCCM/NLC contingency plans in the event of non supply. Accidents, strikes , flood, fire, explosion etc need to be included.

Arbitration and Termination

Procedures to resolve, disputes should be clearly understood by both parties as well as all the grounds upon which either side can terminate the contract.

Assignment

Covers the transfer of either business to another body, and allows for the contract to carry on with agreement.

4.2.8. Future Proposals

Rehabilitation and Expansion

With the exception of the hydrator, the output capacity of the existing plant at NLC is sufficient to meet foreseeable levels of demand. This business plan therefore proposes the rehabilitation of the existing plant (with replacement of some mobile plant) to secure its future output capacity and remedy environmental issues but does not propose expansion of the kiln capacity. There are potentially significant cost savings to be made by converting the fuel supply on the rotary kiln to coal and therefore this is also proposed. A summary of the major elements follows.

Rehabilitation

Quarry

- New pumps will be required for the quarry and a drilling programme implemented to dewater the surrounding area. Cost $1,000,000. This will need to be implemented as soon as possible.
- A 75-100 tonne excavator will be required within the first year at a cost of $750,000 to replace the existing electric shovels which are old and expensive to maintain and repair.
- 4 new dump trucks should be purchased over the next four years at a cost of $400,000 per truck to replace old vehicles.
- The fleet of four dozers has been reduced to one over the last few years. To rectify this an additional dozer will need to be purchased at a cost of $675,000

Crushing and screening plant

- If the recent repairs to the primary crusher prove to have been unsuccessful then this item of plant will need to be replaced at an estimated cost of $1,000,000. This cost has not been provided in the capital expenditure requirements. 2-3 months will be required to prove whether or not the repair has been successful.

Vertical Kiln

- As previously discussed the dust collector on the vertical kiln has never been operational and current emissions will certainly contravene environmental legislation once implemented. Replacement of the existing "gravel bed" filters, which are easily blocked, with bag filters is estimated to cost between $300k and $750k. This would reduce emissions significantly though not to European standards. $500k has been provided in the capex requirements.

- Production problems on the vertical kiln often relate to poor airflow. Stoppages are very costly since they result in a transfer of production to the rotary kiln for which production costs are currently $16/tonne higher. Airflow will be improved by provision of a new exhaust fan at an estimated cost of $450,000.

Rotary kiln

- Some minor repairs are required to the rotary kiln but these will not require significant capital expenditure.

- Emissions from the rotary kiln are significantly in excess of international standards and rehabilitation of the existing unusable electrostatic precipitator will be required to reduce them to acceptable levels. The NLC 1996/97 budget provides $350k for complete rehabilitation of the electrostatic precipitator on the rotary kiln but with privatisation imminent this significant capital expenditure may well be postponed. The Rugby lime consultants estimate that up to $750k will be required for this rehabilitation and therefore a further $350k should be provided as a 1997 expense. The rotary kiln should be converted to coal firing as soon as possible. With conversion costs estimated at $1.2million and resulting annual savings of up to $1.8 million there is a strong financial case. See below for more details.

Hydrating Plant

Although the hydrating plant is in a poor state of repair, a decision regarding replacement requires careful consideration of the future market. It is considered in more detail below.

Coal Conversion

In 1986 Kuwait and Zambia signed an agreement for oil to be supplied on highly concessional terms resulting in low oil prices. However, since 1993 oil has been sold in Zambia at commercial rates and fuel costs for the two kilns have risen accordingly. The vertical kiln, by nature of its design is fuel efficient (900kcaJJkg), so that despite its oil firing, fuel costs are approximately $19 per tonne of quicklime. Fuel costs for the rotary kiln however,(I55Okcallkg) are approximately $35 per tonne of quicklime.

By converting to coal, available from the Maamba collieries in southern Zambia, fuel costs for the rotary kiln could be reduced to $17/tonne of quicklime. One of the reasons given by NLC for not converting to coal in the past has been that it results in off white hydrated lime which would be unsuitable for some customers. However by retaining oil firing on the vertical kiln and using quicklime from this kiln for production of hydrated lime (only 10% of quicklime is used for production of hydrated lime) this problem can be overcome. In practice dual firing capability (coal and oil) would be retained for the rotary kiln and a mix of fuels burnt to improve combustion. Cost savings would be as follows:

Calorific value of Maamba coal 575OkcalJkg. Calorific requirements of rotary kiln when burning coal I72OkcalJkg of quicklime. Cost of coal delivered to NLC $57/tonne (3 1/12/95). Therefore the cost of coal per tonne of quicklime is (1720/5750)x57$ 17.2

Present oil costs are $35/tonne
Assume production of 100,000tpa
Then saving is 100,000(35-17.2)$1.78million p.a. Allowing for the burning of 10% oil savings would still be $1.6 million p.a.

The estimated costs of converting the rotary kiln to dual firing capability are $1.2 million. Assuming savings of $1.6m per annum the simple payback period is less than one year. Though unlikely to be a problem, verification that the trace elements present in the coal ash would not interfere with the chemical processes in which the quicklime is used by ZCCM is needed.

Hydrator

As previously described there are significant dust emissions from the present hydrator which is working at maximum capacity and unable to meet a potential increase in demand. Over the last 10 years many quotations have been received for refurbishment and replacement. The most recent, from IMS Process Plant (RSA) was for an upgrade of the present plant by replacing the hydrator with a l2tph plant and packer but using existing transport and storage systems. Cost $1.25 million. This plant may not be acceptable to the ECZ because of low level dust problems. Dust levels would nevertheless be significantly lower than from the existing plant.

The ideal solution would be to build a new plant adjacent to the quicklime storage hoppers where conveying and loading distances would be kept to a minimum. Svedala KVS could supply such a system with a capacity of 13.5tph for $2.85million. A l2tph system would allow production to more than triple to 89,000tpa. As significant additional sales would be required in order to justify the cost of replacing the hydrator this business plan proposes postponing the decision until a more detailed assessment of the costs involved and the achievable sales can be made once management control of NLC has been taken.

4.2.9. <u>Availability and Security of Inputs</u>

Water

There appears to be adequate supply of water, indeed between 30 and 50 thousand cubic metres are pumped out of the quarries each day in the wet season to allow the quarry to be worked. In the dry season water can be obtained from water filled old quarry workings.

Heavy Fuel Oil

The Indeni refinery and its associated pipeline operated by Tazama provides the means by which oil is supplied to Zambia. The age of the pipeline and foreign exchange shortages have prevented adequate maintenance of its 1,710km length in the past, although a $26 million repair programme was completed in 1989. As Tazama and Indeni supply most of the oil consumed in Zambia every effort is made to ensure that this supply line is not interrupted and NLC has not suffered serious shortages of oil in the past. Conversion of the rotary kiln to coal would reduce significantly NLC's reliance on Tazama and Indeni

Coal

Although coal is not currently used by NLC, security of coal supply would become important should the proposed conversion of the rotary kiln take place. Coal is supplied by road from Maamba Collieries in southern Zambia. Poor management and a shortage of foreign currency for spares has meant that Maamba Collieries is now in a very poor state of repair and there are significant interruptions in supply. However, privatisation is anticipated concurrently with that of NLC and the significant reserves suggest that future supply should be assured. Alternative supplies are available at slightly higher cost from Wankie Collieries in Zimbabwe.

Spares

Spare parts for some of the obsolete plant will become more difficult to obtain. A plant survey should be carried out to identify critical items and areas of scarcity/obsolescence so that insurance stocks can be kept.

Power

Although dwindling water levels from the drought have resulted in reduced hydropower capacity, imports of power from Zaire have enabled ZESCO to meet its commitment to industrial consumers whilst continuing to export power to Zimbabwe. Domestic consumers have however been subject to quotas. Supply of power to NLC has generally been satisfactory with only occasional interruptions. The link with Zaire provides some comfort should the hydropower situation deteriorate.

4.2.10. <u>Financial Analysis</u>

BASE CASE FINANCIAL PERFORMANCE

FIRR current ZK terms	30%
FIRR constant ZK terms	16%
ROE current US$ terms	20%
Minimum DSCR	2.0

Base Case Assumptions

Market and Price

- It has been assumed that the market for quicklime wifi grow to 231,000 tonnes per annum by the year 1999/2000 (as projected by NLC, an increase of 37% over 94/95), and then will remain static thereafter. Demand is expected to recover from its current low levels following privatisation of ZCCM.

- A real price increase of 10% on all products in all markets has been applied following acquisition. Thereafter prices increase in line with local inflation. Current pricing policy is to recover costs only without providing for a return on capital and therefore a price increase following privatisation is reasonable. The domestic market is well protected from imports by high transport costs.

Profit & Loss account

- Fixed and variable costs have been based on the actual costs incurred in 95/96 escalated at the local inflation rate. Fuel costs for the rotary kiln have been reduced by 40% from 98/99 onwards to reflect a fuel mix of 20% oil and 80% coal following conversion to dual firing capability.

- Dividends have been maximised subject to available cash and retaining reserves at approximately March 1995 levels.

- Depreciation has been provided at 10% on a straight line basis on all new capital expenditure.

Balance Sheet

- It has been assumed that the ZCCM loan of ZK625,000,000 (US$550,000 March 1996) will be repaid in March 98.

Residual Value

- Financial projections have been prepared up to the year 2013/14. No residual value has been assumed after this date because of uncertainty over the availability of limestone.

Exchange Rates

- ZKperUS$:

Average rate for the 12 months to March 1996	940
As at 31 March 1996	1120

Future ZK exchange rates are calculated by reference to the accumulated inflation differential.

Inflation rates

• US$ inflation rates,	3% all years.
Zambia Kwacha inflation rates	
September 1995 to September 1996	30%
September 1996 to September 1997	20%
Thereafter	10% pa

Sensitivity Analysis

Interruption in supply of Maamba Coal.

Coal would be sourced from Maamba Collieries in Southern Zambia. Maamba are however experiencing some supply problems due to the poor state of their plant and equipment. If the supply of coal from Maamba were to fail completely it would be necessary to import at a higher cost from Wankie Collieries in neighbouring Zimbabwe.

Assuming that:

- the cost of Wankie coal delivered to Nclola is $80/tonne (this is the price paid by Chilanga in April 1996, for comparison the cost of Maamba coal delivered to Ndola was $57 at 31/12/95),
- the calorific content of Wankie coal is similar to "Standard" quality Maamba coal. (i.e. G55Okcallkg),
- that NLC had to source all its coal from Wankie rather than Maamba,

then the return on equity would reduce to 17.5% (current US$) and the minimum debt service cover ratio would reduce to 1.9.

Lower demand in early years

The base case assumes that demand and production will increase in accordance with the NLC plan as described above. If uncertainty over the privatisation of ZCCM was to have the effect of postponing the anticipated increases in demand by 4 years (demand remaining at 95/96 levels in the meantime) then an additional $3 million of financing would be required to replace internally generated funds of $1.8 million and finance losses incurred in early years. If this additional finance was supplied as 50% equity and 50% debt then the ROE would reduce to 13.9% (current US$) and the minimum debt service cover ratio would reduce to 0.9 in the year to March 2000, but would be greater than 1.5 thereafter. Rates of return and the ability to service debt can be seen to be sensitive to levels of demand in the early years. It is proposed that CDC provides an end finance commitment of $3.0 million to provide for the lower demand scenario described here.

4.2.11. Environmental Impact

Since the plant was first commissioned in the early 1960's, little or no thought has been given to environmental considerations, partly because the factory is situated in an industrial area with no housing, through roads or other sensitive sites close by and partly because historically management have felt that any adverse environment effect of NLC operations were insignificant compared to the pollution caused by ZCCM's activities elsewhere in the copper belt.

Dust

One of the main environmental problems is dust. The plant was built with inadequate dust arrestment equipment and this remains the case today. The hydrating plant does not have a dust scrubbing unit, the electrostatic precipitator on the rotary kiln partly burnt out three months after operations commenced in 1973 and has not functioned properly since, while the sandbed filter system installed with the vertical kiln in 1986 was never commissioned and has consequently never been made to work. A further source of dust is the quarry, primarily as a result of bench drilling, the movement of traffic during the loading process and the crushing operations. These problems can be fairly easily rectified however; in the first instance by the use of a water mist or dry filter system, in the second by routine water sprinkling or tarmacking the roads and in the third, simply by rehabilitating the existing systems.

Noise

As in most quarrying activities some noise generation from drilling and operating mobile plant is inevitable. Steps could be taken to minimise the noise, vibration and nuisance effect of blasting through the adoption of more modern techniques but in practice as the operating bench is below ground level, most of the noise is currently either absorbed by the banking or reflected upwards.

Visual Appearance

The visual appearance of the site is scarred by the dust from the kilns and hydrating plant and by the huge tips of waste rock surrounding the quarry. The current arrangement with Chilanga Cement Plc for the removal and processing of the tips will eventually reduce this problem.

Water Pollution

NLC is in a water resource area, which forms part of the Ndola town water supply. Because of this it is extremely important that effective steps are taken to prevent hydrocarbon and other chemicals from entering the ground water table. Tins is not currently a problem but as a precautionary measure it is recommended that a system of drains be constructed to direct rain water away from the quarry site to one or more settling ponds from which any solids can then be recovered.

Current Initiatives

Local NLC management are now having to come to terms with two government bodies that are introducing new regulations. The Health and Safety section of the Mines and Quarries Inspectorate are currently investigating environmental working conditions, while the Environmental Council of Zambia (ECZ) has been set up to implement World Health Organisation (WHO) ambient air quality guidelines. It is ECZ's intention to set up systems of licences, permits and authorisations similar to those in more developed countries but early indications suggest that they are adopting a realistic approach with NLC management as regards the time and cost of implementing any changes.

Future Plans

One of NLC's stated objectives for the 1996/97 budget is to 'strive to observe statutory regulations on environmental pollution' and to this end the company has allocated some K300m or 25% of its total Capex budget on items that could be considered as environmental or health and safety benefits. These include the rehabilitation of the roof structure for the hydrator, dust collectors for the quarry, a fire tender, and provision for plant road resurfacing. In addition the repair budget allocates $O.35m for the reinstatement of the electrostatic precipitator on the rotary kiln. However, discussion with a FLS engineer working at Chilanga Cement suggests a more likely sum would be between $O.7m and $lm, and there is considerable uncertainty amongst NLC management as to when this work will be scheduled. It looks likely therefore that insufficient money will be spent on repair and maintenance before privatisation. The ECZ and M&QI do not appear to be strong enforcing bodies and management does not have environmental issues at the top of its list of priorities. It will therefore take considerable time and effort to make real significant local improvements and the burden of education and expenditure will in all probability fall upon the newly privatised company.

4.2.12. Conclusions

- NLC has suffered from a lack of investment and as a result now produces lime at a high environmental cost. CDC would invest in the installation and rehabilitation of dust control equipment which would reduce emissions significantly.

- NLC is a high cost producer as a result of the use of oil for firing its kilns. It is proposed that CDC would convert the rotary kiln to a dual firing capability (coal and oil) significantly reducing production costs. As oil is imported but coal is mined locally this would also result in reduced reliance on imported fuel and a consequent foreign exchange saving for Zambia

- Under CDC management significant cost savings should be realisable through merging certain functions with those at Chilanga.

- Acquisition of NLC at an appropriate price will provide attractive returns for CDC.

- Acquisition of NLC by a third party may, in the future, pose a threat to Chilanga.

NB

This report recommended that CDC should submit a bid for NLC, based on the proposals described in this report and at a price to be finalised during appraisal. The financial report was prepared by a team of three experts by the Commonwealth Development Corporation, the writer was a member of the team. [ref 87]

4.3.0 CHILANGA CEMENT PLC

This is the financial statement of the Chilanga group for year 1997, it was produced by, Pangaea Partners and Chilanga Cement Plc and adapted for this document by the writer.

4.3.1 Financial Statement

Figure 4-10 [ref 28] Financial highlights

Financial Highlights		
Kwacha Millions	31 Dec 97	% Change from 1996
Net Turnover	44,601.00	35.00
Profit before Tax	7,598.00	62.00
Profit after Tax	5,424.00	54.00
Dividends	1,730.00	24.00

Figure 4-11 [ref 28] Financial summary

Summary of financial years		
	31,Dec,1997	31,Dec,1996
Earnings per share (Kwacha)	27.12	17.59 (15.741)
Dividend / Share (Kwacha)	8.65	7.00
FYE Share Price	155.00	70.00
FYE P-E Ratio	5.70	2.9 (3.241)
FYE Dividend Yield	5.60	13.70
FYE Price-Net Asset Value Ratio	1.28	0.50
Market Capitalisation per Tonne (US$)	9.87	18.26
Revenue / Tonne Sold (Kw)	114,655.00	94,335.00
Cost / Tonne Produced (Kw)	107,605.00	85,260.00
FYE Exchange Rate (Kw per US$)	1,446.00	1,299.00

4.3.2 Description

Chilanga Cement Plc is the monopoly manufacturer of cement clinker and cement in Zambia. It has two plants:

Chilanga (outside Lusaka) and in the Copperbelt at Ndola. The plants were built in the 1950s and 1960s, but have been upgraded since then. The plants will need replacement but management feels they still have life left in them. Environmental control equipment, financed by a low interest rate loan from the Danish Government, was installed in1996. Chilanga's largest customer is ZCCM, typically taking 10% or more of the company's production, this is likely to fall as ZCCM is virtually bankrupt and is subject to privatisation. Wholesale distribution takes place at the plants while retail sales occur at other locations. Domestic sales have been stagnant in the last few years due to the weak economy as well as high interest rates, which also discourage construction. With ZCCM's difficulties, sales to ZCCM have been weak during the last few years. Market forces set domestic prices, but substitute materials are not readily available and so the company has been able to maintain fairly high prices. In general, management attempts to set domestic prices so as to stay relatively constant in US$ terms. This helps to hedge the company's results against inflation in Zambia.

With domestic sales relatively flat, the company has developed export sales to nearby countries such as Malawi, Zimbabwe, Congo DR, Namibia, Botswana, Rwanda and Tanzania. Malawi is the company's main export market and offers the most attractive margins. At the other end of the spectrum, Rwanda's low margins mean that Chilanga will stop exporting there if it could make a more profitable return from its extra capacity. Export prices usually equal the price in a given market less the cost of transport. As such, export prices are usually lower than domestic prices. They are greater than Chilanga's production costs, however, and thus contribute to the company's profitability.

4.3.3 Ownership and Management

Chilanga Cement was founded in 1949 by the Government of Northern Rhodesia and the Colonial (now Commonwealth) Development Corporation (CDC). During the early 1950's the company's shareholder base was broadened to include Anglo-American and Premier Portland Cement. In 1957 the government's shares were offered for sale to the general public and 400 individuals invested in Chilanga shares. As part of Zambia's turn towards socialism, the Government nationalised Chilanga by acquiring a majority of its shares in 1973. However, with the election of the MMD party in 1991, Zambia's privatisation program got underway in earnest. In 1994, Chilanga became the first large state-owned company to be privatised when the Commonwealth Development Corporation increased its shareholding to 50.1% and assumed management control. The remainder of government's shares was sold in May 1995 to Zambians in the country's first public offering. At the same time, Chilanga became the first company to be listed on the Lusaka Stock Exchange (LuSE). In 1997, Premier Portland sold its 2.7% shareholding into the market via Pangaea. Also in 1997, Anglo-American (Zambia) exercised its right-of-first refusal on shares held by a former state-owned holding company and thereby increased its ownership from 6.5% to 12.6% of the total shares outstanding.

Figure 4-12 [ref28] Share holding

Share holding		
Current Shareholding	Number of Shares	% of Equity
Commonwealth Development Corporation	100,219,992.00	50.10%
Zamanglo Industrial Corporation Limited	25,169,006.00	12.58%
Civil Service Pensions Fund Board	13,000,000.00	6.50%
Others (individuals and institutions)	61,650,906.00	30.82%
Total	200,039,904.00	100.00%

4.3.4 Directors

NJ Braithwaite Chairman (CDC)
P R Gorman Chief Executive Officer (CDC)
D V Johns CDC representative
J M Mwangala Minority shareholders representative
M Ndhlovu Shitima Civil Service Pensions Fund representative
Dr. R Morton CDC representative (1999 left Chilanga)
T A Mordue Company Secretary
A K Mazoka Zamanglo representative

The previous Chairman, Mr. Beecham, resigned with effect from 27 March, 1997, and was transferred to other duties by CDC. Mr. Justin Braithwaite of CDC London replaced him. The Company Secretary is Mr. T A Mordue (CDC) who also serves as Chilanga's Manager of Finance and Accounting. The firm's 784 employees (77 of whom are part-time) are managed by CDC in accordance with a management contract that expires in 1999. At the moment, CDC has three expatriate personnel on-site: the Chief Executive Officer, the Manager of Finance and Administration and an MIS expert and in 1995 to 1996 a Chief Quarrying Engineer. Other specialists are provided as necessary. In return, CDC is paid a management fee. In 1997, the fee amounted to approximately 1.96% of turnover.

1997 Performance and Financial Condition:

Chilanga had an outstanding year in 1997. While domestic sales only increased 1.7%, export sales zoomed upward 31%. Overall, this meant Chilanga increased its sales in 1997 to 389,000 tonnes, up 11% over the previous year. Total turnover increased 35% to Kwacha (Kw) 44.6 billion. All told, the increase in sales led to an increase in capacity utilisation from 72% in 1996 to 79% in 1997.

Figure 4-13 [ref 28] Production and sales

Production & Sales			
('000 tonnes)	1997	1996	1995
Cement Produced	348.00	348.00	312.00
Cement Sold			
Domestic	242.00	238.00	235.00
Export	147.00	112.00	76.00
Total Sales	389.00	350.00	311.00

In 1997, Operating costs were Kw 36.5 billion, up 35% in Kwacha terms (38% before restatement). This was mainly due to the inflation-driven rise in the cost of inputs, particularly coal and electricity. The company's selling prices did not keep up with the rising expenses and so the ratio of Operating Profit to Turnover declined to 18.1% from 18.4% the previous year (19.7% before restatement).

Accounting Note: After the 1996 financials were issued, the Zambian Revenue Authority asserted that Chilanga would have to pay Value-Added Tax on its exports – a position contested by Chilanga. As it was too late to pass this cost to its clients, Chilanga has had to make a "prior year adjustment" to provide for this potential liability. As a result, operating expenses for 1996 have been revised upward kW 417.3 million. The Income Tax, Net Income, Accounts Payable, Taxation Payable and General Reserves accounts were also affected. With 1996 earnings now reported lower, it has the effect of making the improvement in 1997 look even bigger – we have tried to provide figures for both before and after restatement. Should Chilanga eventually prevail in this matter, the liability will be reversed and additional earnings reported. In real terms, however, Chilanga's operating costs are largely fixed so that increased utilisation of available capacity is the key to improved financial performance. Hence, Net Income jumped 54% in 1997 to KW 5.4 billion (72% after restatement). Return on Equity was 24.0% in 1997 versus 17.7% in 1996 (16% after restatement).

Figure 4-14 [ref 28] Profit and loss summary

Profit & Loss Summary			
(KW millions)	1997	1996	1995
Net Sales Revenues	44,601.00	32,995.00	20,027.00
Profit Before Taxation	7,598.00	4,269.00	2,319.00
Taxation	(2,173.00)	(1,120.00)	(1,444.00)
Profit After Taxation	5,424.00	3,148.00	875.00
Dividends	(1,730.00)	(1,400.00)	(400.00)
Retained Earnings for Year	3,694.00	1,748.00	475.00

The company's already strong balance sheet got even stronger in 1997. Excellent earnings and cash flow enabled the company to repay debt ahead of schedule. Total debt is now only 8.7% of shareholders funds. The Current Ratio of 1.94 is similarly good. Last year Pangaea forecast a 50 -100% rise in earnings per share.

4.3.5 Share Performance

After being sold to the general public at a price of KW 65 per share, Chilanga's shares fell for over 18 months as a result of a lack of funds available for investment, uncertainty about Zambia's economy, poor understanding of capital markets, Chilanga's low dividend of KW 2 per share and the company's weak results in 1995. However, after the issuance of Pangaea's buy recommendation in early January 1997, Chilanga's share price tripled from KW 51 to KW 155. Consequently, Chilanga shares were among the top performers at the LuSE in 1997. The Company's Directors recommended the payment of a final dividend of KW 6.15 per share and it was approved by the members at the Annual General Meeting held 30 March, 1998. This, together with the interim dividend of KW 2.50 per share already paid, brought the total distribution to KW 8.65 per share, an increase of 23.8% over the previous year.

4.3.6 Future Performance

As mentioned above, the key to rising profits at Chilanga is high capacity utilisation. Sales are strongly linked to the growth in the country's GDP. While the really big gains at Chilanga are dependent on the privatisation and subsequent redevelopment of ZCCM, the company is moving forward through an aggressive marketing strategy. It continues to market its products, aggressively. So far in 1998 sales are strong, in fact stronger than the company's own budget. Export bright spots are the Congo and Zimbabwe. Domestic sales will be steady or perhaps slightly higher. At the Annual General Meeting held on 30 March, 1998 the Chairman, Mr. Braithwaite, confirmed this information by stating that the company will maintain growth in the local sales and consolidate its strong export performance in order to maintain its growth record. Other CDC personnel have expressed similar opinions.

Figure 4-15 [ref 28] SWOT Analysis

CHILANGA CEMENT SWOT ANALYSIS	
STRENGTHS • Monopoly producer in domestic market • Company's production facilities have capacity to meet modest increases in demand • Elimination of price controls by government • Company's activities are not affected by abnormal weather conditions company has maintained fairly good labour relations in the past • High quality cement	**WEAKNESSES** • Ageing plants • Poor packaging • Poor roads and high transportation costs to export markets • Weak government support of the construction industry • Lots of Government-owned houses being sold (via privatisation) cheaply which will discourage new building projects
OPPORTUNITIES • Reopening of certain ZCCM projects and development of new Quarrying projects in Zambia would stimulate demand at least 50%, if not more, and lead to vastly increased earnings • Future operations of the company's factories at full capacity would reduce unit costs spread overheads beneficially, thus increasing profits • Potential demand from the Congo • Potential demand from the Kafue Lower Gorge dam/power project	**THREATS** • Regional competitors can capture Chilanga's export markets • Deregulation of domestic markets makes it easier for competitive imports • If a competitor purchases the soon to be privatised Ndola Lime Company, it could use that as a base to compete with Chilanga

The company has carried out exploration activities to establish the extent of further limestone reserves in the Chilanga area as part of planning for the future expansion of productive capacity. If investments in ZCCM are realised Chilanga will be ready to capitalise. Indeed, once the privatisation of ZCCM is complete, demand may rise so much that it may be necessary to build additional cement plants at a cost of up to $80 million. Should that happen, short-term earnings might suffer, but in the long-run shareholders will reap significant returns. All told we expect 1998 to be another good year for Chilanga: earnings should rise 20-25%. Dividends are likely to rise as well.

Figure 4-16 [ref 28] Profit to earnings ratio

COMPARATIVE P-E'S FOR SELECTED CEMENT STOCKS		
COUNTRY	COMPANY	P-E Ratio
Australia	Pioneer International Ltd.	18.30
Canada	St. Lawrence Cement	20.40
Chile	Cementos Bio-Bio S.A.	6.90
Czech Republic	Cement Hranice	17.30
Egypt	Alexandria Cement	10.40
Egypt	Ameriyah Cement	7.50
Egypt	Helwan Portland Cement	11.40
Egypt	Suez Cement	14.60
Egypt	Torah Portland Cement	10.90
France	Ciment Francais	107.80
France	Lafarge	19.90
Ireland	CRH	20.80
Kenya	Bamburi Portland Cement	15.30
Kenya	East Africa Portland Cement	22.00
Lithuania	Akmenes Cementes	114.10
Malaysia	Cement Industries Malaysia	5.10
Mexico	Cemex	7.20
Nigeria	W.A. Portland	9.40
Nigeria	Benue Cement Co.	7.10
Nigeria	Ashaka Cement	14.10
Switzerland	Holderbank	18.20
South Africa	Pretoria Portland Cement	12.70
United States	Calmat	35.50
United States	Giant Cement Holding	17.00
United States	Lonestar Industries	15.30
United States	Medusa Corp.	17.10
United States	Puerto Rico Cement Company	16.50
Zambia	Chilanga Cement	5.50

For the near term the company is likely to pay out earnings in the form of dividends, but at some point the company may issue bonus shares instead. Because dividends are taxable in Zambia but capital gains are not, this is a more tax efficient alternative. Lastly, it should be noted that the Government intends to privatise Ndola Lime during 1998. Should Chilanga decide to bid on this limestone producer and win, earnings could be driven higher.

4.3.7 Conclusion

As predicted Chilanga Cement continued its exceptional performance in 1997. The share price went up 204% during the year, providing significant capital gains to shareholders. The stock is currently trading at a P.E of 5.7 and a dividend yield of 5.6%. Chilanga is set to continue it growth trend in 1998, and its prospects will be further enhanced if and when the privatisation of ZCCM is concluded. Chilanga remains an excellent investment.

Postscript

Since this report was completed, due to poor management of the economy, particularly regarding privatisation of the copper industry, the national financial situation of Zambia has deteriorated markedly, production from Chilanga has dropped considerably and the company is now showing a negative return.

[ref for all the above 28]

Chapter Five

Physical and Social Environment

5.1.0 ENVIRONMENT

5.1.1 Environmental controls

Environmental controls within the African countries are related to the European standard that has now emerged into a coherent system of laws concerned with environmental regulation relating to the use, protection and conservation of the three environmental media of earth, air and water. Liability is linked with attributing responsibility to meet the costs and consequences of environmental harm, and for past environmental wrong doing, albeit intentional or otherwise. Many European and environmental laws developed historically from laws relating to public health from the nineteenth century, with the need to protect people from private operating practices. This developed into actions in respect of a statutory nuisance and onwards to specific legislation such as the UK Environmental Protection Act 1990.

UK Controls

It is likely that further legislation in Zambia and Malawi will follow the UK practice, for example, in the UK, environmental protection is enforced in a number of ways. First and most enforceable under legislation, such as the Health and Safety At Work Act 1974 and the Mines and Quarries (Tips) Act 1969, the purpose of which is to prevent disused tips constituting a danger to the public, and to provide for the security of tips. The control over mineral extraction as a use of land is exercised within the general planning system, but no single legal code embraces extraction and infilling, as other controls exist under public health, transport, safety, wildlife and environmental protection legislation. The operation of the quarry itself is in Europe and the USA also strictly controlled by planning law exercised by the issue of modern planning conditions. An example of a set of modern conditions for a limestone quarry are shown below:

1. No waste transfer operations to be carried out
2. The winning and working of minerals shall cease not later than 21st February 2042, and the site restored to agricultural use (1995 Environment Act)
3. In the event of the prior cessation of mineral extraction on the site completion in excess of a period of 60 months, all buildings plant and machinery shall be removed from the site and restored with an aftercare scheme
4. Overburden to be backfilled into the void
5. Five metre standoff from the boundary
6. Means of access as directed by the authority
7. Any accidental spillages removed immediately
8. A scheme for the prevention of mud and other materials submitted to the authority with wheel cleaning facilities to be provided for
9. Internal access roads hard surfaced

10. All vehicles leaving the site to be securely sheeted
11. Details of measures to control dust to include measures of reducing dust emissions
12. These schemes to be implemented before extraction commences
13. Noise not to exceed 55 DBLeqA at site boundary or site sensitive locations
14. All plant and machinery fitted with efficient silencers
15. Working hours by approval with the authority
16. No working on sundays or bank holidays
17. No blasting on the site
18. All oils and lubricant materials stored in a compound with an impermeable base
19. No contaminated discharges into groundwater
20. No surface extraction below the water table
21. No top and subsoil removed from the site
22. All top and subsoil to be stored in mounds no higher than 3m
23. These mounds to be kept free from weed growth and grass seeded
24. Top and subsoil spread to a minimum of 750mm
25. A minimum of 100mm of topsoil spread throughout the site
26. Upon completion of operations all internal roads, buildings plant and equipment to be removed from the site within 36 months
27. If satisfactory growth of grass is not achieved it must be replanted, and repeated if necessary
28. An efficient land drainage system must be provided for
29. An aftercare scheme for five years by approval with the authority
30. Annual review of conditions
31. EIA every 15 years [ref 31]

International standards

Obligatory compliance with identifiable national standards first emerged in the USA in *The National Environmental Policy Act of 1969*, which embodied the idea of an Environmental Impact Statement (EIS). This statement is now an essential element in any new quarrying proposal. EIS requirements now encompass all aspects concerned with land development and quarrying. Generally the appropriate World Bank standard can be applied, particularly if external funding is required.

The policy of the World Bank was summarised in a 1979 report as;

> The Bank's environmental experience demonstrates that it is feasible, with government agreement and cooperation, to incorporate suitable measures to protect health and environment into almost any developing project. Perhaps the key has been the Bank's insistence on a pragmatic approach - one tailored to local circumstances - that precludes the application of rigid environmental standards. Further, it is Bank policy that environmental conditions are part and parcel of all

> economic considerations and rank equally with all other project assessments. Project planning or implementation may fail to anticipate adverse environmental consequences, or the necessary impact data may be unavailable or faulty, but in no instance is the monetary cost of environmental and health safeguards (usually no more than 3% of the project costs) disqualifying. Moreover, the Bank will not help finance any project that seriously compromises public health and safety, causes severe or irreversible environmental deterioration, or displaces people without adequate provision for resettlement.

The above passage shows its age regarding costing, but the other principles remain good. Costs of an environmental impact study (where impacts are identified together with measures of mitigation) or a "green audit" (where policies and targets are set) will vary widely. The end cost is likely to be at least 10% of a typical feasibility study. It is certain that before any project can be considered for finance, a green audit will be required. A green audit is a cradle to grave survey of a project including energy use and ascribing costs to preventing the despoliation of the countryside. It will cover all the physical implications of a project. The Terms of Reference for many investment projects require that the environmental aspects are subject to the provisions of the European Union guideline, CE 85/337/EEC of 1985 as amended by 97/11/EEC, which requires the collection of data, its evaluation and from that study, the incorporation of measures to mitigate against the any adverse impact arising from the project.

European Council

In 1975 the European Council made recommendations to the member states on the allocation of costs for the intervention of public bodies in the case of environmental measures being required. Article 130r (2) of the EEC Treaty, as amended by the Single European Act, provides that "Action by the community relating to the environment shall be based on the principles that the polluter should pay". The recommendation introduced the "Polluter pays principle" and stated; [ref 75]

> That the "Polluter Pays Principle" provides that the natural or legal persons governed by public or private law who are responsible for the pollution must pay the costs of such measures as are necessary to eliminate that pollution or reduce it so as to comply with the standards or equivalent measures which enable quality objectives to be met or, when there are no such objectives, so as to comply with the standards laid down by the public authorities. Consequently environmental protection should not in principle depend on policies which rely on grants of aid and place the burden of combatting pollution on the community.

Sound environmental practices equate to good engineering and operations management. Initial and ongoing costs must adequately recognise the need to build in and maintain proper safeguards to ensure that satisfactory standards can be met over the lifetime of the project. Restoration of the land will usually require it to be returned to an approximation of its original contours. The social environmental aspects of any quarry development encompasses the changes it makes to the environment within and outside of the project area and the effect it may have either directly or indirectly on peoples health and welfare, both of neighbours and the workforce. It should be noted that being environmentally sensitive should not be considered as being an unwanted expense, costs can be avoided by appropriate site selection. Construction and operation in an environmentally sensitive manner can avoid prosecution, fines and even temporary closure notices being applied. Careful quarrying can ensure a suitably rehabilitated area which will add value to the quarry as being a disposable asset. Environmentally sensitive aspects of quarrying include the health and safety of the workforce and the population in general, dust, noise, water pollution and visual amenity.

The Environmental Council has put into place, regulations covering water pollution (1963) and pesticides and toxic substances (1994). The concept of "Best Practical Means" is an accepted expression used when dealing with environmental problems, and the concept of "Best Available Technology Not Entailing Excessive Cost" or BATNEEC, (although in some industries the NEEC part has recently been dropped) is the expression used to describe integrated pollution control systems, this is a code of law founded less on the perceived needs of the environment but as on technical and commercial expediency and is expected to be applied in Southern Africa.

5.1.2 <u>Definitions</u>

The social and physical environmental aspects of any quarry development encompasses the changes it makes to the environment both within and outside the project area and the effect it may have either directly or indirectly on peoples health and welfare, both of neighbours and the workforce. The following definitions help identify the relevant environmental aspects; [ref 75]

- The natural environment can be identified as the relationship between man, plants, animals and the environment, where the environment is the sum of all these external influences.

- Environmental pollution is any discharge of material or energy into water, land, or air that causes or may cause acute or chronic detriment to the Earth's ecological balance or that lowers the quality of life.

- Land pollution is the degradation of the Earth's land surface through misuse of the soil by poor agricultural practices, mineral exploitation, industrial waste dumping, and indiscriminate disposal of urban wastes.

- Sustainable development is development that meets the needs of the present generation, incorporating the principle of; "Inter generational equity" without compromising the ability of future generations to meet their own needs. At a project level, usage rates of renewable resource inputs should be within the assimilative capacity of the local environment to absorb without unacceptable degradation of its future absorptive capacity.

5.2.0 ENVIRONMENTAL STATEMENT

5.2.1 Organisation of European Community Directives

Additional standards are the Organisation of European Community Directives - Environmental degradation from quarrying and processing in developing countries and the LOME IV Environmental Manual of 1993, one of a series of agreements known collectively as the Lome Convention, negotiated between 1975 and 1989 with practically all products originating in 69 African, Caribbean, and Pacific (ACP) countries receiving tariff-free access to the European markets. The European Guideline CE 85/337/EEC of 1985 describes an Environmental Impact Assessment as the application of a systematic approach to;

- the collection of baseline data
- the evaluation of that data in terms of scale and significance
- the development of measures to mitigate against the impact of the development, and their application in the quarrying and land restoration processes.

The 1985 Regulations have now been amended by 97/11/EEC of 3rd March 1997 on the assessment of effects of quarry projects on the environment. In addition the new regulations extend the range of projects that are subject to EIA and make a small number of procedural changes. These are:

- A scoping opinion from the planning authorities on what should be included in the EIA.

- For all Schedule 2 development (including mineral extraction) the relevant planning authority will decide if an EIA is required.

- The developer must provide information on alternatives.

Environmental Statements are now required for periodic mineral reviews.

At an average cost of £25,000, this is an additional charge that operators see as high, particularly for the smaller developer or for those quarries that are nearing the end of their productive life, and in the long term there could be an impact on the market as these smaller operators are squeezed out and prices rise. It is the writers belief that the aim of environmental control is for sustainable development to become an established culture within which the quarry industry, which must progress to ensure high standards of environmental performance that are acceptable to the global community.

Environmentally sensitive aspects of quarrying include the health and safety of the workforce and the population in general, dust, noise, flora and fauna, soil and water waste, agriculture and visual amenity. Usually, these aspects are controlled by national legislation, where no legislation exists or is considered inadequate, the controls have to be determined after consideration of the particular environmental circumstance. Within the normal quarry planning process, the writer commonly adopts measures that restore the site in a manner compatible with the location of the site and the surrounding land uses, in particular agricultural land, woodland or grazing land. Whilst planning permission as recognised in the UK is not required for African quarrying operations outside of South Africa, it is now becoming to be recognised that an environmental Statement represents good practice. A standard environmental statement (EIS) normally incorporates the following areas; [ref117]

Need for the development

- Background to the proposals
- Relevant legislation
- Need for the product
- Site selection and consideration of alternatives

Project description

- Operating process
- Plant details
- Restoration
- Emissions

Development methods

- Hours of operation
- Development works
- Infrastructure

Land use

- Land use
- Potential impact of land use

Geology and soils

- Superficial geology
- Solid geology
- Potential impacts on geology

Hydrogeology and hydrology

- Baseline conditions
- Potential impacts due to operation
- Phreatic surface
- Mitigation measures

Ecology

- Base line information
- Habitat survey
- Potential impacts
- Assessment of effects
- Mitigation

Landscape and visual

- Landscape character and visual qualities
- potential impacts due to operations
- Landscape design and mitigation

Air quality

- Background air quality
- Releases from operational activities
- Potential impacts
- Mitigation

Noise and vibration

- Base line noise levels
- Operational noise
- Vibration
- Mitigation

Traffic and transport

- Base line conditions
- Traffic during operations
- Potential impact of operations
- Mitigation

Socio economic

- Employment
- Community facilities
- Regional growth
- Cultural heritage

Non technical summary for public information.

EIA surveys are usually undertaken by a team of specialists in which the writer has participated in his area of expertise. The following areas are of particular concern to the writer;

5.2.2 African State Controls

African environmental protection measures can be criticised for several reasons, some of which are associated with ignorance, government secrecy, maladministration, corruption and lack of concern regarding environmental effects. It is also the writers belief that environmental legislation and codes of practice are a high cost for developers, and that not all countries, particularly developing countries have got the economic and investment infrastructure in place to be able to put forward and police such proposals. Much of Africa is underlain with a substantial array of minerals, but not wealth or the health of its people. Inward investment in mineral extraction is central to economic growth, therefore to impose high environmental penalties would place such investment in jeopardy. Notwithstanding this, closely related to the World Bank funding policy, is the now common standard that quarries are worked to a high environmental standard, with the needs of people, wildlife and the environment safeguarded for the needs of the present and future generations. While environmental statements may not be a mandatory requirement in some African countries, the producers in this document see them as a necessary prerequisite to successful site development. In the past and in some cases present, quarry operators have carried out projects with little concern to the impacts that these "bad neighbour developments" have on the environment. Global concerns now dictate that such statements are carried out for any developments that involve the depletion of finite mineral resources. The World Bank also sets such standards and will not fund any operation that compromises the health and safety of people and their environment.

Southern Africa is blessed with rich natural resources and a more solid economic base, and the countries remaining relatively unspoiled. Increasing public consciousness and awareness of the effects of tourism on the economy ensures that care of the environment is considered to be of vital importance to the national development. Because of this, ensuring that any industrial projects are fully compatible with the overall environmental requirements of the country is vital.

The Department of the Environment of South Africa has introduced the Environmental Conservation Act 1989 followed by the Environmental Management Guidelines 1992 and more recently the Environmental Impact Assessment regulations 1997. These are legally binding and are in addition to existing planning and other procedures. The *Integrated Environmental Management procedures* were introduced in the early 1990's and are designed to ensure that the environmental consequences of development proposals are understood and adequately considered in the planning process. The term *environmental* is used in its broad sense, encompassing biophysical and sociol-economic components. The purpose of IEM is to resolve or mitigate any negative impacts and to enhance positive aspects of development proposals. Mining, mineral extraction and mineral beneficiation is a development process subject to IEM procedures for which the following stages are prescribed:

- Stage 1: Plan and Assess Proposal
Develop proposal
Classification of Proposal
The Impact Assessment
The initial Assessment
No formal Assessment

- Stage 2: Decision
Review
Record of decision
Appeal

- Stage 3: Implementation
Implementation of Proposal
Monitoring
Audits

5.2.3 Controls in Zambia and Malawi

The governments of both Zambia and Malawi have fledgling departments dealing with environmental issues, unfortunately legislation to date has concentrated more on taxation. In Zambia an Environmental Protection and Pollution Control Act was passed in 1990, under which, an Environmental Council was established, this to be charged with setting pollution standards for;

- water
- air
- waste
- pesticides and toxic substances
- noise
- ionising radiation
- natural resource conservation

5.3.0 ENVIRONMENTAL MANAGEMENT TOOLS

The following section will be concerned with three systems of environmental management:

- Risk assessment
- Safety management
- Environmental management systems

5.3.1 Risk Assessment

Introduction

In the UK, the legal requirement for risk assessments to be carried out can be traced back to the 1930s, where case law established that the standard of care fell into three headings: [ref 117]

- Foreseeing the existence of risk
- Assessing the magnitude of risk
- Devising precautions in response

The cost of accidents

In the humane and economic sense there are many implications in the actual or potential occurrence of accidents, and include pain, suffering, loss of earnings, possible death, interruption in operations, time to repair damaged equipment and subsequent retraining.

Some of these accidents and losses can be insured against, and include:

- Employers liability
- Public liability
- Damage to buildings
- Damage to vehicles and plant
- Business interruption
- Product liability.

Others cannot be insured against, and include:

- Hiring and training of replacement workers

- Any sick pay
- Some items of repair
- Lost/damaged product
- Clearing the damage/site
- Loss of expertise
- Expenditure on emergency supplies.

The British Health and Safety At Work Act 1974 established a producers responsibility for the health, safety and welfare of its employees as far as is reasonably practicable, and although this law does not apply in either Zambia or Malawi, legislation is in place such as the Mines and Quarries Acts. Those acts as identified by law balance risk against costs.

Regulation 3 of the British Management Of Health And Safety At Work Act (MHSW)1992, further enforces this requirement through the application of risk assessment to all activities. In the UK this Act now forms the cornerstone of successful health and safety management.

Definition

The British MHSW 1992 Approved Code of Practice identifies two important definitions:

- Hazard, as something with the potential to cause harm.
- Risk as the likelihood that harm will occur and its severity

Risk assessment identifies a hazard and enables a balanced judgement of the degree of risk attached to it. The situation with regard to risk assessment and safety procedures in Zambia is such that the writer was satisfied with the standard operating procedures when entering the site in a managerial capacity. This was not the case in Malawi, where policies for the management of risk and health were non existent. One of the main tasks of the writer was to carry out a review of policies at the quarry, and following on from this to design a practical and systematic programme for health and safety. In addition inspections, working practices, documentation checks, and accident reports were examined and interviews conducted with selected members of the workforce. This was the first time that such initiatives had been instigated at the quarry. The writer firmly believes that an operation that is run safely is one that is more productive, as operating practices are carried out systematically following the adoption of risk and safety policies. This in turn has a positive effect on workers, as they feel more valued, and are more competent in their work practices following a comprehensive training programme. At this stage it is important to stress that risk and safety measures were introduced gradually, so that workers became familiar with the new procedures over a period of time, and accepted these principles as good practice. A radical programme would not be appropriate for Changalume, as education in Malawi was discouraged under the political regime.

Practical risk assessment

A risk assessment procedure was undertaken for all the major activities in the quarries. All three case studies have had a series of accidents, some of which have been reported in this document, and could have been avoided had certain procedures been in place. The writer observed work practices, activities and accident records, and particularly at the Changalume quarry followed the steps below:

- Identify the hazard
- Assess the effectiveness of existing precautions
- Assess the risk and likelihood of harm
- Assess the extent of the risk
- Record significant findings
- Prioritise risks
- Create procedures to mitigate risk and harm
- Action procedures
- Plan regular reviews

In order for the programme to be effective, endorsed and understood by all recipients, the techniques adopted by the writer needed to be quantitative and easily understood. This was achieved by using a matrix commonly used by many British public bodies such as council departments, whereby:

- 1 = minor injury, no time off work
- 2 = injury, up to 5 days off work
- 3 = significant injury, more than 5 days off work up to 20 days, with medical attention required
- 4 = major injury, long term absence
- 5 = death

Following on from this, a risk assessment can be undertaken for each major activity. Three risk bands were designated for each activity from matrix results:

- Minor - 0 to 5
- Intermediate 6 to 14
- Significant 15 to 25

- Minor - Activities that demonstrate minor risk include all aspects of quarrying
- Intermediate - Activities that demonstrate intermediate risk include operating the loading machines and crushers.
- Significant - Activities that demonstrate significant risk include drilling and blasting.

5.3.2 Safety Management

Safety management is a part of physical environmental planning and is central to all planning within any quarry or mine, and is treated as a matter of priority at all times by the writer. The UK Health and Safety in Quarries Regulations 1999 Approved Code of Practice comes into force on 1 January 2000, and in the UK each quarry operator will be required to adhere to the regulations. Following on from quantitative assessment, the writer developed a unique safety policy for each quarry, the main elements being:

- Risk assessment and safety policies to be part of overall planning decisions
- To ensure the identification, assessment, prevention and subsequent control of hazards and risks to all workers and others coming onto the site
- To ensure adequate training to prevent accidents
- To ensure that all persons identified as being at risk as a result of their work, to be informed of that risk and mechanisms put in place to lessen that risk, whereby appropriate training will be provided.

Emphasis is placed upon:

- Manual handling operations
- The working environment, in particular quarry floors, ventilation, restricted spaces, weather conditions affecting performance, lighting, loading requirements
- Activities that involve lifting, dragging, carrying and so forth
- Parts of the body that are at greatest risk
- Protective equipment, this means all equipment to be worn by a worker to protect against hazards likely to endanger health
- Potential sources of harm, in particular physical sources such as falls, vibrations, electrical, noise and chemical sources such as dust, fumes and vapours.

Hazard and risk control strategy

When the writer was actively integrating safety procedures as good management practice, the goals expressed generally were to:

- Reduce illness and injury
- Reduce other losses in particular damage to plant and machinery
- Comply with regulations

The following sources were identified as hazardous:

- Chemical hazards such as, handling laboratory products, fuel and oil, and working with unslaked lime.

- Manual handling hazards such, hand picking from conveyor belts.
- Hazards from working at heights
- Hazards from working in confined spaces
- Vehicle hazards
- Hazards arising from energy sources such as, electricity, fuel oils and welding gases.

The writer introduced the following measures for the control and prevention of accidents:

- Eliminate — switch off, abolish process, hazardous article or substance.
- Substitute — replace with a safer product, or introduce new product.
- Control — engineering design, and job design.
- Safety reps — safe systems of work introduced and monitored, inform, instruct and train workers. Consider levels of exposure to risk and reduce where possible.
- Protective — equipment last resort measure and for emergency use.
- Discipline — outline of quarry procedures, warnings, signs and posters.

5.3.3 Environmental management systems

The International Organization for Standards (ISO) has produced a series of standards applicable to the environment, these are known as the, 14000 Series for Environmental Management Systems, that amongst others, comprise; [ref 117]

- ISO 14000. Guide to Environmental Principles, Systems and Supporting Techniques.
- ISO 14001. Environmental Management Systems - Specification with Guidance for use.
- ISO 14004. General guidelines on principles, systems and supporting techniques.
- ISO 14010. Guidelines for Environmental Auditing - General Principles of Environmental Auditing.
- ISO 14011. Guidance for Environmental Auditing - Audit Procedures - Part 1 : Auditing of Environmental Management Systems.
- ISO 14012. Guidelines for Environment Auditing - Qualification Criteria for Environmental Auditors.
- ISO 14013/15. Guidelines for Environmental Auditing - Audit Programmes, Reviews & Assessments.
- ISO 14020/23. Environmental Labelling.
- ISO 14024. Environmental Labelling - Practitioner Programmes - Guiding Principles, Practices and Certification Procedures of

Multiple Criteria Programmes.

- ISO 14031/32. Guidelines on Environmental General Principles and Practices.
- ISO 14050. Glossary.
- ISO 14060. Guide for the Inclusion of Environmental Aspects in Product Standards.

Many quarry operators are now aiming towards quantitative controls for the full scale introduction of management systems such as ISO 9002 which targets consistency in the quality management of products), and then to install an environmental management system (EMS) such as ISO 14001 (which came into effect September 1996) or an eco-management and audit scheme (EMAS) that became operational in April 1995. The aim of EMS is to seek continual improvements in environmental management and set environmental objectives and targets. Whilst the writer himself would not undertake the logistics of an environmental management system (EMS), he would be involved in its implementation and supervision. For this reason a discussion of EMS is an integral part of this document , as the writer believes that in the future, EMS will be a mandatory requirement for any quarrying operation. Furthermore it is believed that ISO 14001 would be the preferred choice rather than EMAS, due primarily to the strict requirement to produce environmental performance statements. At present EMS is an entirely voluntary undertaking, however increasingly quarry operators are introducing them as standard. Another reason to choose ISO14001 over EMAS is that the requirement is only to have a "commitment to comply" with environmental legislation, EMAS obliges full compliance with legislation. In Africa this is seen as to onerous as it would involve acquiring the most up to date technology to reduce environmental impacts.

Benefits and problems of EMS accreditation

Benefits

- Reduction of impacts on the environment
- The producer is seen as a "green" firm, this is now much favoured by the finance houses and corporate organisations it therefore creates market advantage.
- Ensures a consistent, thorough approach to the management of environmental concerns.
- The producer is less likely to be caught out by new environmental controls in the future. There is now a global commitment towards reducing environmental impacts, and it is expected that some quarrying and mining in Africa will soon be seen to produce unacceptable impacts.
- EMS is a good framework for pursuing environmental controls.

Problems

- The provisions for public information are very demanding.
- It is not a legal requirement that environmental impacts are listed, therefore to admit to them on a voluntary basis may not be a good idea.
- The demand on resources and the cost of putting the system in place (as high as $80,000 per site) may not be justified by increased competitive advantage and environmental cost savings.
- EMAS and ISO 14001 do not identify universal minimum standards. EMS is therefore not an objective tool, which begs the question, why do it?.
- Certification guarantees little to the customer or the public.

Environmental issues have already been discussed and notwithstanding this, the key elements that would be addressed in an EMS are:

- Emissions to the environment.
- Energy consumption.
- Use of raw materials.
- Waste minimisation.
- Noise nuisance.
- Water pollution.

Steps to certification

There are several steps to achieve ISO 14001 accreditation and these comprise the following tasks. They are:

- Environmental policy formation and initial environmental review
- Planning environmental aspects legal and other requirements
- Set objectives and targets
- Create environmental management programmes
- Implementation and operation of EMS
- Set out structures and responsibilities
- Training awareness and competencies defined
- EMS documentation created
- Operational control procedures defined
- Emergency preparedness and response procedures defined
- Checking and corrective action procedures
- Define procedures for monitoring and measurement of EMS
- Define procedures for non conformance, corrective and preventive action
- Define procedures for record system
- Environmental management systems audit
- Management review of EMS

In order to carry out the tasks identified above, it is necessary to define the status of any existing environmental management systems, and to determine the quarry operators commitment and allocation of available resources. It is also necessary to carry out an existing document and systems review, for which the following information will be needed:

- Training records
- Employee qualification records
- Operating procedure documentation
- Review procedures
- Audit (if any) results and procedures
- Relevant environmental legislation requirements
- Emergency and hazard control procedures
- Accident reports
- Worst case scenario procedures
- Methods of document control
- Plant and machinery specifications, maintenance records
- Relevant information on identified environmental issues including emission levels, rotes for emission generation, energy inputs and usage, product life cycle, waste levels and production, waste disposal routes, levels and generation of noise, water quality, polluting pathways and targets.

Environmental targets and policies

The writer believes that should ISO 14001 be introduced to the sites in this document that it may be possible to set targets and policies to ensure environmental improvement by:

- Emissions to the atmosphere,.eg dust controls with say 20% reduction
- Energy consumption 10%
- Use of raw materials. No specific target set as raw materials are used for processing, policy of quarrying in the most effective way to extract limestone
- Waste minimisation. Target say 20% reduction. Policy for use of overburden for restoration purposes
- Noise nuisance. Target say 20% reduction to sensitive recipients
- Water pollution. Target say 50% reduction. Policy of water treatment and recycling of dirty water within the site.

5.4.0 ENVIRONMENTAL IMPACTS

5.4.1 Dust Pollution

Definition

For environmental purposes, dust is defined in BS 3405 as particulate matter in the size range of one to seventy-five microns. Atmospheric dust is a natural occurrence caused by air movement over dry ground. Mans activities can add to natural dust levels, and it is these increased atmospheric dust levels that have an environmental impact. In industry dust can mean particles up to two millimetres and in quarrying terms, dust can be used to describe a crushed rock of up to five millimetres. The process by which dust becomes airborne is termed dust emission, this is mostly caused by the wind, and mitigated by the rain. Fine particles will remain airborne longer than coarse ones and as a consequence, will travel farther from the source. Generally with light wind conditions, dust greater than 30 microns will settle within 100 metres, dust of 10 to 30 microns will travel 250 to 500 metres and dust less than 10 microns will travel a kilometre or more. In residential areas a dust limit of 0.26 mg/m^3 may be considered reasonable whereas in the mine a level of 2.0 mg/m^3 may be applicable. The World Bank 24 hour average standards, measured at the project boundary require kiln dust not to exceed 0.5 mg/m^3 and the UK the air quality standard is 0.05 mg/m^3 or one tenth that of the World Bank. [ref 32]

Dust can cause significant nuisance in a number of ways; [ref 32]

- To residential areas, to people, soil and vegetation
- The soiling of agricultural produce and pasture. Dust can effect consumption and commercial value of crops and can curtail plant and fruit growth, conversely lime dust can be beneficial to acidic pastures.
- Adverse effects on growth and diversity of woodland near to mineral workings and process plants.
- In African climes the above effects can be more extreme.

In addition to problems off site, there may also be dust impacts on site;

- Reduction of visibility and consequent reduced safety
- Deterioration of plant equipment due to ingress of dust
- Greater maintenance costs from more frequent changes of filters
- On dusty roads increased fuel consumption and tyre wear
- Unpleasant and unhealthy conditions for workers
- Vegetation and restoration schemes can be damaged

Nuisance effects

Silica dust produces a distinctive reaction in the lung that eventually leads to the development of masses of fibrous tissue and distinctive nodules of dense fibrosis, which, by contracting, distort and damage the lung. Silicosis is a hazard in any occupation in which workers are exposed to silica dust, particularly rock drilling in quarrying. Silicosis is usually fairly easy to detect on radiographs, and in its later stages it causes considerable shortness of breath and a reduction of the vital capacity. Protective masks must be provided to workers who are likely to come in contact with silica dust. The type and quantity of dust generated by a mine and processing plant and the public perception of the nuisance varies with the following;

- The colour of the material to be mined, for example, limestone usually produces a light coloured high contrast dust, whereas coal produces a dark high contrast dust. For example, in the UK over 20% of a surveyed group saw limestone dust as a major problem, whereas about 15% viewed slate as only an occasional problem and nobody reported it as a major problem.
- The hardness of the material, it is reasonable to assume that breaking a hard material such as granite will produce less dust that breaking soft materials such as chalk and coal.
- The type of processing, for example, aggregate production, asphalt plant, concrete batching plant, cement plant, heavy metals recovery or coal beneficiation plant.
- The population density, land use and general environment with particular emphasis on the chemical and physical effects on agriculture and the ecology, for example, limestone dust making the soil alkali.
- Climate and topography, The topography can produce local wind patterns and large hills will due to less disruption, be subjected to stronger winds. Long dry periods will have a significant effect on dust pollution and excessive rain can cause river pollution by carrying dust in solution out of the site.
- Visibility of the dust both airborne and settled.
- Living conditions, the tolerance of people and their awareness of the law.

The main sources of dust generation in quarrying are;

- bench drilling
- traffic movement, product loading and general activities in the processing and mine area
- crushing and processing [ref 32]

5.4.2 Dust Mitigation

The site layout can be designed to place the maximum distance between dust production and sensitive areas. These sensitive areas can be protected by use of the topography, either natural, such as with, woodland, or man made with the careful positioning of buildings. The travelling distance of dust can be reduced by taking advantage of the direction of the prevailing wind and building screens to reduce wind velocity and if possible disruption in the form of vortices.

Figure 5-1 [ref Mills] Wind vectors

Month / year	1993	1994	1995	1996	Average wind direction	1993	1994	1996	Average of greatest wind velocity kn/s
January	274	245	280	245	261.0	6.8	6.8	7.8	7.1
February	257		263	271	263.7	6.8		5.8	4.2
March	241	224	270	245	245.0	7.8	8.7	13.6	10.0
April	167			168	167.5	5.8	7.8	8.7	7.4
May	141	145	150	118	138.5	7.8	6.8	5.8	6.8
June	153	134	143	105	133.8	7.8	6.8	5.8	6.8
July	143	130	137	116	132	7.8	6.8	7.8	7.5
August	123	132	171	115	135	6.8	8.7	7.8	7.8
September	134	135	150	123	136	6.8	6.8	6.8	6.8
October	136	110	150	183	145	5.8	7.8	6.8	6.8
November	189	134	270	185	195	11.7	4.9	7.8	8.1
December	210	100	281	256	212	8.7	9.7	7.8	8.7
Average	163	139	180	156	**163**	6.8	7.2	7.0	**6.6**

It is normal practice to prepare tables showing the average wind velocity and speed (vectors), below are tables prepared by the writer for a mine in Indonesia, data for Africa was considered secret and therefore, not available. The above table give wind vectors, the averages are; direction 163 degrees at a velocity of 7.1 knots. The stronger winds are in months October to March with an average of 8.2 knots and a direction of 220 degrees. The airborne dust can be reduced by less handling, this can be designed into the site layout by having adequately sized storage facilities close to the processing areas.

Method of working

Dust arising from the bench drilling operation can be significantly reduced by using a fine water mist (atomiser) or a dry cyclone and filter system. A dry filter system is often more appropriate in Africa as often, there is little water. Although a Down The Hole drill will produce less dust, this type of drilling system, because of its cost and complications is not widely used, therefore drifter drilling systems are more commonly found, even with these relatively inexpensive drilling systems, it is rare to find the installation of any dust suppression systems. Dust generated by traffic and processing can be reduced by routine water sprinkling and limiting vehicle speeds. Due to their availability in Zambia, molasses have been used to suppress dust on the roads of the sugar farms.

On a longer term basis, dust can be reduced by using a hard rock surfacing or preferably, coating the road with bitumen or asphalt, keeping haul routes as short as possible and reducing gradients. In addition, haul routes waste dumps and stockpiles can be located in the lee of prevailing winds and away from sensitive locations, such as, residential locations, and main highways.

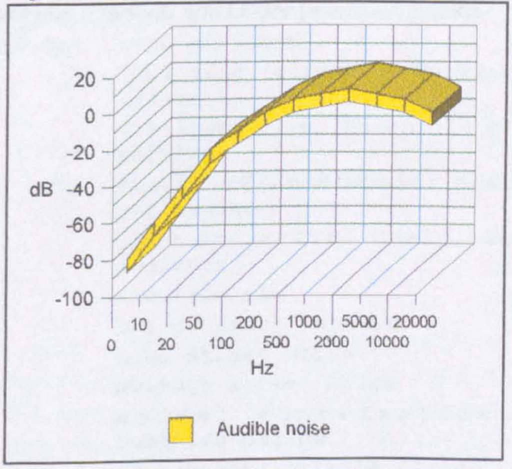
Leafy trees can be grown at the sides of the road which will filter the air and trap the dust particles. Dust nuisance from crushing and processing is primarily generated by the crushers, screens, transfer points and the discharge points of product conveyors. In more developed countries the equipment is usually housed, and a central de-dusting system installed. Waste dumps and stockpiles should be designed with gentle slopes to reduce the impact of wind effects and the pick up of dust.

5.5.0 NOISE POLLUTION

5.5.1 Definition and perception

Noise can be described as unwanted sound and is a recognised form of pollution. The average background noise in a typical home today is between 40 and 50 decibel. Noise is often the pollution which causes most complaints to industry and is identified as being a major factor in the deterioration of quality of life. The United Kingdom has legislation cited as the Noise at Work Regulation 1989, these are based on European Community Directives for standard laws on reducing the damage to hearing as far as is reasonably possible and give a recommendation of 55dB. The World Health Organisation's publication "Environmental Health Criteria 12:" gives a maximum noise level to prevent community annoyance as 55 dB. Spain sets the level at 55 dB night and 65 dB day.

Figure 5-2 [ref 86] Noise sensitivity curve



Perception of noise nuisance is different to other pollutants, as a sound that has passed leaves no trace unless measures have been taken to record the sound, even then its effect on people cannot usually be reproduced from reading a trace on a machine. Sound effects people in different ways, very loud volume will cause direct physical hearing damage, other effects can be described as physiological effects, whereby the mind or body naturally responds to the sound. A physiologically important level is the threshold of pain, at which even short-term exposure will cause physical pain, this can occur at 130 to 140 dB. Any noise sustained at this level will cause a permanent threshold shift or partial hearing loss. At the uppermost level of noise of greater than 150 dB, even a single short-term blast, as for example a warning siren may cause traumatic hearing loss and physical damage inside the ear.

5.5.2 Measuring sound

The ear mechanism is able to respond to both very small and very large pressure waves by virtue of being nonlinear; that is, it responds much more efficiently to sounds of very small amplitude than to sounds of very large amplitude. Because of the enormous non-linearity of the ear in sensing pressure waves, a nonlinear scale is convenient in describing the intensity of sound waves. Such a scale is measured in decibels (dB). The decibel scale is somewhat misleading because it is logarithmic rather than linear; for example, a noise source measuring 70 dB is 10 times as loud as a source measuring 60 dB and 100 times as loud as a source reading 50 dB.

Figure 5-3 [ref 47] Sound Levels for Nonlinear (Decibel) and Linear (Intensity) Scales

decibels	intensity*	amplitude~	type of sound
140	100	300	explosion (permanent hearing damage)
130	10		artillery fire (threshold of pain)
120	1	30	amplified rock music; near jet engine
110	10^-1		loud orchestral music, in audience
100	10^-2	3	electric saw
90	10^-3		bus or truck interior
80	10^-4	0.3	Loud street noise
70	10^-5		average street noise
60	10^-6	0.03	normal conversation; business office
50	10^-7		restaurant; private office
40	10^-8		quiet room in home
30	10^-9	0.0009	people whispering one metre away
20	10^-10		Inside a recording studio
10	10^-11	0.00009	soundproof room
0	10^-12	0.00002	absolute silence (threshold of hearing)

*In watts per square metre (W/m^2) ^ indicates exponentiation ~ in Pascals (Pa)

The reception of the sound in the human ear is not linear and a doubling of the loudness will not necessarily seam to be twice as loud, variables are; depending upon individual susceptibility, duration of exposure, nature of noise (loudness), and time distribution of exposure (such as steady or intermittent). In addition to the loudness of sound is the pitch or frequency, the human ear in a youth will hear sound in the frequency range of 20 to 20,000 Hertz (Hz), with age the upper range will drop to 10,000 Hz, with the most sensitivity being in the 1,000 to 5,000Hz range. The nuisance value of sound is most perceived in the 500 to 10,000 Hz range, however people will be troubled by sounds in their particular sensitivity band. Low frequency sound has been reported to cause feelings of illness, nausea, vertigo and general sickness, whilst high frequency sounds tend to cause acute pain in the ears and headaches. Low frequency sounds will travel much farther distances than high frequency and high frequency sound is more likely to be dulled by barriers such as trees or fences. In an effort to compensate for the average ear, a weighting basis has been developed which is shown as dB(A) and is used in the UK as the basis for the government control of noise regulations, together with equivalent continuous noise level (Leq). Leq is a noise index which gives a reasonable indication of peoples subjective reactions to most sources of noise. A factor which can mitigate complaints is if the ambient noise level is high, thus conditioning the people to a high level of sound.

Typically 55 dB(A) heard from a site during the daytime and 42 dB(A) at night can be regarded as unacceptable, this is especially true if the noise is not constant, or contains impulses. Permanent hearing loss can be caused by prolonged exposure to noise levels above 85 dB(A) and if the noise is in a narrow frequency band hearing loss can occur below 85 dB(A) even though the exposure is only for a short time. Most engineering works in the UK are enforced through legislation to operate at sound levels of less than 89 dB(A).

Sources of noise

Noise only becomes a nuisance when it has an impact on people and animals. In Africa, the highly significant socio economic effects of industry greatly outweigh the magnitude of noise nuisance. The overall aim of an operating policy is that noise levels are kept to an acceptable level to maintain the health and safety of the recipients of the pollution. The principal sources of noise within an operation are;

- Reversing signals on vehicles
- Noise generated from caterpillar tracks
- Site vehicles
- Blast hole drills
- Blasting
- Site construction
- Process plant
- Earthmoving such as overburden removal

Mitigation

Assessments should be taken to quantify the extent of the problem and identify the sources, once the nature of the problem has been established appropriate measures should be taken to deal with the situation, these may include;

- insulation
- absorption
- isolation
- damping
- road maintenance
- ear protection
- identification of high risk area and posting of suitable warnings
- establishing a system of reporting

Insulation involves installing an acoustic barrier between the source and the area to be protected, for example, trees, walls etc. A noise reduction of up to 10 dB can be expected from efficient screening. In a mine with sub level workings, the benches and faces will cause a further reduction in noise escaping the site, however, there may be an increase of noise within the working area. The use of acoustic fencing on the top of an earthen mound around parts of the site perimeter can improve its sound reflecting qualities, and a well designed screen can be visually as well as aurally beneficial.

Absorption in wave motion is the transfer of the energy of a wave to matter as the wave passes through it. The energy of an acoustic wave is proportional to the square of its amplitude *i.e.*, the maximum displacement or movement of a point on the wave; and, as the wave passes through a substance, its amplitude steadily decreases. The change in energy as the wave passes through a layer is a constant of the material for a given wavelength and is called its absorption coefficient, a typical material such as foam will have a density of around 30 kg per cubic metre and can be used to line noise producing machinery. Noise mitigation by absorption involves using a purpose designed material fixed to an acoustic barrier.

Isolation involves separating the machinery from any buildings or other structures which may vibrate and convert the vibration to noise.

Damping, that is, the restraining of vibratory motion, such as mechanical oscillations and noise, this involves modifying machines and buildings to reduce their ability to vibrate.

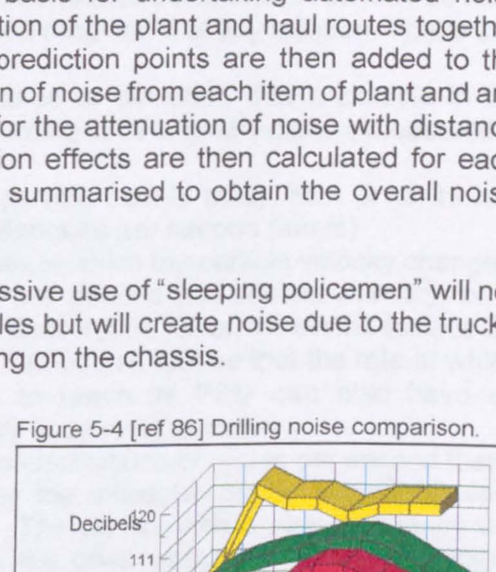
As in most industrial activities, noise generation from a quarry is inevitable, however, careful planning at the feasibility stage can minimise complaints in a number of ways. The writer assessed noise generation within a typical plant in terms of BS 5228 'The code of practice for basic information for noise control'. In particular, the following measures are commonly used;

- Buying plant which has sound attenuation
- Possible improvement to existing plant

- Buying plant which generates less noise to carry out the same task, for example, using a down the hole drill instead of a drifter
- Positioning the plant with due regard to the ambient winds
- Machine which are used intermittently to be shut down between work periods or left at idle.
- Limiting hours of operation if near to residential areas
- Haul routes screened by the topography and trees where possible, minimise gradients to avoid low gear, high revving and unnecessary revving of engines.
- Maintaining the plant
- If such technology is available computer aided design such as "site noise' computer programme, which enables accurate noise modelling of site operations to be undertaken. The programme uses a three dimensional computer model of the topography and adjacent areas as a basis for undertaking automated noise calculations. The location of the plant and haul routes together with details of noise prediction points are then added to the model. The contribution of noise from each item of plant and any haul routes, allowing for the attenuation of noise with distance and any noise reduction effects are then calculated for each point. These are then summarised to obtain the overall noise levels in terms of Leq.

Poor road maintenance or excessive use of "sleeping policemen" will not only cause damage to the vehicles but will create noise due to the trucks bouncing and the bodies slapping on the chassis.

Figure 5-4 [ref 86] Drilling noise comparison.



If a machine is likely to cause persons at work to receive a daily personal noise exposure of 85dB or a sound pressure at or above 140dB the manufacturer should provide adequate information on the amount of noise that is likely to be generated, this may help the user to select suitable products and design appropriate working areas. The noise which is generated from mobile quarry plant can be mitigated by operating benches are that are below ground level, whereby the noise is either absorbed by the earth or reflected upwards. The possibility of operating below general ground level or of constructing earth mounds should be considered when planning the quarry. Other screening such as tree planting and acoustic fences could be considered.

5.6.0 BLASTING NUISANCE

5.6.1 Areas of concern [ref for this section 5]

Blasting causes, noise (air overpressure), dust, ground vibration, fumes and can be a source of structural and other damage. Most of these unwanted effects can be minimised by careful planning and execution of the blasts. Ground vibration from blasting will be composed of various wave types of differing characteristics and significance collectively known as seismic waves. These seismic waves will spread radially from the vibration source, decaying rapidly as distance increases. The human body is an excellent receptor of vibrations and as a result of this, is very sensitive to, and able to detect even the slightest ground movement with perception levels sometimes approaching 0.5 mm/s but more typically being 1.5 mm/s. There are four interrelated parameters that may be used in order to define ground-vibration magnitude at any location. These are:

- Displacement - the distance or deviation that a particle in the ground moves before returning to its original position, measured in millimetres.
- Velocity - how fast the particle travels away from or to its rest position, measured in millimetres per second (mm/s)
- Acceleration - the time rate at which the particle velocity changes, measured in millimetres per second per second (mm/s^2), or in terms of the gravitational acceleration (G) on the earths surface G= 9,810mm/s^2. Some informed bodies believe that the rate at which the particle accelerates to reach its PPV can also have an influence on the possibility of causing damage.
- Frequency - the number of oscillations or cycles per second that a particle undergoes under the influence of the seismic waves, measured in Hertz (Hz). The waves with a high frequency will decay more rapidly than the ones with a lower rate of cycles, therefore, the lower frequency waves are more likely to cause nuisance and damage. Much investigation has been undertaken, both practical and theoretical, into the damage potential of blast-induced ground vibration. Although widely researched, the most eminent of such research authorities are the United States Bureau of Quarrys (USBM), Langefors Kihlstrom and Westerberg, Edwards and Northwood. They have concluded that the vibration parameter best suited as a damage index is particle velocity. Studies by the USBM have clearly shown the importance of adopting a monitoring approach that also includes frequency. Therefore, the parameters most commonly used in assessing the significance of an impulsive vibration are those of particle velocity and frequency which are related for sinusoidal motion as follows:

PV=2 pi fa where
PV = the particle velocity expressed in mm/s

f= frequency refers to the number of waves that pass a fixed point in unit time, expressed in Hertz, (Hz)
a = amplitude (the maximum displacement or distance moved by a point on a vibrating body or wave measured from its equilibrium, expressed in mm). pi = 3.1415926

Figure 5-5 [ref Mills et al] Damage criteria to structures

VARIOUS PPV TO DAMAGE CRITERIA, IN AVERAGE STRUCTURES	
Crandell's Energy Ratio 1947	
below 75 mm/s	no damage
75 to 150 mm/s	some damage, use caution
above 150 mm/s	damage will occur
Langfors, Kihlstrom and Westerberg 1957	
below 70 mm/s	no noticeable damage
70 to 110 mm/s	fine cracking and falls of plaster
110 to 160 mm/s	cracking of plaster and masonary walls
160 to 230 mm/s	serious cracking
Edwards and Northwood 1959	
below 50 mm/s	safe, no damage
50 to 100 mm/s	caution
more than 100 mm/s	damage
US Bureau of Quarrys 1971	
below 50 mm/s	no damage
50 to 100 mm/s	plaster cracking
100 to 175 mm/s	minor damage
more than 175 mm/s	major damage
Canmet, Bauer and Calder	
more than 50 mm/s	plaster cracking
more than 200 mm/s	cracks in concrete blocks of new building
more than 375 mm/s	horizontal offset in cased drill holes
more than 1,000 mm/s	shafts misaligned in mechanical equipment
more than 1,500	cracked concrete pads and distortion in steel building

The maximum value of particle velocity (PV) in a vibration event is termed the peak particle velocity (PPV) and it will usually be measured in three independent, mutually perpendicular directions at any one location in order to ensure that the true peak value is captured. These directions are longitudinal (or radial) vertical and transverse and are defined as follows:

Longitudinal, back-and-forth horizontal particle movement in the same direction as the travel of the vibration wave.

Vertical, up-and-down particle movement perpendicular to the direction of travel of the vibration wave.

Transverse - horizontal particle movement perpendicular to the direction of travel of the vibration wave.

It is possible to combine these three measurement directions into a single parameter known as the resultant value. This value must be calculated at any one precise instant of time from the simultaneous vibration magnitudes in the three orthogonal planes. Such a calculation is most readily facilitated by digital recording equipment which will generally record the maximum resultant value of any vibration event. It is, however, the maximum measurement of any one plane that is the accepted criterion worldwide and is recommended by the British Standards Institution and the International Standards Organisation among others. It is also the basis for all the recognized investigations into satisfactory vibration levels with respect to damage of structures and human perception. A PPV of 50mm/s is generally recognised as being the potential threshold for vibration to cause damage to structures, this figure is a globalization and actual figures may vary greatly. The United States Bureau of Quarries (USBM) have concluded that in the worst case of weakened structures, no damage has occurred at vibration levels of less than 12.7 mm/s, and in the UK, typical limits imposed on quarries are; an average of PPV of 10 mm/s over a six month period and a PPV of 12 mm/s for any single blast. The British Standards Institution produced a document in 1992 (BS 6472) that recommends a maximum PPV of 12.7 mm/s and a daytime satisfactory level of 8.5 mm/s. The nighttime maximum is identified as 2.8 mm/s, both these maxima being valid for three events per day.

Figure 5-6 [ref Mills et al] Studies of damage thresholds

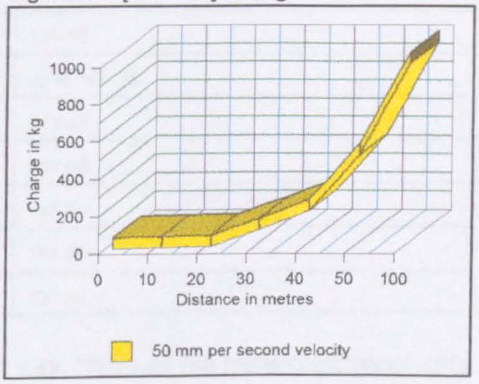
RESULTS OF STUDIES TO DETERMINE THE DAMAGE THRESHOLD TO STRUCTURES			
study	wall covering	cracking threshold	frequency
Langefors and others 1958	Na	109 mm/s	50 to 100 Hz
Edwards and Northwood 1960	plaster	76 mm/s	4 to 50 Hz
Northwood and others 1963	plaster	100 mm/s	7 to 100 Hz
Wise and Nicholls 1974	gypsum plasterboard	178 mm/s	4 to 10 Hz
Siskind and others 1980	gypsum plasterboard	20 mm/s	10 to 90 Hz

To put the above into a reasonable perspective, typical daily activities will cause PPV of up to 20 mm/s and thermal changes will give PPV values up to 75 mm/s and a foot stamp onto a wooden floor can give a PPV of 52.7 mm/s (USBM). Atlas recommend that ground vibrations within the frequencies of 3 and 12 Hz should be avoided for risk of foundational damage and frequencies of between 6 and 209 Hz avoided to reduce mid-wall or diaphragm response.

Figure 5-7 [ref 5] Average PPV versus distance

MAXIMUM PPV AT VARIOUS DISTANCES (ATLAS)	
0 to 100 metres from site	32 mm/s
100 to 1,500 metres from site	50 mm/s
1,500 metres and over	20 mm/s

Figure 5-8 [ref Mills] Charge/ distance ratio



Good blast design, with particular attention being paid to the loading on the explosive (burden, spacing and sub drilling) will minimise ground vibrations. Generally, the more explosive which is detonated at any one time, the greater is the ground vibration, therefore, to reduce vibration, efforts must be made to design an initiation sequence which reduces the blast to one of that consists of a series of smaller separate detonations. This can be achieved by firing either individual drill holes or short rows of drill holes with millisecond delays between them. In extreme cases individual charges within the same drill hole can be detonated with delays separating them. The USBM determined that a delay period of not less than eight milliseconds is required between each charge to prevent amplification of the vibrations. An operational advantage of delay blasting is the potential for an increase in the amount of fragmentation.

Overpressure or air blast

Air overpressure can be caused by the high pressure expanding gasses venting to the atmosphere and also by energy being transferred from the solid to the atmosphere, this may occur when the shock wave reaches a free face. Wrongly, air overpressure is often perceived by the public as the cause for damage to property, this is because the effects can be more noticeable than with the real problem, which is ground vibration with, for example, loose windows and doors rattling. In fact, unless the overpressure is intentionally very high, such as, when military devices are detonated, no damage will be caused.

Values for air overpressure are usually given in kg per cm^2 or to a log scale in decibels, windows may be broken with overpressure in the range of 0.05 to 0.15 kg per cm^2 or 150 dB and structural damage can be expected at 180 dB or 0.211 kg per cm^2. It is likely that no damage will occur below 140 dB and the USBM recommendation for maximum exposure is between 129 and 134 dB depending on the frequency. A high pressure shock wave will rapidly degenerate into sound waves and the velocity of sound in air depends on a number of factors including; temperature, density, wind speed and direction, other factors are; cloud cover, temperature inversion and wind shear.

Figure 5-9 [ref 5] Studies of safe overpressure

RESULTS OF STUDIES TO DETERMINE SAFE OVERPRESSURE	
Study	Safe Overpressure
USBM	134 dB
Reed	136 dB
Taylor	up to 140 dB
Redpath	141 dB
Poulter	141 dB
ANSI	146.00
Perkins	151 dB
Windes	151 dB

A good quarry manager will, on blast day, have all his meteorological data available to help in deciding if a blast will cause nuisance to the neighbours. The sources of overpressure can be controlled by using a non explosive initiation system, suitable stemming and paying attention to the loading on the explosive, in this case, the burden. Instruments are now available at little cost which will record the received decibels. A record can be made of the results, which are be acceptable in a court of law as a true record of the blast.

Fly rock

Fly rock is the term used to describe any rock projected beyond the planned blasting area, whether this involves leaving the boundaries of the site or not. A typical safety boundary for quarry blasting depends on many variables and each site will be unique. Generally a safe area is considered to be a circle of beyond 400 metres centred on the blast. It is recommended that extensive training be provided to the shotfirer to reduce the risk of damage or injury.

5.7.0 WATER POLLUTION

5.7.1 Definition

Water is required for every form of life and for human life, clean water is a must. The Earths resources are constant and finite, it is estimated that 97% of all the worlds water is found in the oceans in the form of salt water and of the worlds fresh water 77% is found in the polar ice caps, 22% is ground water 0.5% is found in lakes and rivers and the rest is in the atmosphere.

Figure 5-10 [ref Mills] Typical African river scene.

General

Hydrology is the science of dealing with the occurrence, distribution and movement of water on and above the Earths surface and hydrogeology deals with the same matters below the Earths surface.

Water pollution can be characterised as; The discharge by man either directly or indirectly, of substances the results of which will cause hazards to human health, living resources, aquatic ecosystems, amenities or interference with other uses of water. Because of this, the first priority when considering de-watering of a quarry should be the prevention of water entering the site, this can be reduced by excavating a drain around the perimeter of the site and building an earthen bund.

The main impacts from de-watering and drainage are;

- The removal of overburden of rock and its replacement which can after the quality of water filtering into aquifers
- The timing and levels of aquifer and surface water recharge
- Pumping out of workings or water course diversions, can by taking it from the sources and placing it in another, change the supply of water to spring fed surface water courses
- Cause subsidence at both ground and sub level
- Alter water quality before being discharged

- There may be physical and chemical contamination from operational discharges
- Slope instability, by reducing the supporting phreatic surface
- Saline intrusion and the drawing in of contaminated water from adjacent areas
- Widespread lowering of the phreatic surface

In both Malawi and Zambia there is much cultural use of the watercourses for drinking, washing, bathing and sanitary waste disposal. During the rainy season the rivers carry a high load of suspended solids, and many of the rivers are highly polluted. Before any quarrying takes place a full hydrological and hydro-geological survey must be completed with particular emphasis being placed on natural water drainage and flows.

A reasonable standard of water flow would be to take a 25 year, two hour duration storm event as the maximum flow rate and design the quarry accordingly. Generally, it is preferred that relative changes to peak flows, flow timing and base flows are minimised, this can usually be achieved by paying particular attention to the way in which the surface water is to be disposed of. In most cases, water pollution in quarrying is caused by suspended solids entering surface drainage from the quarry floor, the solids are often contaminated by residues from explosives or from fuel and oil spillage. At some stage of the quarrying operation, water containing suspended solids, abnormal pH values, or raw sewerage will be produced. The United States standard for suspended solids in water entering a stream is 70 mg/l and pH should be between 6.0 and 9.0. The World Bank requires a maximum of 50 mg/l suspended solids.

5.7.2 <u>Monitoring of water supplies</u>

The monitoring of water supplies is an important function as weather and other causes can result in changes that are similar to the effects of surface extraction on water supplies. To ensure that the surface and underground water is not polluted and flows altered, a regular surface water monitoring system should be instigated to site measure; [ref 45]

- acidity
- dissolved oxygen
- temperature
- salinity

- ▸ provide laboratory analysis of;

- conductivity
- dissolved solids
- suspended solids
- chlorides

- turbidity (clarity)

- and organic matter such as;

- biological oxygen demand
- chemical oxygen demand
- total organic carbon
- bacterial quality (faecal coliforms as an indicator of pathogens)

A more detailed examination of a full suite of metals analysis could be carried out on a three monthly basis to establish the levels of;

- calcium, magnesium, sodium, potassium, iron, manganese, copper, sulphate, bicarbonate, nitrite

- nitrate, organic nitrogen, ammonia nitrogen, dissolved and total phosphate

The samples should be named and numbered before being referenced on an analysis table with an established procedure protocol. Regular examination of the table will show both the development of long term trends and show periodic highs and lows, this will enable any required corrective action to be taken.

Where water and contaminants pass through the site and below ground level this can result in;

- Further curtailment of phreatic surface
- Blockage or contamination of water sources by suspended solids (such as silt, quarry fines and dust from processing) solvents (used in processing and spillage of noxious chemicals especially oil during maintenance) contamination by waste water discharged either directly or indirectly discharged into water courses and contamination by salts in overburden if it is incorrectly replaced.

5.7.3 Drainage

To reduce the carry over of solids into the surface water system and to protect against erosion, it is normal to provide a system of drains to direct rain water away from the quarry site, waste dumps and any haul roads. Any discharge originating from the quarry or from pumps situated within the quarry must before being returned to the natural environment, pass through a system of settling ponds to allow any solids in the water to deposit and to provide a holding point where pH can be corrected and any pathogens destroyed. If the material is to be commercially recovered the reference term is, tailings dams.

Drains must be designed with full consideration given to the maximum flow requirements and where required, geo-textiles and armour rock can be used to stabilise and strengthen the channels. A flow velocity of 1 m/s is the maximum rate suggested to control erosion in earthen drains, this is a maximum rate and for easily erodible soils the velocity should be reduced by the use of rock dams and slopes of less than 3%.

Erosion is a factor which must be dealt with, it can be controlled with good design, particularly with regard to bench height and angle of slope. Uncontrolled erosion will, apart from being unsightly, cause an increase in suspended solids and the destruction of vegetation.

5.8.0 VISUAL AMENITY, LANDSCAPE AND LAND REUSE

Existing conditions

The landscape surrounding the case studies are rural in character, with open agricultural land interspersed with woodland, except the Malawi site where the quarry edges into the great rift valley. The operational activities of the quarries will mean that the general appearance and character of the site will have a significant impact on the landscape and visual amenity. A good restoration scheme will mitigate some of the visual effects as some of these are of temporary impact only, this includes the plant and buildings. The long term effects on landscape can be to destroy existing topography and introduce alien features that are unsightly.

5.8.1 Planning

All aspects of quarrying will have an impact on the landscape and will have a long or short term effect, however, the problem is surmountable and good quarry design will take consideration of the environment. Visual amenity must be considered at all stages of the life of the project;

- at the planning and development stage, funding alone will dictate the effort that can be given to reducing the impact
- during the production phase, care must be taken to develop measures of mitigation as the quarry progresses
- before and when the project is ended a plan must have been implemented to restore the site to an acceptable standard

Less impact will be made on the visual aspect if dumping of the waste is carried out in the quarry in areas that have been worked out for "landfill". This method of disposing of waste can sometimes provide an opportunity to re-create pre-working or a similar acceptable landscape. Landfill is most successful when the material being quarried is in a thin seam with a high waste ratio, in this case the high value material can be removed and the waste used to refill the void. Care must be taken if the infill material is high in moisture or contains any pollutants as these may leach into the ground water. When quarrying limestone for cement or lime production it is unlikely that sufficient waste will be produced to fill the void, this may provide an opportunity to gain revenue by developing part or all of the site as a waste facility.

Geo-technical and engineering factors will have a large influence on the shape and form of surface waste dumps, even so, they should be constructed to resemble as closely as possible the native ground contours. The dumps must be carefully designed to prevent erosion, normal practice will require the dump to be benched, with the surfaces of the benches engineered with a longitudinal slope of 2%, a back-slope of 5% and a forward slope of 15%. To reduce the risk of slippage, the waste dumps should be well consolidated with compaction on the forward slopes reaching 90%. A longitudinal drain should be constructed between the front of the higher bench and the rear of the lower bench, the drain to terminate either at the end of the bench or preferably in a purpose designed and landscaped valley containing an armoured run off channel.

Should the material be susceptible to erosion or have a high absorption ratio, the drain should be constructed in a way that will prevent the water from penetrating the dump and possibly causing a circular failure. The run of channel should terminate in a pond, suitably constructed to allow sufficient residence time for settling of any suspended solids. Clarified water will overflow the settling ponds to natural drainage via an armoured spillway. Re-vegetation will help control the flow of water, reduce erosion and improve the visual amenity.

Restoration of the tips will include the re-vegetation of the area with flora that matches the surrounding areas with as little importation as possible of non native species. The construction of habitats for fauna with private and protected areas should be included in the tip management plan. The reported incidences of tip and slope movements in the UK in 1996/7 was 19. Other areas of mitigation include screening and resighting the plant to be remove it from general view, tree screening, unobtrusive location of mounds and stockpiles and generally keeping a tidy site.

5.8.2 Reclamation and restoration

It is normally a condition of government that any quarrying site shall be restored to a condition suitable for one or more of the following;

- agriculture
- forestry
- amenity

The basic elements of good practice with regard to progressive restoration are schemes to be designed from the outset so as to improve the appearance of the site of any plant and concealment by screening. To restore a site it is necessary to correctly strip and restore the soils, topsoils should be carefully sorted to ensure that valuable top and sub soil is not lost as these materials will be required to enable successful re-vegetation. Prolonged stockpiling or inappropriate use of topsoils will reduce their value as a growth medium because of the oxidation or leaching of the organic material. Wherever possible soils should be moved directly from areas being stripped to areas being restored, this process being known as progressive re-instatement. Areas to receive special emphases are;

- the location size and management of stockpiles with particular attention paid to their height and shape, and avoid obviously made banks by shaping to be rounded and undulating.
- a running register of the amount of soil in unworked areas
- the preservation of soil for use in restoration and landscaping, generally, soils should not be stored in wet conditions and they will improve if kept planted
- the methods of stripping and storage with particular care being exercised in wet conditions
- the potential for recovery of soil from overburden
- Quarry faces where possible blasted in such a way so that final faces are as similar as possible to original contours.
- Rock faces to be treated and sprayed to facilitate re-vegetation process
- Access to the quarry landscaped with a curved access road into the site.
- Haul routes, where possible below the rim of the quarry
- Tree planting where appropriate
- Tidy, well maintained and as far as possible, colour co-ordinated plants

Restoration scheme

Re-vegetation sufficient to stabilize the soil should be established on all disturbed areas and erosion control measures need to be established along the steep slopes. The ability of post-quarrying land to support plant life is determined by the properties of the soil in the area where plants lay down their roots, the seed mix, and the local climatology. Efforts should be made to grade for minimum slope requirement and replace soil that approximates to the pre-quarrying chemical and physical properties of the original soil. The planting of trees of the following species should be carried out ensure vegetal cover, neem (Azadirachta indica), white Cedar (Tabebuia pallida), guava (Psidium grajava), tamarind (Tamarindus indica) and various Cacti species. It is important to have exposed surfaces high in soil content (versus rocks) planted with grasses to help bind the soils, trees will take a number of years before their root systems develop sufficiently to provide the soil holding capacity that is required. The eventual aim of the rehabilitation program in the site is to re-establish a Dry Scrub-Woodlands Forest. To achieve this, rehabilitation should be carried out continuously behind the quarrying operation, commencing as soon as the rock has been quarried.

Topsoil from the next section of the operation should be spread on newly formed soil capping so that all the valuable attributes, such as organic matter, plant nutrients, micro-organisms and seeds, suffer minimal deterioration. Planting the site with useful tree crops including mangoes, citrus, cactus pear trees among others, will be a distinct possibility after quarrying has ceased. Since forest vegetation plays an important role in maintaining slope stability, new trees should be planted to restore the stabilizing root network. Maintaining a supply of plants and shrubs on site for replanting in the areas that have been quarried would assist in gradually restoring the site when quarrying will have ceased. It would be beneficial to erect temporary plastic mesh fences in the newly planted areas in the first couple of years of rehabilitation.

5.8.3 Recommended plants [ref 88]

For Wind Break

- Mango (Mangifera spp.) Eucalyptus (Eucalyptus spp.) Bamboo (Bambusa spp.) Neem (Azadirachta indica) White Cedar (Tabebuia pallida) Guava (Psidium grajava) Tamarind (Tamarindus indica)

For Contour Barrier

- Leucanea or Wild Tamrind (Leucaena leucephala) Elephant Grass (Pennisetum purpureum) Sisal (Agave spp.) Pine (Pinus caribaea) Bay Trees (Pimenta racemosa)

For Channels, Slope Stabilization, and Ground Cover

- Bahia Grass, Bermuda Grass, Pangola Grass, St. Augustine Grass

5.9.0 HYDROCARBONS

The correct disposal of hydrocarbons is vitally important if ground water is not to be contaminated. Hydrocarbons will be found in the quarrying environment as, lubricating oils and greases, oils in transformers and capacitors, fuel for plant and fuel for explosives. Spillage of oils and fuel will be minimised if good procedures are imposed and the operators well disciplined and trained.

Oil and fuel locations need to be in a position where spills can be controlled. Oils and greases should be kept in a purpose build store with methods in place to prevent spillage reaching ground water. Fuel oil must be stored in secure above ground tanks, positioned in a suitable area and correctly installed with a containment facility which can accept the total volume of the tanks. Greases are usually used in a total loss system of lubrication and loss is unavoidable, the situation can be mitigated by avoiding over-greasing machinery.

Care must be taken to apply all suitable methods to extend the life of oils used in vehicles, this can be achieved by adding extra filtering capacity which has smaller voids in the filter paper and by using additives. After use, lubricating oils must be drained into secure containers and returned to the suppliers for treatment for re-use or disposal.

Fuel oil is used in the plant and as a fuel in ANFO type explosives. Proper maintenance of fuel circuits and engines in plant will ensure that vehicles perform to their optimum this will reduce the amount of fuel being wasted as exhaust smoke and dilution of sump oil. Any leaks in the system should be dealt with as a priority. Residues from explosives will be reduced if the ingredients are correctly mixed and care is taken not to spill fuel oil when mixing the ANFO. Good blast design will ensure that all the energy of the explosive is used in the blast and a minimum of the gases are toxic.

Oil from transformers may contain polychlorinated biphenyls (PCB),these are any of a class of highly stable organic compounds that are prepared by the reaction of chlorine with biphenyl. A commercial mixture of such chlorinated isomers of biphenyl provides a colourless, viscous liquid that is relatively insoluble in water, does not degrade under high temperatures, and is a good dielectric. The presence of PCBs in transformer oil has been identified as a toxic hazard that may produce damage ranging from acute biological effects (complete sterilization of stretches of waterways) to chronic sub-lethal effects that may go undetected for years, because of this, advice should be sought for its removal from an approved disposal facility. PCBs cause liver dysfunction, dermatitis, and dizziness in humans exposed to them.

5.10.0 SOCIAL ENVIRONMENT

Administration and land purchase

Several administration centres will be involved in preparing the site for a large quarrying project, care and patience in dealing with administrative bodies will reduce long term problems. In most African countries, the user of the land will probably have no official title to it, but will have been given the land by the local Chief, even though the accountants of most international companies may find this strange, it is the way of Africa and the rights of the land user will be acknowledged in a Court of Law. Generally, a producer would find it advantageous to purchase a buffer zone around the quarry with perhaps offering the option of the agricultural use of the land to retired (safe) quarry workers.

Changes in land use

The principle social-economic effects of quarrying in Africa are the changes in land use. These changes will occur in both the project area and in the towns and villages nearby and the social implications relate to the needs of any inhabitants displaced by the development to relocate their homes and agricultural activities elsewhere. Tribal and family ties will cause considerable resentment against the project and a substantial compensation package may be required to enable the project to proceed without hindrance.

Employment considerations

Any new quarrying project is likely to be a major source of employment opportunities for local residents. This is provided that appropriate training programmes are instituted as a component of development. Efforts should be made to promote interaction between local residents and newcomers. Few of the quarry jobs will because of skill and education requirements attract women, this is largely because most of the educated women in Africa prefer office work and the lesser educated women are homemakers, notwithstanding this difficulty, it would be politically expedient to aim recruitment policies to recruit as many women as possible.

Urbanisation

A quarry project will stimulate the growth of the local community, with benefits in education, health, recreation and other social needs of the population. These generally will be local level facilities, but the cumulative effect of the direct and indirect population growth will increase the threshold population for social activities.

Local economic effects

Care and attention to the support of shops and other small businesses will improve the monetary base for the local community, this can be augmented by seasonal employment for such jobs as gardening and general labouring.

Cultural heritage

It is unlikely that any major intrusion will be made into cultural heritage, but care should be taken to encourage such aspects as dancing troops and support of football and other sporting facilities. Support in these areas will promote support for the company at very little cost. The company may wish to provide land and assistance with the construction of places of prayer, particularly if the work force has a high Muslim content.

Health and education Facilities

It is normal practice in Africa for the quarry to provide primary school education and transport for the older children to attend high school. Grants or loans are usually given to support further education. The company will be legally required to provide comprehensive first aid facilities and will probably wish to provide a health centre and a clinic. An ambulance will be required and provision made for visiting specialists. Due to the prevalence of acquired immune deficiency syndrome (currently estimated at about 50% in Zambia) and endemic malaria, health care is of paramount importance if the work force is to perform adequately.

Summary

Knowledge about the environment is freely available to all countries but it would seem that it is only the rich countries that can afford to implement workable policies, to most of Africa, maintenance of the environment is a luxury that they either cannot afford or do not wish to be bothered with.

5.11.0 CHILANGA WORKS

5.11.1 Introduction

Chilanga township is a growing settlement area surrounded by farmland. The company's own township is located adjacent to the factory. Mount Makulu National Agricultural Institute lies three kilometres west of the factory and an asbestos manufacturing company is 500 metres north. The Chilanga cement Works, is situated fifteen kilometres south of Lusaka, close to, and east of, the main Lusaka-Livingstone highway. RP3 mine is found eight kilometres to the south west of Chilanga works and approximately three kilometres west of the Lusaka - Livingstone highway. Chilanga Works has a cement production capacity of 175,000 tonnes per annum. The process begins in the quarry where limestone is won by drilling and blasting. The rock is loaded onto 30 tonne dump trucks by wheeled front end loaders. The limestone is trucked 8 km along an unpaved haul road, passing through both private and state land. The Company has a wayleave over this land.

Elevation

For this document all elevations shown in the mine are reported in metres relating to a local bench height which is based on a surveying beacon. The actual height above mean sea level of the beacon is 1156.38 metres. The arbitrary local height of the beacon is 100 metres. The highest point is to the west, reaching 125 metres, the north is 106 metres, the south is 80 metres and east reaches 100 metres. The centre of the mine is at 86 metres. With the exception of hills and ridges, the slopes rarely exceed 3%, thus the area is largely level to gently sloping. A natural north, south slope was originally found, however, mine development has now caused a reverse slope. The mine is approximately 730 metres long, 520 metres wide and covers an area of 379 hectares and the mining activity covers 198 hectares.

Vegetation

The RP3 mine, situated in area 38A, was classified in a 1930s land use study carried out by the Department of Conservation and Extension, Ministry of Agriculture as suitable only for rough grazing and existed as part of a cattle ranching farm that once supported extensive natural vegetation. The active mining area has generally been cleared of vegetation apart from a three hectare site that has been planted with eucalyptus trees, the remainder of the site has been left intact.

Agricultural activities are concentrated in areas further east and west of the quarry, where the land is primarily used for growing flowers and vegetables under irrigation.

The soils are classified as belonging to Acrisol and Luvisol-Phaeozem associations. Luvisols are perhaps the most fertile soils in the region; they are extensively used by both large scale commercial and small scale peasant farmers [ref 91]

The Chilanga area is primarily "munga", this is open woodland where grassland has been invaded by trees. This may occur because of some disturbance such as fire, over-grazing, or cultivation. Munga, literally means thorn, and munga woodland often has Acacia species, but not always. Species of Terminalia and Combretum are also common, but any of a number of other species, especially those which are fire hardy could be present. The munga around RP3 quarry, consists of grouped trees reaching up to eighteen metres. The trees form a discontinuous canopy hence allowing an undergrowth of either bush or grasses. The trees species are, Acacia Polyacantha and Terminalia, the acacia dominate especially on the more poorly drained areas and river valleys. Terminalia is a genus of the family Combretaceae and is found on the better drained and elevated sites. These trees are commercially important for products such as gums, resins, and tanning extracts and yield woods that are used for cabinetwork, tools, and boat construction. Acacia's *(Acacia albida)* are members of the mimosa family (Mimosaceae) and are well-known landmarks around the quarry, their distinctive leaves take the form of small, finely divided leaflets that give the leafstalk a feathery or fernlike appearance. Other common trees are the thick trunked baobabs (Adansonia digitata), Brachystegia and Ficus (Cape or wild fig). [ref 36]

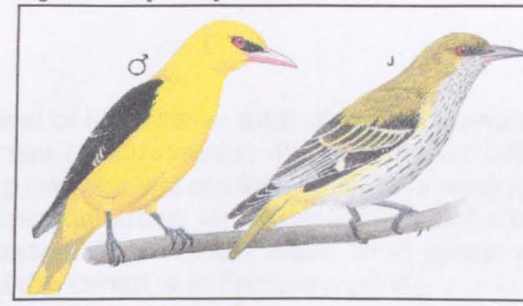
Figure 5-11 [ref 36] Wild fig

Among the most prevalent grasses are species of Andropogon, Hyparrhenia, and Themeda. The tall, coarse red grass Hyparrhenia can form prominent stands, but it makes poor grazing land and often harbours insects that spread disease. Much better for the pastoralists are the induced swards of Themeda. The genus Andropogon (family Poaceae), are coarse plants that have flat or folded leaf blades, solid or pithy stems, and flower spikelets clustered at the stem tips or in the leaf axils. The stems are often hairy, sometimes reddish or greenish in appearance. Several species have underground stems. [ref 36]

Fauna

In recent years, most of the areas surrounding the quarry have been cleared of all but a few species of the fauna that are of uneconomic value or are not of consumptive importance to man. The faunae that is now found consists of mostly rodents, such as, cane rat, pygmy mouse, striped grass mouse, pouched mouse, creek rat. Other fauna found include amphibians, reptiles and invertebrates, the latter including a wide variety of insects. The reptiles include several varieties of both harmless and extremely venomous snakes including green and black mambas, cobras and vipers. Common bird species of Zambia have been observed in the Chilanga area, including the fork tailed drongo, African golden oriole and eastern barred thrush warbler. Many other species have been observed but there is no evidence to suggest that the area is important for rare species or as a significant staging area for migratory birds. Despite the biological diversity of the Chilanga area, it is not thought to warrant consideration as a special site for nature conservation, mainly because none of the flora or fauna found in the site are unique or restricted in their distribution.

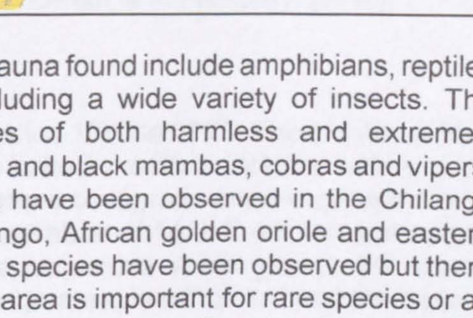
Figure 5-12 [ref 98] Golden Oriole



Habitation

Present land use is dominantly maize and sorghum growing with a few cotton fields. The maize is grown by squatter subsistence farmers usually planting by hand or by using oxen. Sorghum is restricted to family consumption. Mangoes and bananas are common and a few local farmers own either goats or cattle, these browse the areas close to the mine. No gardens or small holdings exist within the immediate proximity of the quarry. Care is now taken by the managers to avoid any further impact on the flora and the endemic destruction of the trees by outside agencies is actively discouraged. Unfortunately in the areas outside of the control of the mine, tree cutting continues at a great pace and uncontrolled fires are rampant. Excessive burning and over frequent burning will reduce the vegetation into savannah shrub, suffix savannah and finally grassland.

Figure 5-13 [ref 14] Green Mamba



There are no natural water courses in the quarrying area and collected surface water is pumped from a sump in the quarry to drain into the surrounding farmland.

Climate

The climate of Chilanga is typical of the plateau area of central Zambia, were the elevation of the plateau (1,300 metres) modifies the climate. Fresh easterly winds, averaging twelve knots are found in the dry season. Light variable winds, with occasional strong winds are associated with thunderstorms in the rainy season. The highest mean wind speed is attained during September and the lowest is in February. [ref 86]

Dry season

These figures are correct for the period 1960 to 1970. The months of May through to November are dry, the hottest month is October with a mean maximum temperature of 26.6 degrees centigrade and the coldest month is June with a mean minimum temperature of 14.7. Frost can sometimes be found in June and July (three occasions in ten years), the lowest temperature recorded in the Chilanga area, is minus 1.6 and the highest 37.2. [ref 86]

Average rainfall

The rainy season usually begins in November and continues until April, the average annual rainfall in the Chilanga vicinity is 836 mm. The highest rainfall is in December at 219 mm, January at 203 mm and February at 177 mm. Humidity ranges from 37% in September to 83% in February. In recent years the global climate has changed, this has manifested itself in Zambia by extremes of both drought and heavy rainfall. Evaporation ranges from 284 mm in October to 111 mm in February and averages 2,500 mm per year. [ref 86]

5.11.2 <u>Impact of quarrying</u>

The quarrying operation has impacted the area with;

- deterioration of the visual amenity
- noise and dust.

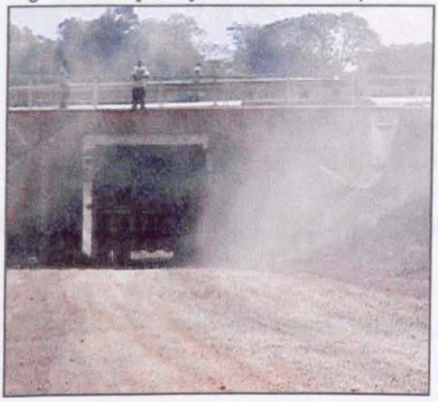
Most of these problems arise not from the quarry but from the stock pile area and the haul road.

Figure 5-14 [ref Mills] Typical dust cloud

Within the cement works and close to the primary crusher an area has been set aside for stock piling run of mine limestone. The area is situated on a slope and the ground surface is very uneven and untreated. With

Figure 5-15 [ref Mills] Dust free view.

Figure 5-16 [Mills] Dust from dumper



heaping it is estimated that the area has a stockpiling capacity of 40,000 tonnes. The main haul route runs to the south west of the stockpile area on an unconsolidated dirt road. In the dry season the dust raised by trucks

Figure 5-17 [ref Mills] View to the east

Figure 5-18 [ref Mills] View to the west

using the road cause a visibility risk to travellers on the main highway, and a health risk to users of the office block and golf course. Before leaving the cement works the road passes under a small bridge to emerge on the other side of the main southern highway. This bridge has been the scene of many accidents with dump trucks striking all surfaces of the bridge. The haul road is nine kilometres long and 50 metres wide, this covers an area of 45 hectares, it is a serious intrusion on the landscape and has a significant visual impact. Dust caused by the dump trucks remains airborne for more than two minutes and even in a light wind can travel several hundred metres before it settles, this changes the area of influence to more than 250 hectares. Repairs to the road, made in 1996 involved tipping about one-hundred thousand tonnes of fill on the road to compensate for the material that had been lost since its construction. A lack of water in the Chilanga area and the lack of a water tanker means that reduction of dust by wetting the roads is not an option.

5.11.3 Environmental Policy and Plan for Chilanga Quarries [ref 53]

Introduction

The following is an environmental policy and plan, it was produced by the Chilanga management in 1996 and it gives an indication of the train of thought that was current at that time. Examination of the plan will show that it concentrates almost entirely on the cement plant with little attention paid to the quarries.

A more thorough plan would have included details of reclamation, restoration and further land use

Management believes that the Company should conduct its business with a commitment to be a good neighbour, to respect the natural inheritance and to comply with local legislation and with CDC's policy guidelines in order to minimise the effects of its operations on the environment. In order to emphasise the importance of good environmental practice to its operations, an environmental policy has been formulated which has as its objectives:

- Compliance with all relevant legislation and in particular the Environmental Protection and Pollution Control Act, 1994.

- Operation and maintenance of the Company's plant and machinery so as to minimise their impact on the environment.

- Progressive improvement in energy efficiency and the use of non renewable energy sources.

- Reduction of waste disposal and emissions.

- Operation of a system of open information and pro-active communications with all relevant authorities and organisations.

- Environmental impact assessment prior to implementation of any new development.

Policy Implementation

Chilanga has appointed an Environmental Manager, who reports directly to the General Manager, to implement and oversee its environmental policy. The Company Technical Manager has been designated as the Environmental Manager. Works Technical Managers are the on-site managers charged with the day to day implementation of the policy and are accountable to the Company Technical Manager. In order to implement the policy effectively, the following guidelines will be used in the collection of data and as an aid to decision making.

(A) Dust Emissions

- Electrostatic Precipitators. A filter outage is defined as a failure of the precipitator for more than 5 minutes while the plant is operating. The Works Technical Manager's authority is required for the continuation of production of all outages longer than 15 minutes. Isokinetic dust tests with the filters operating are performed monthly on each plant.

- Bag Filters. Each bag filter installation is monitored weekly for visible dust emissions and the pressure drop across the bags is checked.

(B) Other Emissions and Wastes

- Water. The quantity and quality (suspended solids, oils and BOD levels) of all water effluxes are monitored on a quarterly basis.

- Process Residues. As far as possible, all process residues are recycled in within the plant. If process residues have to be dumped, the quantities must be recorded.

- Fugitive Emissions. Fugitive emissions are defined as emissions in any part of the factory other than through the stacks Steps taken to minimise such emissions include:

  Reducing internal handling of dusty materials;

  Using water sprays where appropriate to keep down dust;

  Returning all major spills (defined as those greater than 5 tons) to the process as quickly as possible.

  Maintaining the sheeting on enclosed stores in good condition.

(C) Energy Efficiency

The energy consumption of each kiln and the electrical energy consumption of each factory section is monitored on a monthly basis.

The use of wastes from other processes as secondary fuels is maximised provided that they are safe to utilise in this manner and are consistent with product quality and records of usage levels are kept.

Power factor correction equipment is in place at both factories and is continuously used to maximise the effective use of electricity. Load shedding is used when necessary to keep the maximum demand to a minimum (no automatic supervision equipment is available). However, as all electricity in Zambia is hydro-generated, power conservation will remain important chiefly from a cost point of view until thermal or other power plants come into use.

(D) Recording

The Environmental Manager will maintain a record of environmental performance at the two factories as follows:

Kiln filter outages - updated monthly
Isokinetic dust tests - updated monthly
Other electro filter outages - updated quarterly
Weekly bag filter checks - updated quarterly.
Copies of quarterly reports of water quality.
Process wastes dumped - updated quarterly.
Fuel consumption, secondary fuels used and electricity consumption updated monthly.

All complaints on environmental matters outlining the complaint and the action taken. The Environmental Manager will prepare a quarterly report for the General Manager to present to the Board.

(E) Annual Audit

The Environmental Manager will conduct an annual audit of environmental performance and issue a report highlighting achievements for the year, areas to be targeted in the next year and an assessment of the likely requirements for achievement of the targets. The annual audit will also address the training needs of employees to implement the environmental policy.

Operating Environment

The Company operates two factories: Chilanga Works, located at Chilanga, 16 km south of Lusaka, and Ndola Works, sited 5 km east of Ndola. Chilanga Works is situated in Chilanga township, a growing settlement area surrounded by farmland. The Company's own township, Musamba, is located adjacent to the factory. The Mount Makulu National Agricultural Research Institute lies 3 km west of the factory. An asbestos manufacturing company, Turners Asbestos Products, is 500m north.

Ndola Works is situated in an open wetland area. The nearest township is 2 km south-west and Ndola Airport is 3 km away, more or less in the same direction. The factory lies at an altitude of about 1,350 m above sea level. The daily average temperature ranges between 14 and 28C while the relative humidity ranges from 23% in the hot season to 96% in the wet season.

Land Use

(A) Chilanga Works

A comprehensive land use capability study of the Chilanga area was carried out in the 1930s by the Department of Conservation and Extension, Ministry of Agriculture. The study identified soils and land characteristics that are important in determining the suitability of the area for different agricultural activities and culminated in the compilation of several development plans, such as the Dem Regional Plan, which covered, among others, farm 38A on which the limestone quarry (RP3) is situated. Due to limitations imposed by the rough terrain, the area now occupied by RP3 quarry was classified as suitable only for rough grazing or afforestation Agricultural activities are concentrated in areas further east and west of the quarry, where the main land use is the growing of flowers and vegetables under irrigation. The rest of the land has been used for livestock grazing without clearing of natural vegetation. Controlled burning is also practised in areas adjacent to RP3 quarry.

Until 1981, when RP3 quarry development started in the subdivision of farm 38A, the land was solely used for livestock grazing. The main development in the 198 ha subdivision, enclosed by a wire fence, is limestone mining. other developments have~included an access road from the quarry to the cement factory about 8 km away and the construction of an office, a workshop and store room next to the quarry. The gravel haulage road passes through an area of very little activity other than a few maize plots run by squatter subsistence farmers. The vegetation on the rest of the subdivision has been left intact, except for about 3 ha of land that has been cleared by the Company for the purpose of establishing a plantation of eucalyptus trees, but there is little control over trespassers, so tree cutting and uncontrolled fires are rampant.

(B) Ndola Works

Ndola Works is situated in an open swampy area east of the City of Ndola. The areas has been designated as an industrial area, though the only other industrial company presently located in the area is Ndola Lime Company. There are no agricultural activities in the vicinity of the factory apart from a few gardens located on bordering land owned by the two companies. Most of these gardens are run by employees of the two companies who have no legal claim to the land. The principal fauna of the area consists of rodents (on account of the proximity of a densely populated area) and a few species of fish in the surrounding marshland. The vegetation is mainly tall Savannah grassland that is common in Zambia. The Company does not have a special site for housing at Ndola as it does at Chilanga; Company-owned houses are spread around the city in residential plots. The factory has no "idle" land.

Cement Production Process

Cement is manufactured in four basic stages -

- Quarrying and crushing of raw materials (limestone, sand and shale phyllite
- Grinding and blending of raw materials into slurry rawmeal
- Clinker production
- Finish grinding

Production of cement starts with raw material extraction: phyllite and limestone for Chilanga Works; shale, Sand and limestone for Ndola Works. Only limestone and shale are crushed; sand and phyllite are introduced at the milling stage. The raw materials are proportioned according to chemical requirements and milled in rotary ball mills. At Chilanga Works, water is added during milling to produce a slurry with a moisture content of about 34%. This marks the difference between the two factories - Chilanga Works is a wet process plant while Ndola is a dry process plant. The resulting product (slurry and rawmeal at Chilanga and Ndola respectively) is then homogenised and fed to rotary coal-fired kilns (two at each factory) for burning into cement clinker. The clinker is ground together with approximately 5% gypsum by weight to produce the final product - cement. Gypsum acts as a retardant to control the rate of setting.

The process is further explained in more detail for each factory as follows:-

Chilanga Works

Chilanga Works has a cement production capacity of 175,000 tonnes per annum. The process begins in the quarry where limestone is won by drilling and blasting. The rock is loaded onto 30 tonne dump trucks by wheeled front end loaders. The limestone is trucked 8 km along an unpaved haul road, passing through both private and state land. The Company has a wayleave over this land. The limestone is dumped either directly into a primary gyratory crusher or into a stockpile adjacent to the crusher. The primary crushed stone is stockpiled in an open space via gravity fill, after which the stone goes through an impact secondary crusher on its way to a covered store. The secondary crusher is fitted with a bag filter. Phyllite is quarried from an adjacent site 1 km east of the factory by ripping with a bulldozer. The ripped phyllite is trucked to the factory in 30 tonne trucks on a laterite road and off loaded in a covered store next to the secondary crushed limestone.

Raw milling is by three Vickers Armstrong ball mills. There are two kilns in operation: kiln 2 was supplied by Vickers Armstrong of the UK and kiln 3 by FL Smidth of Denmark (kiln 1, which was also a Vickers Armstrong kiln, was taken out of service in the early 1980s). Two electrostatic precipitators, both supplied by FL Smidth, are in use. Coal is ground in two open circuit air-swept mills. There are no coal de-dusting or filtration units. The combustion energy requirement of the two indirectly-fired kilns averages 1650 KCal per kg of clinker.

Three open-circuit cement mills are in use. Only one mill is fitted with a bag filter, which is being replaced by an electrostatic precipitator adequately sized to cater for the other two mills as well. The packing plant has one 12-spout rotary packer and two bulk loading facilities. There is also a rail loading facility which is out of commission. Cement is not pre-packed as there are no pallet handling facilities. One bag filter de-dusts the packer, bulk loading equipment and various transfer points.

Being a wet process plant, Chilanga Works requires about 20Q000 cubic metres of process water per annum at rated capacity. Over the years, the source of this water has been a disused limestone quarry 600m south-east of the factory. The "quarry" is now part of an 11 hole golf course owned by the Company.

Chilanga Works requires the following quantities of raw materials at rated capacity:

Limestone	250,000	tonnes
Phyllite	16,000	
Coal	46,750	CV=6000 KCal/kg)
Electricity	$25x10^6$	KWh
Basic refractory bricks	270	tonnes
Non basic refractory bricks	130	
Gypsum	9,000	
Paper sacks	3,250,006	pieces

Ndola Works

Ndola Works was commissioned in 1968 as a single line unit; a second line was added in 1974. Current production capacity is 315,000 tonnes of cement per annum. There are 300 employees. The limestone quarry is located ½ km north of the factory Limestone is loaded onto 30 tonne dump trucks by wheeled front end loaders and trucked 0.3 km to a hammer mill. Limestone is also bought from Ndola Lime Company, which operates a quarry adjacent to the Company's own. The bought-in limestone has been rejected as unsuitable for lime production but is of a quality suitable for production of cement. The primary crusher is equipped with a bag filter which also removes particulate matter from various other transfer points The crushed stone is stored in a covered store fitted with a bag filter.

Shale is quarried by ripping with a bulldozer from a quarry 300m south of the factory. It is hauled to a hammer mill at the factory in 20 tonne trucks on an unpaved road. Crushed shale is stored in a covered store. Sand is bought in from local suppliers and is stored in the same store as the shale. There are two closed circuit raw mills, one of Danish origin, the other German. A coal-fired furnace and a standby oil-fired heat generator are available for drying the ground material in the mills.

There are two kilns,

Kiln 1 is a FL Smidth kiln with a single-stage cyclone pre-heater;
Kiln 2 is a Polysius kiln with a four-stage single string cyclone pre-heater.

Both are fitted with electrostatic dust precipitators but that on kiln 2 was under-designed and is currently being replaced. Two coal mills are available for coal grinding, one for each kiln. Combustion energy requirements and production capacities are as follows.

Kiln 1	1100	Kcall	kg of clinker; 550 tonnes per day
Kiln 2	900	Kcall	kg of clinker; 500 tonnes per day

There are two open circuit cement mills, rated at 25 and 30 tonnes per hour respectively. Each is fitted with an electrostatic precipitator. The packing plant has two 12-spout rotary cement packers, two bulk loading and one rail loading facilities. There are two bag filters. Process water for cooling is obtained from the limestone quarry and from a "dambo" located midway between the factory and the City of Ndola.

Ndola Works requires the following quantities of raw materials at rated capacity:

Limestone	400,000	tonnes
Shale	63,000	
Sand	24,000	
Coal	55,000	
Electricity	$34x10^6$	KWh
Basic refractory bricks	390	tonnes
Non basic refractory bricks 114		
Gypsum	16,000	
Paper sacks	6,000,000	pieces

5.11.4 Environmental Impact

Occupational Health and Safety

The major health hazards in the factories are free silica (SIO^2) and iron oxide. Silica is present in cement as a compound. Inhaling finely-ground silica in its free crystalline state can cause silicosis, manifested by shortage of breath and rapid breathing. An acute form is usually identified after 18 months of massive exposure and becomes chronic pulmonary silicosis after about 15 years of exposure. Iron oxide is a chemical compound contained in cement It is classified as nuisance dust because it is not known to produce any toxic effect or disease on contact, though excessive concentrations in the air may cause skin irritations (dermatitis) or irritation to mucous membranes. It should be noted that skin irritation can also be caused by vigorous scrubbing in an effort to remove nuisance dust.

Native Fauna and Flora

The Chilanga area is covered with an open savannah woodland called Munga' - a vernacular word for thorn - with extensive grassy undergrowth. Munga consists of scattered or grouped trees up to 18m tall. The trees form a discontinuous canopy hence allowing an undergrowth of either bush or grass herbs. The dominant tree species are Acacia although Combretum and Terminalia species are also common, predominately on better drained, more elevated sites; Acacia are commoner on the more poorly drained areas, especially in river valleys. The grassy undergrowth in the area is dominated by grasses such as Hyperrenia Like any type of vegetation, the quality of Munga varies. Excessive burning and over-frequent cultivation reduce the level of canopy trees and shrubs so that it progressively degrades into savannah shrubs, suffrex savannah and finally grassland. However, in the RP3 area there is no evidence of massive pressure that could lead to degradation of vegetation.

Except for a few fauna species that are of economic or consumptive importance to man, most of the others that flourish in Munga woodlands exist in the RP3 area. Wildlife such as rodents, shrews and duikers are found. Observations in other parts of the Lusaka Munga woodlands have revealed the existence of cane rat , pygmy mouse, striped grass mouse, pouched mouse and creek rat. There are no strong reasons to suggest that such species are not present in the RP3 area. Other fauna found in the area include amphibians, reptiles and invertebrates, the latter including a wide diversity of insects that flourish in Munga woodland. Common bird species of Zambia have also been observed in Chilanga, including the fork tailed drongo, African golden oriole and eastern barred bush warbler. Many other species have also been observed but there is no evidence that the Chilanga area is important as a niche for rare species or as a significant staging area for migratory birds.

Despite the biological diversity of the Chilanga area, it does not deserve any special consideration for nature conservation because none or the fauna or flora species found in the area are unique or restricted in their distribution.

5.11.5 Legislative Framework

As yet, Zambia has no legislated environmental pollution limits. However, an Environmental Protection and Pollution Control Act was passed in 1990, under which an Environmental Council was to be established, charged with responsibility for setting pollution control standards for:

- Water
- Air
- Waste
- Pesticides and Toxic Substances
- Noise
- Ionising Radiation
- Natural resource Conservation

The Environment Council of Zambia has since been set up and has so far put in place regulations covering water pollution (1993), pesticides and toxic substances (1994). Some consultative meetings have taken place with industry (including the Company) regarding the establishment of regulations for air pollution and waste control. In the absence of enforceable pollution regulations, the Company, like almost all industry in Zambia, has operated over the years without written internal regulations. The Company is now putting in place measures to comply with current European standards, and preliminary work has been undertaken. It needs to be noted, however, that the Company's factories are both relatively old in comparison with European factories.

Over the years the public has developed a negative image of Chilanga Cement in relation to environmental issues because of particulate pollution of the atmosphere at both Ndola and Chilanga works. At Chilanga Works, the major complainant has been the Mount Makulu Agricultural Research Station which contends that the particulate emissions have had the effect of liming the soil, thereby producing test results which in most cases cannot be reproduced in the field. At Ndola, the general public and the City Council have complained about dust pollution of the city and residential areas, all of which are sited downwind of the factory.

	NEGATIVE EFFECTS	MITIGATING MEASURES
1	Siting of plant on or near sensitive habitats such as mangroves, estuaries, wetlands, coral reefs.	Ndola is located in wetland area but one which is legally designated as an industrial area. Chilanga Works has no problem in this regard but is in a growing human settlement area, something which was not true when the factory was first sited.
2	Siting along water courses causing their eventual degradation.	Ndola is sited along a water course but the process has no liquid discharge other than cooling water. Plans are under way to recirculate the water.
3	Siting can cause serious air pollution problems for local area.	Unfortunately the City of Ndola and Mount Makulu Research station are located down wind of Ndola and Chilanga works respectively.
4	Siting can aggravate solid waste problems in an area	(A) The plots sizes at both plants are large enough to accommodate disposal areas but fortunately not much waste is generated. • Both plants are conveniently located for contractors to collect and haul solid wastes for final disposal should need arise
DIRECT : PLANT OPERATION		
5	Water pollution from discharge of liquid effluents and process cooling water or runoff from waste pipes **Plant**; total suspended solids (TSS); total dissolved solids (TDS); temperature, pH. **Material Storage piles** runoff; TSS;pH	(B) At present, analysis of liquid effluent is limited to temperature and pH. Plans are afoot to include TDS, TSS, salts alkalinity, potassium, sulphates and hydrocarbons (for oil spills) (C) Discharge cooling water is recycled at Chilanga, at Ndola it is at ambient temperature. (D) No discharge of slurry tank wash or spills. (E) TSS <5 g/tonne of product. (F) TDS no greater than levels of water incoming to plant Apart from primary crushed limestone, and gypsum at Chilanga works, all other raw materials are stored under

6	Particulate emissions to the atmosphere from operations	Particulate emissions are collected by fabric filters and returned to the process. (G) Kiln emissions are controlled by electrostatic precipitators (with moisture conditioning only for kiln two at Ndola) Particulate emissions are controlled to the following levels on a dry basis; • ground level outside plant boundary, $80mg/m^3$ • stack discharge, $100mg/m^3$•
7	Particulate emissions from ground sources (fugitive dust), roads, stockpiles.	Control measures are; • road treatment by wetting • water treatment • frequent manual sweeping of roads and other surroundings • speed limits in the plant areas (set at 20 kph)
8	Gaseous emissions of SO_x to the atmosphere from fuel burning	Sulphur levels in the raw materials are not high enough to warrant additional control equipment. No kiln is equipped with a by-pass for alkaline materials. All materials discharged from the kilns are re-cycled. But exhaust gases are not utilised for drying raw materials in grinding.
9	Gaseous emissions of NO_x to the atmosphere from fuel burning	• All kilns are coal fired, resulting in reduced levels compared to many other fuels. The kilns at Ndola are equipped with cyclone preheaters (one single stage and the other four stage) which further reduce the incidence of NO_x • All waste fuels are analysed before use (including by outside laboratories), not only to control levels of NO_x but also to ensure that there are no other harmful emissions.
10	Air pollution during start up of the kiln (when the electrostatic precipitator is not available)	• Kiln start up procedures include the use of a diesel burner up to a temperature high enough to ensure spontaneous

11	Air pollution as a result of malfunction of the electrostatic precipitator.	All kiln precipitators have parallel chambers, which enable the use of one part if the other breaks down, kilns are shut down if the faulty chamber is not repairable within a time limit of 15 minutes.
12	Incomplete combustion of hazardous wastes or waste oils used as supplemental fuels can result in emissions of toxic air pollutants and metals such as lead, cadmium and arsenic.	• Care is always exercised to ensure that hazardous waste and waste oils are analysed by own laboratory as well as independent laboratories before acceptance as suitable waste fuel. In addition, no fuels are used which would adversely affect kiln stability and efficiency.
	Handling and storage of hazardous wastes pose risks to the community and the environment.	• No known hazardous waste fuel is taken in.
13	Surface runoff of constituents leached from kiln dust (alkalis) coal (iron oxides) and gypsum (sulphur) can pollute surface waters or percolate to ground waters.	• All raw material storage sheds are covered (except for coal, gypsum and primary crushed limestone at Chilanga works). Used mag-chrome refractory bricks are kept under shelter and used in situ for making castable. Chilanga now uses only chrome-free refractories. • Dyked areas are capable of containing 24 hour rainfall, thus avoiding spill-off and percolation to ground waters.
INDIRECT: PLANT OPERATION		
14	Occupational health effects on workers due to fugitive dust, materials handling or other process operations	Workers stationed in dusty areas undergo annual medical examinations for silicosis and other ailments. All workers are provided with suitable safety clothing. A safety officer, accountable to the works manager, heads a committee that reviews safety issues on a monthly basis. Safety training sessions are held quarterly.
15	Inadequate on-site storage can exacerbate solid waste problems.	There is virtually no solid waste or by-product from the manufacturing process at either plant.
16	Heavy trucks carrying materials to and from the factory can disrupt transit patterns, create noise and congestion and aggravate hazards to pedestrians.	• Haulage of raw material is limited to day time as much as possible at Chilanga works. Ndola works is located in an industrial area and noise pollution is not an issue to non-employees.

17	Mining of limestone can create conflict with other industries using the same resource and can aggravate erosion and/or sedimentation of water courses by uncontrolled or unrestricted operations.	• Quarrying of limestone is carefully controlled through a mining plan and limited to what is necessary for plant requirements. • Regular inspection by the Department of Mines is a statutory requirement which assists in checking any abuses. • De-commissioned quarries are sealed off and
		flooded with water, becoming sources of water for the factory and, to a lesser and controlled extent, for the local farming community.

Chapter Six

Site Investigations

6.1.0 SITE INVESTIGATION

6.1.1 Introduction

The case studies shown in this document are typical of quarries and mines that have simply evolved and although the studies are located in central Africa they remain typical of mines throughout the world that have been developed without the benefit of a business strategy, a workable quarry plan and often without suitable reserves.

Chilanga works was positioned because of the 'supposed' immediate location of vast reserves of limestone, unfortunately, it would seem that geologists failed to check for levels of magnesium. It was only after two kilns had been installed and a substantial financial investment made before a serious effort was made to locate suitable deposits of non dolomitic limestone. The first quarry was closed down after one years production because of high magnesia, and a survey was carried out to find a new source of rock. The distant location of the new source resulted in the plant being located some fourteen kilometres from the second quarry and ten from the third. A fourth quarry is soon to be developed fourteen kilometres from the plant.

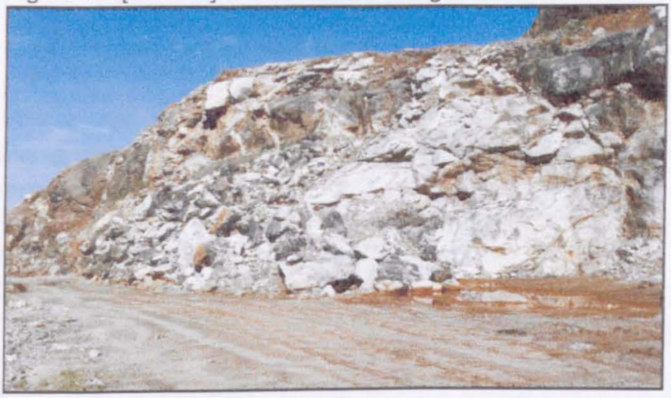
Ndola Lime works was located close to Ndola, where there were known huge deposits of limestone The first plant was installed with small vertical kilns and then subsequently equipped with a large capacity rotary kiln, later, the output from the works was supplemented by the installation of a large and more cost effective vertical kiln. However, it was soon found that the physical characteristics of most of the limestone was not suitable for use in the vertical kiln, this now leaves the company in a situation where to remain competitive it has to rely increasingly on the less fuel efficient and older rotary kiln.

Ndola cement works shares the same deposit as the lime works, but, more through good luck than planning or investigation, has a massive deposit of high quality material. The 'good luck' refers to this vast reserve being selected from the information gained from only five bore holes.

The limestone in the Malawi quarry is heavily contaminated by igneous intrusions and other geological faults and is probably the least attractive limestone deposit in Africa. As the cement industry developed from being solely a grinding facility for imported clinker, a decision was taken to select a local source of limestone and install a rotary kiln. Because of the poor rail and road network, transport is difficult in Malawi, therefore, it was deemed important to find a deposit of limestone close to the grinding facility in Blantyre and despite its poor quality the reserve at Zomba was considered to be the only feasible option.

The minimum requirement for establishing a modern cement factory is to have a reserve life of not less than thirty years and if possible, forty or more years. A modern plant, to be cost effective would have an output of one million tonnes of cement per annum and a rock requirement of double that.

Figure 6-1 [ref Mills] Mixed rock at Changalume



Generally, to establish a new plant or invest in a new upgraded kiln, a reserve of forty million tonnes of limestone would need to be established.

6.1.2 Preliminary Investigation

Desk study

This generally describes the search through records, maps and charts, papers, fly-over images and satellite data that relates to the site, and interpret as far as possible the geological conditions indicated by these sources.

The study of existing information, or "desk study" is generally the most cost effective part of any site investigation, and time spent here will often save money later on. An effective desk study will cost less than 5% of the total of an average site investigation. The first study will require searching for existing data, such as; topological, topographical, geographic, geological, geophysical, thematic, hydrological, hydro-geological and seismic maps of the area. Also details of any existing or previously operated mines and quarries, excavations and any other local knowledge which may be relevant. Information of stratigraphy and lithography may be obtained, possibly from previous mining research, details of which may have been deposited with the local authorities or from the local university.

Often, governments will have contracted to have areas of the country mapped by aerial or satellite photography, usually these can be made available and used to evaluate the topography, structure and lithography of an area. At this time, study of the local environment including rainfall, water tables, vegetation, fauna and habitation should be carried out. A more comprehensive hydrological survey can be completed later in the project. Interpretation of the data will, for a limited cost, provide sufficient information to enable a preliminary report to be prepared upon which, further investigations can be based. After these enquiries the site is visited to collate the data so far obtained, and to identify areas where engineering difficulties may exist and target areas where further investigations are needed.

Field investigation

For a simple quarrying operation the research will proceed through the following stages of investigation;

- survey and prospecting
- detailed exploration and evaluation
- assemble and analyse findings
- appraise mining prospects
- produce a preliminary mining plan
- quantify the reserve

Using information gained from the above investigations, the whole of the mineral deposit can be mapped and quantified. This information, when consolidated with expected rates of abstraction will give the life of the deposit and enable operations to be planned in detail. Restoration and aftercare of the site must be included from the outset into the main plan, this is particularly important if international investment is required. At this stage, a plan can be developed to conform to the environmental standards which are currently in force and consideration can be given to any expected or proposed legislation.

It is likely that the underwriters and investors will require an environmental audit which will use World Bank recommendations as the standard for compliance and customers will probably require suppliers to have an ISO 14000 accreditation. Armed with a detailed knowledge of the site and operation it is now possible to apply for planning permission and the various authorisations required to develop the mine.

6.1.3 Aerial Reconnaissance [ref 47 et al]

Unless the investigation is taking place in some previously unexplored part of the world it is almost certain that some kind of aerial reconnaissance has already taken place, probably by using one or more of the following satellites;

- Landsat Multispectoral Scanner (MSS)
- Landsat Thematic Mapper (TM)
- SPOT Multispectoral Scanner (SPOT-XS)
- SPOT Panchromatic (SPOT-P)
- European radar satellite (ERS -1)

In 1972 the National Aeronautics and Space Administration (NASA) launched the first of a series of Landsat satellites, two others were launched in 1975, and 1978, which began a program of remote sensing of earth-resource data. These satellites are located in a polar orbit which passes the illuminated area of the earth several times per day, moving westwards so that within 16 days, the whole of the earth is covered. A fourth Landsat satellite was launched in 1982 and a fifth in 1984. Radio communication with Landsat 6 was lost immediately following its launch in 1993.

With images covering up to 33,675 sq km, the more recent Landsat D series of satellites with their thematic mapper scanner use a new 2.2 micron infrared band that will scan and measure several different wavelengths and intensities of radiation simultaneously. The components are measured in both the visible and infra red frequencies and can detect the so called clay "alteration zones". These zones have been created by the decay of original rock into clay under the influence of mineralizing fluids and are often associated with mineral deposits.

The TM sensor is more useful for geology than is the MSS, this is because it produces images generated from seven specific wavebands in the electromagnetic spectrum with a resolution of between 30 and 120 metres. Each band represents a segment of the electromagnetic spectrum, which can be defined thus;

Band	**Micrometer**	**Spectral range**
B1	0.45 to 0.52	visible blue
B2	0.52 to 0.57	visible green
B3	0.63 to 0.69	visible red
B4	0.76 to 0.90	near infrared
B5	1.55 to 0.75	remote infrared
B6	10.8 to 12.5	thermal infrared
B	2.08 to 2.35	remote thermal infrared

The true colours of bands, B1 blue, B2 green and B3 red correspond to the natural colouring and can be used to distinguish between various rocks and soils, quotients between the colours can demonstrate hydyrophiles and carbonates (blue), iron (red) and green to vegetation. In areas covered with vegetation, plants growing on soil that is rich in calcium carbonate may suffer from a condition known as chlorosis that affects their chlorophyll content and therefore their colour (pale green or yellow). Aircraft will give better resolution than satellites and can use, radar, magnetic anomaly detectors, infra-red photography, polarised light photography and stereoscopic photography. They can also take air samples and the observer can be present at the time of data collection.

6.1.4 <u>Field reconnaissance (prospecting)</u>

This commences with a preliminary survey to confirm the basic geology of the proposed site and its surroundings, which is then followed by a detailed ground investigation study. Field reconnaissance takes place on two levels of both detail and cost, the preliminary investigation will at little cost involve the geologist in examining the topography in general and searching for the general character of the ground (a walk about survey). The geologist will use some or all of the following;

- walking the area to take hand samples
- evidence of ground water
- examining water samples
- panning in streams
- examining changes to flora
- taking soil samples
- examining air samples
- tracing boulders to their origin
- sketching the general site, with attention paid to exposed rocks
- marking on the sketch the dip and strike of outcrops
- taking chip samples
- examining the rock facies
- taking geochemical samples from streams and river-courses

From consideration of all the above, the geologist should be able to produce a quantitative description of the site.

Field tests for limestone and dolomite;

1 Alizarin red staining test

Rock samples are cut and a surface is ground flat with a suitable material, such as silicon carbide powder. The flat surface is etched lightly with dilute hydrochloric acid and immediately washed with distilled water. When dry the surface is painted with alizarin red dye. Proportions of calcite can be estimated by visual means such as point counting methods. For a rapid qualitative test the fresh rock surface can be dabbed with the dye after which, the calcite will stain red and the dolomite white.

2 Bromophenol blue staining test

The CaO to MgO ratio in a rock or mineral can be approximately determined with the aid of bromophenol blue in ethanolic dilute hydrochloric acid. In the presence of pure calcite it is orange. The transition point occurs at 10 to 14% MgO.

3 Hydrochloric acid

Calcite reacts with cold dilute hydrochloric acid (HCl), and the reaction is manifested by vigorous effervescence. (The dilution of the HCl usually used is about 90:10 [water:concentrated Hcl].) The effervescence is due to the spontaneous breakdown of the carbonic acid (H_2CO_3) to produce carbon dioxide gas, CO_2. Dolomite will have little reaction to cold dilute hydrochloride acid, and effervesces only when powdered and then with only a slow, smoldering action, but will readily dissolve when in contact with warm acid. This test is based on the fact that calcite

All the above may initially be used in areas of poor outcrop to further identify a resource. however, they will only provide a two dimensional view of what is a three dimensional situation. Surface investigation, would be ineffective in areas where there is a deep overburden such as exists in glacial or lateritic terrains, or where the target does not outcrop on the surface. Sub ground investigation, therefore, inevitably forms an essential part of the evaluation of any mineral project which may have economic potential.

6.1.5 <u>Sub ground investigation</u> [ref 47.63 et al]

The second level of investigation becomes much more expensive and will use one or more of the following;

- Seismic refraction; This was patented by Ludger Mintrop in 1919 and used by British Petroleum in 1928. It is relatively inexpensive, but at the same time not very accurate, it is usually used as the base system for further investigation with another more precise method of investigation. Refraction has limited application in limestone investigations. The system operates by measuring changes received by a geophone, to the frequency changes made to a low frequency seismic wave, when passing through various strata. The changes being caused by the differing absorbencies and reflectivity of various strata. The assumptions made are, the rock boundaries, the thickness of the layers, faulting and rock density. The ease or otherwise with which a rock can be ripped by a dozer is directly related to the seismic velocity of the material.

- Seismic reflection; This was developed by J.C. Karcher in 1920 and its use perfected by 1927. It is an expensive method but more accurate than refraction. The concept is similar to echo sounding, with seismic waves being reflected from rock boundaries and interpreted to give a reasonably accurate record of a deposit. Measuring the round trip time will give an accurate distance from the reflection. Changes in the amplitude and wave-shape often contain information about stratigraphic changes. In some cases, seismic patterns can be identified with depositional systems, unconformities, channels and other sub-terrain features. Seismic reflection gives good resolution and is most suitable for mapping larger deposits of coal, gas or oil which have good reflective surfaces.

Figure 6-2 [ref 63] Comparison of seismic methods

A comparison of Seismic methods of exploration		
	REFRACTION	REFLECTION
determining rock velocity	very good	good
rock thickness	very good	very good
geometry	weak	very good
geological complexity	poor	very good
cost	cheap	expensive

- Magnetic anomaly survey; This is the oldest of all the methods of prospecting. It is usually used for locating metallic and especially iron ores. Most magnetic surveys are made using proton precession or the more accurate optical-pumping magnetometers. These surveys are usually carried by aircraft equipped with a magnetometer flying in parallel lines at an elevation of 200 metres and 4 kilometres apart. Ground surveys will investigate any anomalies found from the air. This system is particularly useful for searching areas under the sea. Sedimentary rocks have very low susceptibility and thus are nearly transparent to magnetism because of this, magnetic anomaly, has little application, if any when exploring for limestone.

- Gravimetric anomaly; This is a method often used for locating structures which may be associated with oil, gas and water and it can successfully be used to detect high density ore bodies. The survey is usually carried out either from an aeroplane or a ship. The instrument is called a gravimeter and is designed to measure differences in gravity accelerations rather than absolute magnitudes, an accuracy of 0.01 milligal is normal (one milligal = acceleration of, 0.001 centimetre per second per second) It operates by measuring slight changes in the earths gravitational field and accuracies of changes of one hundred-millionth (100,000,000) of the earths total field can be measured. Although it can be used to distinguish the density of a rock mass it is not often used in limestone investigations, it is more often used for the exploration of petroleum. This method can detect caverns and old mine workings.

- Radiometric investigation; This records the intensity and spectral composition of gamma rays. It is used for locating radioactive minerals and the structural differences in granites and other basic rocks.

- Ground probing radar; This, although similar to other radars, operates at a low frequency of between 5 and 500 MHz and can penetrate into the ground. The energy loss is very high, but successful surveys can be carried out to depths of more than ten metres and reasonable detail of shallow deposits can be achieved with 2D profiling used to map shallow structures, locate voids or services.

- Electrical; There are many methods of this type of investigation, they are most effective in the search for metallic ores, the main methods are;

  - Self potential, where a mineral, usually a sulfide together with groundwater acts as a large electrical battery and produces a charge. The current from this charge can be measured and changes in value will indicate the size and concentration of the deposit.

  - Induced polarisation, where a field of electricity is induced into the earth by two electrodes. Mineralisation will cause changes to the charge which can be measured and mapped.

  - Electromagnetic, these survey techniques use a very low frequency radio signal to energise an area and sensitive coils detect changes in the reflections. This system can detect sulfide and other ore bodies.

  - Resistance and conductivity, this very effective and useful method works by the direct application of current in a straight line through an area to measure the resistance or ease of flow. The current can be applied through many directions to build information. It is usually used for measuring metallic ores and establishing water tables and is effective in establishing limestone deposits.

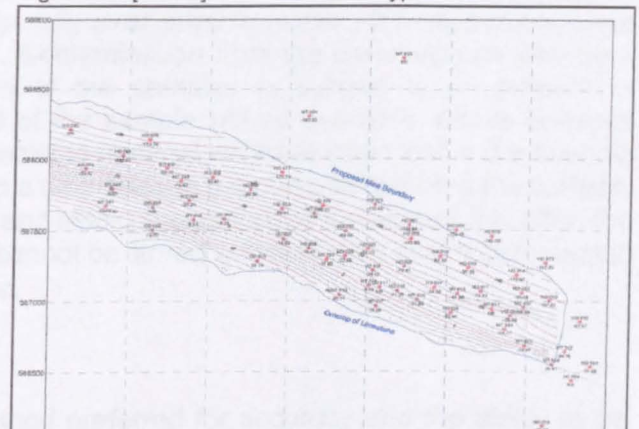
- Core drilling; This can be used when all the above methods have been considered and the most appropriate employed, core drilling will be employed to give a definitive record of the deposit.

For limestone investigations it is certain that the geologist will use one or more of the above as well as drilling, and as limestone cannot be penetrated with an auger, the drilling will be either core or reverse circulation. Drilling aims to verify targets delineated during exploration. Drilling also aims to reveal the overall geology of the deposit. Finally, drilling is also used to establish the concentration of any mineralization. The choice of drilling technique to be used is important as it involves a trade-off between cost and the quality of information required.

6.1.6 Detailed investigation [ref 13 et al]

The cost of most ground investigations is usually between 0.5% and 1.0% of the cost of the project. The principal purpose of ground investigation is to acquire geological and geotechnical data sufficient for the site to be described and its geological history reconstructed, particularly those events occurring during the last 10,000 years with an accuracy that can be relied upon by mining engineers. Ground investigations should never be limited to save money as ignorance of ground conditions will often cost greatly in the long run. After the desk study and a general exploration of the deposit, the geologist will certainly wish to drill a series of holes in order to obtain the most reliable knowledge of the structure and chemical composition of the deposit. Preliminary topographical investigations will have enabled accurate contour mapping of the surface to be made. Imposed upon the surface map will be a grid either based on a country basis or on local regime. All investigative drilling will be accurately positioned (collared) and coordinated within the grid system. Wedges can be placed in holes allowing deflections of up to 1.5 degrees from the original hole. This can be used to provide additional intersections through important geological formations.

Figure 6-3 [ref 94] Bore holes with typical coordinates



Examination of the core samples will enable an accurate contour map of the structure and mineralisation of the deposit to be computed. Other objectives are;

- To determine the character of the ground which is usually the most common reason for drilling.
- To identify diversity in the character of the ground at a specific depth.
- To enable a numerical analysis of the area in terms that are relevant for engineering design.
- To provide data for computerised sub surface mapping

Two methods of drilling are available, these are; reverse circulation and core drilling.

Reverse circulation drilling

Generally it can be said that reverse circulation will give a good indication of what lies beneath the surface. The cost of reverse circulation drilling in Zambia is about $25.00 per metre. Reverse circulation is a type of drilling similar to standard blast hole drilling and uses a similar type of drilling rig. With reverse circulation, the chippings from the drill head are washed to the surface and collected, these form the basis of the sample. As the chippings are not always fully evacuated from the drill hole, there is some mixing of the samples. Contamination from the borehole can also be a problem. Interpretation of the samples is subject to an amount of guesswork and not all of the sample will be available, this is because some of the fines and soluble material will have been lost in the flushing water and there is often a time delay in the material reaching the surface. Depending on the size and lithological nature of the deposit it is often the case that the samples cannot be stored with sufficient accuracy to enable them to be re-examined.

Core drilling

Core drilling is the method preferred for accuracy and the ability to be examined over time without (subject to storage) significant core deterioration, it enables the geologist to obtain a continuous intersection through the geological sequence with all the contact and textural relationships preserved. However, breaks in this continuity can occur when the cylinder of cut rock in the core barrel fractures from the bed rock and starts to rotate with the drill stem. Grinding then takes place resulting in the loss of core rock. With core drilling, the lithology can be precisely defined and the structure of the rock determined. Often, a client will specify that the core recovery and interpretation will be at least 95% accurate. The diameter of the core of a diamond drill can be varied so as to produce the optimum result depending on the characteristics of the rock being drilled. A large diameter core gives a better core recovery and also reduces sampling variance. Down-hole survey probes which provide data on surrounding rock normally require larger diameter drilling.

Figure 6-4 [ref Mills] Rotation unit of a core drill.

Core drilling rigs can be constructed to drill to thousands of metres. For limestone deposits, a capacity to drill to a depth of 100 metres is generally acceptable and the rigs are usually of very simple construction. The depth of 100 metres is dictated by two criteria, one is the cost of operating a relatively deep quarry and the second is the likelihood of the water table being closer to the surface than 100 metres. The rigs can be assembled in difficult conditions and in places with poor accessibility. The drill string is made up of three or six metre lengths of steel or aluminium tubes, less vibration is found with aluminium tubes, but the wear rate is greater. On the end of the tube is a barrel, these usually have a length of three metres. The end of the tube is fitted with a diamond or carbide encrusted annular bit. Thin wall of the bits require less torque than solid bits. [ref 13]

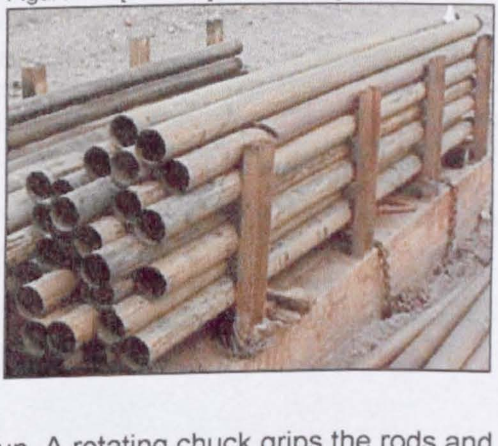
Figure 6-5 [ref Mills] Storage of core samples.

The drill string is identified as series 'X', wireline barrel 'Q', wire wall rods 'T' with;

Figure 6-6 [ref 13] Core drill sizes

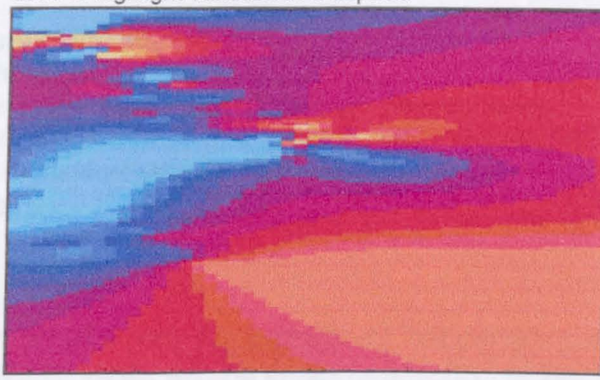
Code	Core size	Bit size	Hole size
EX	22.2	36.5	38.1
AX	29.4	46.8	47.6
BX	41.3	58.7	60.3
NX	54.0	74.6	76.2

Figure 6-7 [ref Mills] Core drilling tubes



The high rotation speeds of a core drill ensure that the drill bits are self sharpening. The drill string is supported by either a slide in a dedicated machine or a tripod in a more portable set up. A rotating chuck grips the rods and either weights or hydraulic rams produce down force. The drill bit cuts a circular core from the rock and fills a barrel which when full is brought to the surface and emptied, this requires stopping drilling and removing the whole of the drill string from the hole. In 1961 a method of removing cores was developed by using a system of wire and specially designed rods and barrels. Spring tangs (core springs) grip the core and prevent it from dropping down the hole. The tangs also give the operator a method of breaking the cores in place to reduce wear to the walls of the rods. Depending on the nature and size of the deposit, in an average mine investigation the bit would produce cores of between 45 and 75 mm. A standard investigation would require a minimum of 1,000 metres drilled whereas a detailed investigation would require up to and possibly more than 3,000 metres. It is almost impossible to drill a straight hole and drill deviation can become a problem in deep holes, a down the hole transponder will help locate the bottom of the hole. The cores are stored in boxes which have several compartments, these must be marked top and numbered to indicate at what depth the core was drilled. A sample drill log is given in Appendix B.

Figure 6-8 [ref Mills] This type of colour image is often used to highlight variation in a deposit.



The core can be sampled with great precision and exact geological associations can be determined. The sampling of core is done by splitting it using a diamond saw at right angles to produce two symmetrical sections, one half is returned to the box in case of further examination. Sample lengths are determined by the minimum weight of material required for analysis of mineral content. The cores are a valuable asset of any mining or exploration company. The material seldom becomes redundant. Cores therefore should be stored in such a way that markings and core boxes do not deteriorate. The cost of suitable storage is normally only a small amount of the cost of the original drilling. A core sample can, by using point crushing equipment, provide details of rock strength, this is vital for computing wall stability and crushing plant selection.

The sample may be subjected to a comprehensive suite of testing, such as;

- atomic absorption
- colourimetry
- compression
- crushing
- density
- fluorimetry
- emission spectrometry
- inductive coupled plasma

- X-ray fluorescence
- neutron activation analysis
- electron microprobe
- radiometric
- fire assaying

Information which should have been collated and documented is;

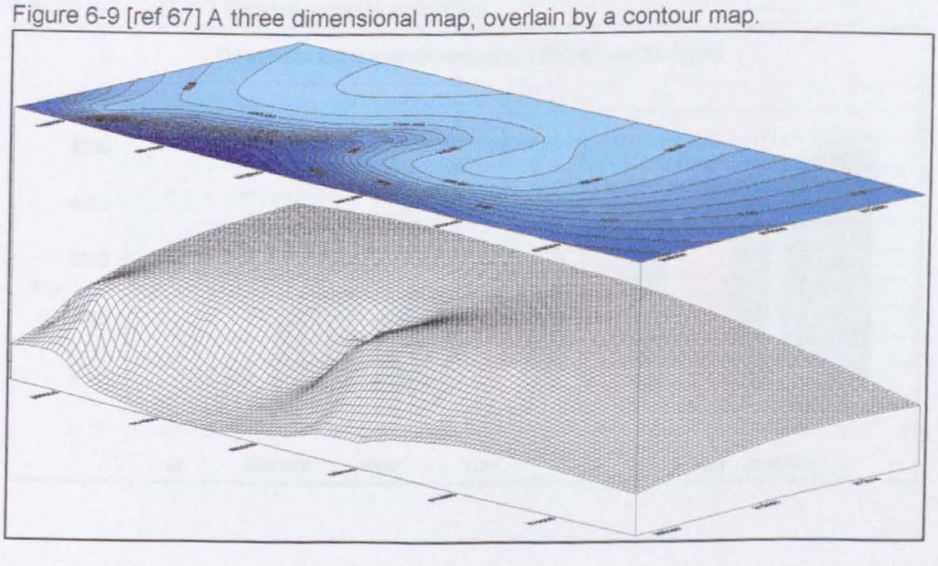
- geological structure of the deposit
- details of overburden
- structure ie, faults, folds, dip, strike, intrusions, Karstic areas
- strength, cohesion, angle of friction and other physical properties
- chemical data ie; qualitative detail
- mineralogical data
- hydro-geology
- hydrology

The drill hole itself can provide varying degrees of information, for example, studying phreatic surfaces, ground temperatures, permeability and geophysical detail. To supplement the core drilling it is normal to excavate a series of trenches, once this has been completed and the information from the core samples logged it will be possible to proceed with geological mapping.

6.1.7 Mapping

The first level of investigation should provide information on; faults and folds, the shape of the deposit, dip and strike and the general formation. The detail gained should be sufficient to enable some geological mapping to be carried out. Initial geological mapping, provides a representation of

Figure 6-9 [ref 67] A three dimensional map, overlain by a contour map.



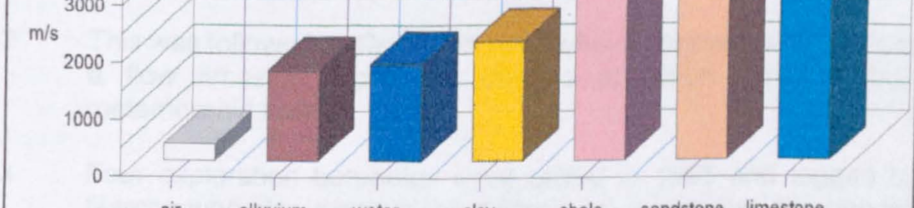
the area as suggested by rock exposures and other easily read signs, the scale of the map will be 1:500 with a height interval of one metre.

Using the above height intervals, together with a general map showing the area of the site it will be possible to arrive at preliminary gross volumes. A geological map of a site may be drawn to a scale of between 1:1000 and 1:100 it will show the contacts between the various rocks and give some indication as to the structure of the deposit and will give details of the engineering properties of the rock mass, in a limestone deposit it is very important to show the chemical variation within the deposit. Often of much use to the mining engineer is a cross section through an area, this will show the angle of dip. The following chart shows the various classifications for limestones.

Figure 6-10 [ref 63] Rock classification

Classification of calcareous and clayey materials		
$CaCo_3$ %	Clay minerals %	Nomenclature
100 to 95	0 to 5	high grade limestone
95 to 85	5 to 15	limestone
75 to 85	15 to 25	marly limestone
65 to 75	25 to 35	calcareous marl
35 to 65	35 to 65	marl
25 to 35	65 to 75	clayey marl
15 to 25	75 to 85	marly clay
5 to 15	85 to 95	clay
0 to 5	95 to 100	high grade clay

Figure 6-11 [ref 47] Typical seismic velocities



6.2.0 CHANGALUME [ref for all the following 1,2, 72, 85]

6.2.1 Introduction

This case study summarises the site investigations carried out on Changalume quarry, and is a typical example of a professional survey.

History

The cement industry in Malawi was established in 1956 with the construction of a clinker grinding plant at Blantyre using clinker imported from Zimbabwe. The identification of the limestone deposits at Changalume and increasing demand for cement resulted in the development of the Changalume reserve and in 1960 the construction was completed of a cement factory close to the deposit. The plan was to quarry limestone and produce cement clinker for grinding in Blantyre.

The original cement factory had used very old second hand equipment of indeterminate manufacture and had a planned capacity of 180 tonnes per day. In 1971 the process was expanded by the installation of a second more modern kiln with a capacity of 350 tonnes per day. The factory achieved its maximum production in 1979 with a throughput of 112,600 tonnes. Since that time, production has declined.

Changalume Quarry Location

Changalume quarry is located 15 degrees, twenty-three minutes south of the equator and 35 degrees, thirteen minutes east of Greenwich. The site is on the eastern escarpment of the Shire valley, approximately 20 kilometres west of Zomba. Access to the site can be made on good unpaved roads from the east and west through the village of Chingale, which is in the Shire valley (pronounced sheeri). A private railway line connects the cement factory to the main Malawi railway network.

Past Investigations

1 Many investigations have been made into this site, the first descriptions were given by Dixey in 1927 in the report, " The Limestone Resources of Nyasaland".

2 This was followed by Cooper in 1955 who described the deposit as a flow limestone, possibly due to migration from a deep metamorphic zone.

3 Four exploration boreholes were drilled in 1955 and logged by Garson who also mapped the deposit. He interpreted the deposit in his report titled "Flow Phenomena in a limestone on Changalume Hill" as an isoclinical fold generated by pressure from an easterly

direction and estimated the reserve at 135,000,000 tonnes.

4 Bloomfield referred to the deposit in 1965 in his, "Geology of the Zomba Area" and Charlsey in 1972 his "The Limestone Resources of Malawi" but they only reflected on the existing information.

5 Chatupa carried out a detailed programme in 1979 and made a detailed report, which was subsequently lost.

6 The Irish Cement Company investigated in 1983 and issued a report on The Reorganisation and Expansion Study for the Portland Cement Company.

7 Coopers and Lybrand reported on Malawi Cement Industries in 1984 and Lorenz produced "Rehabilitation of Portland Cement Company's Mobile Plant and Appertaining Arrangements" also in 1984.

8 In 1985, KHD Humboldt Wedag AG of Cologne Germany and Geotechnical Services Pvt from Harare Zimbabwe were contracted by the European Investment Bank to provide a detailed assessment of the economic reserve.

The following pages are a transcription of the site investigation carried out by KHD, the document has been reduced to be an example only.

6.2.2 Site investigation

The Changalume limestone deposit has been exploited for limestone since 1960 for the production of cement clinker in the Changalume cement plant of Portland Cement Company (1974) Ltd. (PCC).

(1) The duties of Geotechnical Services (1980) (P.v.T.) Ltd., Harare/Zimbabwe (GTS), acting as the contractor of the project, comprised the execution of topographic mapping, of geological mapping, rotary core drilling, core logging and sampling.

(2) The duties of KHD HUMBOLDT WEDAG AG, Cologne,F.R.G by virtue the consultant of the project, comprised the supervision and evaluation of the work carried out by the contractor, the compilation of all results in a report, which had t6 deal furthermore with the mining method and equipment, investment and production costs and the possible treatment of the limestone. The fieldwork in Malawi was executed between Jan. 9th and June 22nd 1985.

The authors would like to thank the staff of Portland Cement Company in Changalume and in Blantyre for their helpful support and their exemplary cooperation during the time of the site investigation in Malawi

which will be ever kept in mind as a enjoyable experience. The authors also acknowledge the quality of the topographical work and the rotary core drilling carried out by the contractor Geotechnical Services.

Previous investigations

Examining the existing literature showed that only limited geological work was performed previously on the Changalume limestone deposit. First descriptions were given by DIXEY (1927). COOPER (1955) described the limestone as a 'flow-limestone', possible due to migration from a deep metamorphic zone.

Four exploration boreholes were drilled in 1955 and logged by GARSON (1955) who also mapped the deposit first. He interpreted the Changalume limestone deposit as a isoclinal fold generated by pressure from easterly direction. GARSON estimated the limestone reserves at 135 mio t. Subsequent quarry operation have indicated that this figure is much to high. Younger publications by BLOOMFIELD (1965) and CHARSLEY (1972) only referred to the existing literature, that means that no further geological investigation on the Changalume limestone deposit was conducted. J.P.CHATUPA, Chief Geologist of the Geologist of the Geological Survey of Malawi proposed in 1979 to carry out a detailed exploration program on the Changalume limestone deposit and to evaluate the quantity and quality of the limestone. Unfortunately this report and its detailed program was not made available to the authors of this report.

More recent work was carried out by the IRISH CEMENT CONSULTANCY SERVICES (1983), COOPERS & LYBRAND ASSOCIATES (1984) and K. LORENZ (1984). Their reports deal with the possibilities of reorganisation and expansion of the plant, the economic situation of the Malawian cement industry and the situation of the mobile equipment of the Changalume quarry.

Topographical mapping

Based on aerial photographs taken in November 1984 topographical maps were produced to a scale of 1 : 1000 and 1 : 5000 covering an area of 200 ha and 720 ha respectively. Four copies of sepia prints and three copies of blue prints from the maps of each scale were handed over to Portland Cement Company (1974) Ltd. in May 1985 respectively in June 1985 during the consultants stay in Malawi. The map to a scale 1:1000 consist of three sheets, the map to a scale 1 : 5000 consists of one sheet.

Geological mapping

An area of 110 ha including the existing quarry' and its immediate vicinity were geologically mapped to a scale of 1:1000. 720 ha of the surrounding area of the limestone deposit were mapped to a scale of 1 : 5000. From both the 1:000 and 1: 000 geological mapping preliminary reports were handed over to Portland Cement Company (1974) Ltd. during the consultants stay in Malawi.

Trenching and bush clearing

Due to overburden cover in the northern part of the limestone deposit and dense vegetation geological mapping to a scale of 1: 1000 had to be supported by trenching work and bush clearing carried out on lines which run perpendicular to the general strike of the deposit. Trenching work was concentrated on the northern part of the deposit where it is not exposed by quarrying in order to outline the surface limits of the deposit. A total of approximately 350 m of trenches were excavated. A total of 3728 m of bush clearing on lines had to be carried out due to dense vegetation covering the unexploited parts of the deposit in its southern and northern part as well as on some marble lenses in the vicinity of the main deposit. Subsequently these lines were geologically mapped.

Rotary core drilling

In the time from January 19th, until June 4th, 1985 18 boreholes were drilled totalling 1914.53 m. From January 13th, to February 26th, 1985 two drilling rigs were on site, a Tone and a Sullivan mk22 On February 27th the contractor had to supply a third drilling rig due to low drilling progress. Out of the total meterage the Tone rig drilled 748.66m, the first Sullivan 22 513.34 m and the second Sullivan 22 652.53 m.

The average drilling progress over the period from January 13th to June 4th, 1985 was 4.99 m/day per rig. The average core recovery was 96.8 %, very satisfactory. It was drilled with NX diameter (approx. 60 mm core diameter). After completion of each borehole its coordinates were surveyed.

Core logging, sampling and sample preparation

The drill cores were carefully logged for their lithology and structure such as fractures, joints, foliaton and contact of rocks where it was possible. A total of 252 core samples were taken only from limestone sections of the core. Due to the irregular distribution of the xenoliths the sample sections of the limestone were of different lengths but they did not exceed 6 m. Also the samples were taken accordingly to their macroscopic quality, e.g. sections of narrow spaced contaminated limestone with xenoliths smaller than 10 cm were sampled separately from those which were not contaminated.

Nine hand specimens of limestone were taken from various parts of the quarry for chemical analyses:

- 1 from the SE hill slope
- 3 from the area which is used as stockpile for primary crushed limestone
- 2 from the quarry workshop area
- 1 from bench no. 2
- 1 from bench no. 3
- 1 from bench no. 9.

- 11 hand specimens were taken from xenoliths within the limestone deposit:
- 6 samples of gneiss xenoliths from the benches 8, 5, 2 and 1
- 3 samples of syenite xenoliths from the benches 8, 5 and 2
- 2 samples of volcanic dykes from the benches 9 and 1.

A total of 7 samples were taken from the two "shale" deposits which supply Changalume factory with iron containing clay as an additive for the rawmix for cement clinker burning: 5 samples we-re taken from the Namadidi shale deposit situated near the small village of Namadidi and 2 were taken from the "Railway shale" deposit which is situated near the coal storing shed at the clinker loading facilities of the Changalume cement clinker plant. 12 chip samples were taken from a percussion drillhole sunk on bench no. 9. A total of 5 samples were taken from the fraction < 2.5 cm of the primary crusher in order to test their quality for clinker burning or for blending with high grade limestone. Thus a total of 296 samples were taken for chemical analyses. The core samples were split into half using a diamond saw. The split core samples and the hand specimens were crushed in a laboratory crusher and ground for chemical analysis. The sample preparation was carried out on Portland Cement Company's sawing, lab crushing and grinding facilities.

Chemical analyses

279 samples were chemically analyzed in the laboratories of Portland Cement Company in Changalume for CaO, MgO, SiO^{2}, $Al^{2}0^{3}$, $Fe^{2}0^{3}$, SO^{3}, L.O.I. and the limestone samples also for total carbonates. Fifty-five samples were analysed in the laboratories of KHD HUMBOLDT WEDAG AG for CaO, MgO, SiO^{2}, $Al^{2}0^{3}$, $Fe^{2}0^{3}$, $K^{2}0$, $Na^{2}0$, SO^{3} and L.O.I.. 38 of these were check analyses.

Evaluation of the quarry operation

From April 24th to May 8th 1985 the KHD mining engineer investigated the limestone quarry of the Changalume cement factory for collecting first hand information concerning the quarry layout, access and hauling roads, waste piles, blasting technics, mobile equipment, machinery, raw material processing, labour and costs.

Location and access

The village of Changalume and the properties of the Changalume limestone quarry and the cement factory of Portland Cement Company are situated at the eastern Rift Valley escarpment some 12 to 15 km west of Zornba at approximately 15 23' south and 35 13' east. Access from the east to the quarry and to the cement factory is provided by a gravel road coming from Zombi Another gravel road connects Changalume with the highway from Blantyre to Lilongwe. From the west Changalume can be approached via the village of Chingale situated in the Rift Valley. The cement clinker produced in the Changalume factory taken to the clinker mill at Blantyre for grinding a ad adding gypsum. The transport is effected by a company owned railway line which is connected with the main railway line running from Blantyre to Balaka.

Climate and vegetation

Dry season lasts from April to October. The general rainfall pattern in the Changalume area for the first rains to fall any time after mid October and from then to continue to about the end of March with frequent dry spells of a week or more occurring in early February. The average maximum temperature ~is between 25 C and 30 C whilst the average minimum temperature range between 12 C and 20 C. Heavy mists are common on the high ground during the wet season.

The clay soil of the area support good stands of trees like Colophospermum Combretum and Acacja tree species. On the lower slopes of the escarpment, Acacia, Combretum, Dornbeya, Flcus and Kirkea species may be encountered. Thick bamboo brake is also developed in this area as well as Brachystegia bush. The higher ground is characterized by grassland with occasional Protea scrub and the occasional Cussonja.

Streams flowing down the escarpment and valleys are thickly lined with evergreen trees such as Khaya Nyasica and Ficus Capewsis. Rock outcrops on the higher ground are conspicuous with huge Ficus Natalensis trees. Large areas have been deforested to make way for agricultural activities of which maize production is the most common in this area. In the lower lying valleys vegetable production is carried out to a large extent.

Topography and Drainage

As a working basis for the site investigations graphical survey of 200 ha to a scale of 1:1000 has been carried out covering the limestone and its immediate vicinity. Additionally, an area of 720 ha of the surrounding area especially the northern extension of the quarry has been mapped to a scale of 1:5000. The following description of the topography is based on the 1:5 000 topographical map. The area under consideration is of fairly strong relief with variations in altitude ranging from 685 m to 1175 m above mean sea level and can be subdivided into several distinct physiographic areas:

The westernmost part of the map is occupied by the Shire plains which is part of the Rift Valley. The elevations on the mapped area vary between 685 m and 750m above m.s.l. In this area the cement factory Portland Cement Company is situated. To the east and northeast the relief rises to the Shire Highlands forming the spectacular Rift Valley escarpment. Changalume Hill situated on this escarpment forms a prominent topographical feature. Running in NNE—SSW direction it has been subjected intense limestone quarry operations. Its maximum elevation is 1082 m above m.s.l. in the northern part Changalume Hill and its geology will be discussed in detail in chapter C. 3. Separated by the deep valley of the Nkalote Stream extends to its east and northeast the high plain of the Shire Highlands with elevations between 1000 m and 1175 m above m.s.l.

The principal drainage feature of the area is the Rift Valley. Numerous small streams and creeks are draining the escarpment in a dendritic drainage pattern directly into the Rift Valley. The Nkalote stream draining the southeastern side of Changalume Hill and the adjacent parts of the Shire Highlands in the southeast of the mapped area flows in southwesterly direction before it swings to join the Linthipe River in the Rift Valley. A notable drainage feature on site is a small horse back ridge on which the main gate to Changalume quarry is situated. The ridge forms a local water shed between the Nkalote stream in the south and wide valley in the northeast of the mapped area. In most cases the drainage pattern is directly related to the structural pattern, being controlled by major faults, such as the Nkalote fault. Most of the streams on the western escarpment area run down valleys which are oriented perpendicularly to the mayor rift valley.

Interpretation of the drilling results

Mapping and drilling revealed a highly complicate configuration of the limestone deposit with respect its structure. The initial drilling programme was planned on the basis of the geological mapping that revealed a steep dip of 80 to 90 degrees preferable to the east along the eastern side and to the west along the western side of the deposit. The first two boreholes sunk to explore the western contact (boreholes 2 and 4) showed that the steep westerly dip which was mapped on the surface dol not continue to depth but turns to an easterly direction of less than 60 . Consequently the initial drilling programme had to be modified. Initially it w planned to drill inclined holes from outside of the marble body into the western contact to encounter it an assumed level. On the new assumption that the western contact of the marble body dips moderately the east vertically and westerly inclined holes we drilled from inside the marble body in order to explore the western contact (boreholes 8, 15 and 18 in the southern area, boreholes 5, 6, 9, 11, 12, 13, 14 a 17 in the central area). Boreholes 1, 6 and 7 were drilled to establish the eastern contact in the central area and boreholes 3 and 10 were drilled in the northern area to establish both the eastern and western contact. Since in most cases it was not possible to determine the dip of the contact between marble and gneiss directly from the drill holes the dip was reconstructed from two boreholes or from one borehole and the mapped contact at the surface between marble and surrounding country rock.

Southern area

In the southern area the eastern contact could be mapped at the foot of the bill down to a level of 895 in above m.s.1. rising to 970 in above m.s.l. near the southern wall of bench no. 1. Due to inaccessibility for drilling rigs on the southeastern hill slopes, with slope angles up to 45 degrees the dip of the eastern contact could not be determined from boreholes. Based on the results of BH 1, BH 18 and geological mapping the dip of the eastern contact between sections Q — Q' and W — WI was interpreted to be vertically respectively steeply to the east. This conservative interpretation was chosen as a realistic presumption for the reserve estimation. Boreholes 15 and 18are the southernmost holes and were drilled in the area which is used as limestone stockpile. They were started in marble. Borehole 15 passed through the contact to the gneisses at 56,54 m corresponding with 871 m above m.s.l. Borehole 18 passed through the contact to the gneisses at 103,40 m corresponding with 852 m above m.s.l. Between these two holes the dip of the western contact, in this case it is better to say: the footwall contact is approximately 20° to the east. The footwall contact in this area is definitely a faulted contact with a rnylonitic zone of 10 m to 15 m in thickness. This mylonitic zone is characterized by frequent open and healed fractures and brecciation of the minerals. Mylonitization has affected both marble and underlying gneisses.

Borehole 8 (annex no. C—26) started in gneiss and encountered marble after 11.35 m corresponding with 915 in above m.s.l. It passed through the contact to the gneisses after 75.0 m corresponding with 864 m above m.s.l. The dip of the (western) footwall contact is approximately 30 to the east. Also in borehole 8 a, 2 m to 3 m thick mylonitic zone shows that the contact was faulted.

Central area

In the central area a total of 8 boreholes were sunk to establish the lower (western) footwall contact of the deposit. Seven of them started in marble (boreholes no. 5, 9, 11, 12, 13, 14 and 17) and one in gneiss from the eastern side (borehole no. 6).

Boreholes no. 1, 6 and 7 were sunk starting in gneiss to establish the eastern contact. The three boreholes on the eastern side proved the eastern contact to dip at high angles of 83 to 90to the east Boreholes no. 1 and 9 are on the same section. Borehole no. 1 encountered the marble body after 54.33 corresponding with 910 m above m.s.l. The marble was not passed through completely and borehole no 1. was stopped after 126.08 m corresponding with 864 above m.s.l. Borehole no. 9 started in marble and passed through it after 69.99 m corresponding with 861 in above m.s.l.. The dip of the western contact was determined to be 55 degrees to the east. No mylonitic zone were encountered. Boreholes no. 6 and 17 are on the same section. Borehole no. 6 started in gneiss and hit the marble body on the eastern side after 79.92m corresponding with 900m in above ms.l, it passed through the footwall (=western) contact after 118.44m corresponding with 860 m above m.s.l.. Borehole 11 intersected marble until 44.70m in corresponding with 932 m above m.s.l. Between these two holes the dip of the western contact is 45 degrees to the east. Again the western contact clearly faulted showing a mylonitic zone.

Boreholes no. 5 and 11 are on the same section and began both in limestone. Borehole no. 5 intersected the marble from the surface until 53.93m in corresponding with 940 m above m.s.l. Borehole no. 11 passed through the footwall contact of the marble at 39.18m in corresponding with 967m in above m.s.l.. The dip of the western contact is 45 degrees resulting from these two holes. A mylonitic zone showing faulted contact is clearly developed in the underlying gneiss. Boreholes no. 7 and 14 are on the same section. Borehole no. 7 encountered the eastern contact of the marble body after 79.95 m corresponding with 920 m above m.s.l.. From 112.21 m to 135.33m drilling depth a big xenolith inclusion WI intersected. The eastern contact is also faulted but not mylonitized. The dip is 83 degrees to the east. The borehole stood at its bottom still in the marble bod Borehole no. 14 passed through the footwall and contacted the marble body at 15.90 m corresponding with 1000 above m.s.l.

From section K northwards to section H to J western footwall contact along the western side of the deposit is nearly horizontal or it dips at very low angles to the east before it steepens to angles around 70 degrees to the east and running almost parallel to the eastern contact. This is also shown in boreholes no. 12, 13, 16 which are on the same section. The vertical borehole no. 12 passed through the footwall contact the marble at 23.37 m corresponding with 1030 m about m.s.1. Borehole no.13 intersected the marble/gneiss contact at 24.82 m corresponding with 1036 m about m.s.l. Borehole no. 16 was drilled almost parallel to the western contact and terminated after 126.55m in the eastern contaminated zone still in marble.

Northern area

In the northern area two boreholes no. 3 and 10 were drilled from outside of the marble body in a western direction penetrating both the eastern and the western contact. After 13.60 m of overburden borehole no. 3 encountered the marble down to a drilling depth of 91.30m corresponding with 977 m above m.s.l. The dip at the eastern contact was determined at 360 degrees. The dip of the western contact is 55 degrees to the east.

Borehole no.10 started at the edge of the limestone deposit in marble. From 6.41 m to 31.64 m drilling depth a big gneiss xenolith was encountered . The footwall contact of the marble body was intersected at a drilling depth of 85.68 m corresponding with 937m above m.s.l.. The dip of the eastern boundary could not be exactly calculated and it was estimated to be 48 degrees to the east. The dip of the western contact is 72 degrees to the east.

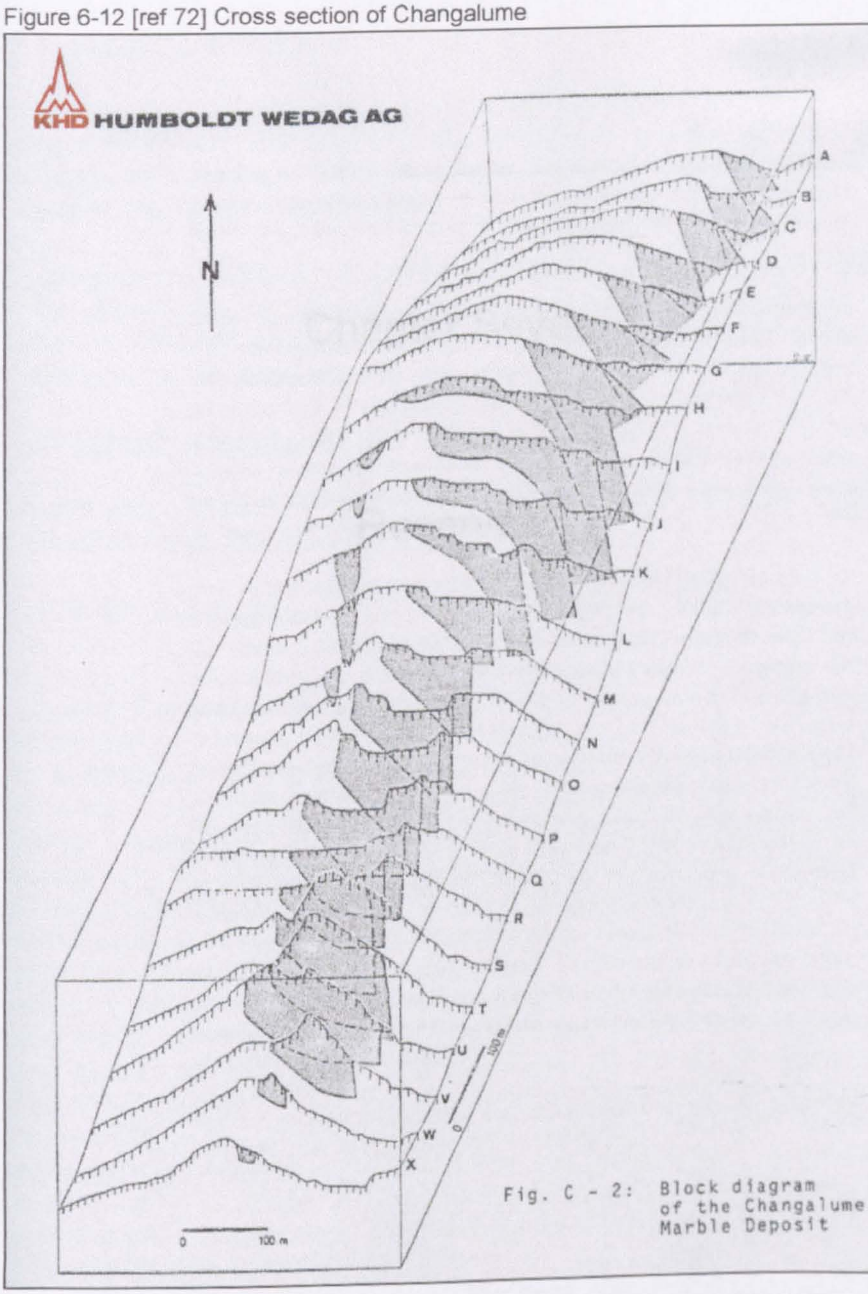
Conclusions for the configuration of the deposit

The evaluation of the drilling and mapping results gave a highly complicated configuration of the deposit which is principally caused by the changing dip of the western contact. For better illustration a 3 dimensional block diagram of the deposit was drawn and is shown opposite. The eastern contact of the marble dips constantly steeply to the east, only in the northernmost section (A to G) the dip is more moderate to the east.

The western contact in the southern sections (P to dips at the surface steeply to the west before it is cut by a fault. This fault is strongly rnylonitized and forms the geological footwall boundary of the marble body to the depth with a dip between 200 to 300 to the east. Also in the central part of the deposit (sections K to 0) the western contact is cut by a mylonitized fault featuring a wedge—like shape of the marble body in this part of the deposit.

The picture of the marble body as originally given by GARSON (1955) was that of an isoclinal fold. However, no evidence for this hypothesis could be found neither by structural elements nor by stratigraphic succession within the marble body. Our interpretation of the structure of Changalume Hill is that the main marble body forms the eastern limb of an anticline which is preserved only in the area of section H. Remnants of the western limb still exist in the marble lens which was found in surface outcrops running parallel to the main marble body. To the north/west the climax of the anticline and most of the western limb was subjected to erosion. In the southern part of Changalume Hill no evidence of the western limb was found. At the southern end the thickness of the marble body is reduced to approximately 10 to 20 m. At the north end, the marble body continues for approximately 250m but with substantially decreasing thickness of less than 30m.

Figure 6-12 [ref 72] Cross section of Changalume



The next investigation of the deposit was made by Anglo-Alpha Technical Services in 1995. Geotechnical Services drilled 21 core holes reaching a total of 1,218 metres, the drill size was NX. This examination used XRF spectrometry to analyse the core samples

Chapter Seven

Reserves

7.1.0 RESERVES

7.1.1 Introduction

The globalization of mineral exploration and extraction has shown that a problem exists with the reporting standards and definitions for mineral resources and reserves, particularly when a figure is required to raise finance or equity in a mining project.

The provision of an International Standard, using consistent terminology for the classification of mineral reserves and resources will reduce this confusion. This will also reduce the perception of risk associated with doubtful claims for reserves.

7.1.2 Classification of reserve

The following Council of Mining and Metallurgical Institutions (CMMI) classification is probably as good as any. [ref 6]

1. A Mineral reserve

A Mineral Reserve is that minable part of a Measured or Indicated Mineral Resource, inclusive of diluting materials and allowing for losses which may occur when the material is removed from the deposit and delivered to the next processing stage, on which appropriate assessments have been carried out, including consideration of and modification by mining, metallurgical, economic, marketing, legal, environmental, social and governmental factors, to demonstrate at the time of reporting that it could justify extraction under realistically assumed technical and economic conditions.

Mineral Reserves are subdivided in order of

2. A Mineral Resource

A Mineral Resource is an in-situ concentration or occurrence of material of intrinsic interest in or on the earth's crust in such form and quality that there are reasonable prospects for economic extraction. Portions of a deposit that do not have reasonable prospects for eventual economic extraction should not be included in a Mineral Resource.

The location, quantity, grade/quality, geological characteristics and continuity of a Mineral Resource are known, estimated or interpreted from specific geological evidence and knowledge. Mineral Resources are subdivided, in order of increasing geological confidence, into inferred and measured categories.

2a. Measured Mineral Resource

Is that portion of a mineral resource for which has been explored, sampled and tested through appropriate exploration techniques at locations such as outcrops, trenches, pits, workings and drill holes which are spaced closely enough to increasing geological, technical and economic confidence into Probable Mineral Reserves and Proven Mineral Reserves.

The feasibility of the specified mining and production practice must have been demonstrated or can be reasonably assumed on the basis of test measurements and studies.

The term "Mineral Reserve" need not necessarily signify that extraction facilities are in place or operative or that all governmental approvals have been received provided that there are reasonable expectations of such approval.

The term 'economic' implies that extraction from the Mineral Resource is viable and justifiable under defined investment assumptions and has been established or analytically demonstrated.

1a. A Proved Mineral Reserve

A Proved Mineral Reserve is that part of a Measured Mineral Resource, inclusive of dilution minerals and allowing for losses which may occur when the material is removed from the deposit and delivered to the next processing stage, on which appropriate assessments have been carried out, including consideration of and modification by mining, confirm geological and grade/quality continuity and from which collection of detailed reliable data allows tonnage/volume, densities, shape, physical characteristics, quality and mineral content to be estimated with a high level of confidence.

This category requires a high level of confidence in, and understanding of, the geology and controls of the concentration or occurrence. Confidence in the estimate of a Measured Mineral Resource is sufficient to allow the adequate application of technical, economic and financial parameters and enable an evaluation of economic viability.

2b. An Indicated Mineral Resource

Is that portion of a Mineral Resource which has been explored, sampled, tested through appropriate exploration techniques at locations such as outcrops, trenches, pits, workings and drill holes which are too widely spaced or inappropriately spaced to confirm geological and grade/quality continuity but which are spaced closely enough to be able to assume geological and grade/quality continuity and from which collection of reliable data allows tonnage/volume, densities, shape, physical characteristics, quality and mineral content to be estimated with a reasonable, but not high level of confidence.

An Indicated Mineral Resource is estimated with a lower level of confidence than for a Measured Mineral Resource, but with a higher level of confidence than for an Inferred Mineral Resource. Confidence in the same estimate of an Indicated Mineral Resource is sufficient to allow the adequate application of technical, economic and financial parameters and to enable an evaluation of metallurgical, economic, marketing, legal, environmental, social and governmental factors, to justify extraction under realistically assumed technical and economic conditions.

1b. A Probable mineral reserve

A Probable Mineral Reserve is that minable part of a Measured and/or Indicated Mineral Resource, inclusive of diluting minerals and allowing for losses which may occur when the material is removed from the deposit and delivered to the next processing stage, on which appropriate assessments have been carried out, including consideration of and modification by mining, metallurgical, economic, marketing, legal, environmental, social and governmental factors, to demonstrate at the time of reporting that it could justify extraction under realistically assumed technical and economic conditions

A Probable Mineral Reserve has a lower level of confidence than a Proved Mineral Reserve because of a lower level of confidence in the geological or modifying factors stated above.

economic viability.

2c An Inferred Mineral Resource

An Inferred Resource is that part of a Mineral Resource inferred from the geological evidence and with assumed, but not verified, continuity where information gathered through appropriate exploration techniques from locations such as outcrops, trenches, pits, workings and drill holes is limited or of uncertain quality and reliability, but on the basis of which tonnage/volume, quality and mineral content can be estimated with a low level of confidence.

The level of confidence associated with an Inferred Mineral resource is lower than that for an Indicated Mineral Resource.

This category is intended to cover situations where a mineral concentration or occurrence has been identified and limited measurement and sampling completed, but where data are insufficient to allow the geological and grade/quality continuity to be confidently interpreted. It should not necessarily be assumed that all or part of an Inferred Mineral Resource will be upgraded to an Indicated or Measured Mineral Resource by continued exploration.

Because of the low level of confidence in this category, in reporting of Inferred Mineral Resources they must not be combined with Measured Mineral Resources and Indicated Mineral Resources, but must be shown separately.

Confidence in the estimate of Inferred Mineral Resources is not sufficient to allow the adequate application of technical, economic and financial parameters or to enable an evaluation of economic viability.

3 Mineral potential

Mineral potential describes a body of rock or mineralization or other material or an area for which evidence exists to suggest that it is worthy of investigation but to which volume, tonnage or grade shall not be assigned.

Costings

A resource becomes a reserve when it is economically recoverable. Although the methods for identification of costs for the purposes of resource estimation are similar from country to country there are currently some differences. The writer has concluded that these differences do not significantly alter the comparability of the resource. Generally all reserves and resources can be identified, delineated and limestone recovered within given cost ranges. All forward costs of production include the direct costs of quarrying, processing and associated environmental and waste management costs, in association with maintaining existing production facilities and providing further facilities, together with an acceptable rate of return on invested capital as well as variable costs such as taxes and royalties where appropriate.

Past exploration costs have not been taken into consideration but future exploration and development costs associated with the conversion of mineral resources into mineral reserves is a main factor. As identified above a measured mineral resource is distinct from an inferred mineral resource, due to the lower degree of confidence that can be placed on estimated amounts. Where costs of extraction are deemed to be too high, there is less assurance that these will ever be exploited. Those resources that are most likely to be converted to reserves are where the costs of exploitation are lowest and are referred to as principle resource categories.

In this document production capability refers to the estimate of the maximum rate of production (output) that can be achieved from specified production facilities (plant and machinery) and the resources attributed to them (finance and labour). The term "production capacity" refers to the nominal level of output that can be achieved based on the design of production facilities.

Once a resource has been identified, its transfer to reserve capacity does not remain static as factors can either increase or decrease the likelihood of it ever being worked. Such short term factors that will increase the possibility that a reserve will be worked are, a rise in prices and improved technology. The factors that will result in a reserve remaining a resource are, inflation, increasing taxation, finance rates, increased transport costs and power prices.

The long term factors determining exploitation of a reserve are;

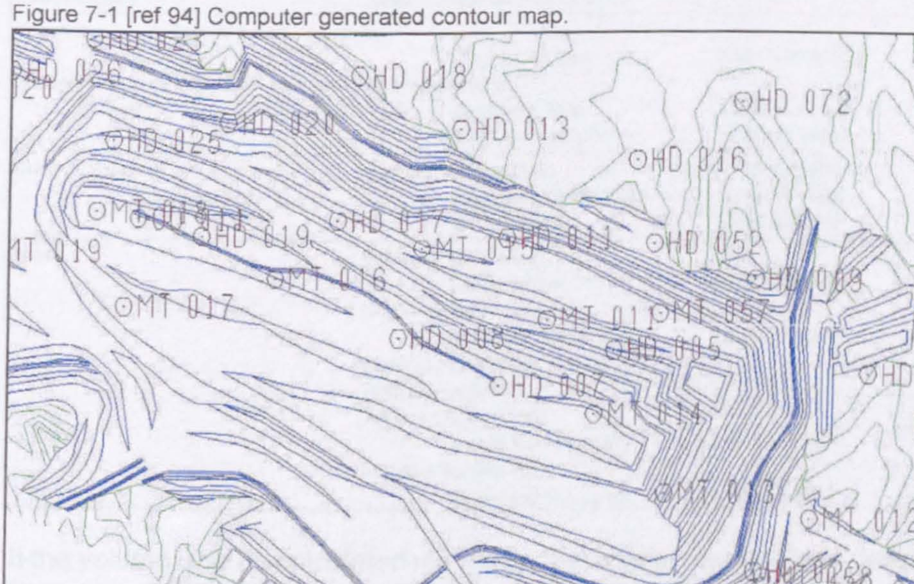
- Volume of deposit
- Grade of mineral
- Depth of overburden
- Accessibility
- Distance from market
- Cost and availability of finance
- Cost and availability of labour
- Cost of fuel and power and availability
- World demand
- Environmental compatibility

7.2.0 METHODS and ASSESSMENT OF RESOURCES

7.2.1 Volumetric calculations (Gross)

It is most important to ensure that the calculations are entirely accurate and can be used as a basis for raising finance for it is normal that when raising capital funding for a new project, experts appointed by a bank will argue the numbers. Generally a bank will insist upon accuracy within 10%. The method of calculating the gross resource is reasonably straightforward and most volumetric calculations are prepared on a computer from data imported from a spreadsheet giving details of topography and core holes. The computer, using a dedicated (3D) three dimensional, CAD (Computer Assisted Design) package will be able to calculate the volume of a particular model, it does this by using a grid

Figure 7-1 [ref 94] Computer generated contour map.



system to establish blocks, at the limits of the boundary and with regard to quality, these blocks will have a full or partial value. The computer will simply calculate the number of blocks in a given model. Lerch and Grossman in 1964 published a 3-D algorithm (a systematic mathematical procedure that produces in a finite number of steps, the answer to a question or the solution of a problem) based on graph theory which could be applied to determine the optimum design for an open pit mine and therefore decide on how much of the deposit could be mined. In 1986 Whittle programming Ltd utilised the algorithm for the first time in a commercial software package. The method produces a computer generated three dimensional block model of the deposit and progressively builds and identifies lists of related blocks which should or should not be mined. The model will display a pit outline designed to take advantage of the best possible pit slopes and achieve optimum viability from the deposit. The image on the previous page shows a computer interpretation of an existing mine, details such as the intermediate water sump which is situated in the top right hand corner of the pit can be seen, as can the haul road and access routes to the various benches. This example has been drawn using the 'SURPAC' 3D modelling system. The table below shows the volumes of the example in the image.

Figure 7-2 [ref Surfer] typical volume calculations.

Upper surface	Grid File: C:/PHD/100100.GRD	
	Grid size as read:	58 cols by 127 rows
	Delta X:	99 614
	Delta Y:	99 9286
	X-Range:	367507 to 373185
	Y-Range:	574412 to 587003
	Z-Range:	-199 385 to 145 153
Lower surface	Level Surface defined by Z = 0	
Volumes	Approximated Volume by	
	Trapezoidal Rule:	3 57317E+009
Simpsons rule is a method of calculating an irregular area		
	Simpson's Rule	3 57419E+009
	Simpson's 3/8 Rule	3 57414E+009
Cut & fill volumes	Positive Volume [Cut]	4 73896E+009
	Negative Volume [Fill]:	1 16592E+009
	Cut minus Fill:	3 57304E+009
Areas	Positive Planar Area	
	(Upper above Lower)	5 29344E+007
	Negative Planar Area	
	(Lower above Upper)	1 85573E+007
	Blanked Planar Area	0
	Total Planar Area	7 14917E+007
	Positive Surface Area	
	(Upper above Lower)	5 30282E+007
	Negative Surface Area	
	(Lower above Upper):	1 86895E+007

If the volume is to be calculated manually, the normal practice is to define from core drilling, the physical parameters of the deposit, much as the computer system does, however, to make the figures more manageable it is normal to reduce the reserve by applying a series of cross sections, these can be made either vertical or horizontal.

The preference of the writer is to cut the deposit horizontally in steps of between five and fifteen metres, if correctly applied, these steps should coincide with the bench development and the local contours. Once a slice of the deposit has been drawn, it can have a suitably sized grid superimposed upon it and the areas of both its base and its surface measured and the average found. The resulting figure can be multiplied by the depth and the volume calculated. A simple CAD package will calculate the area by drawing a marquee line around the deposit and asking the programme to provide the captured area.

Where the levels of the bench reaches the surface, the cut will not be a precise shape and a fill factor must be applied to take cognisance of the natural land form, for example if the bench is taken at ten metres and the topography shows a material depth of five metres, the fill factor will be 50%. If required, a physical model of the site can be built, these are often prepared by a young engineer as a training exercise. A series of CAD drawings have been included in chapter eight on the subject of mine planning, these are used as an example of a long term, preliminary quarry plan, they show a typical gross volume calculation using the CAD method.

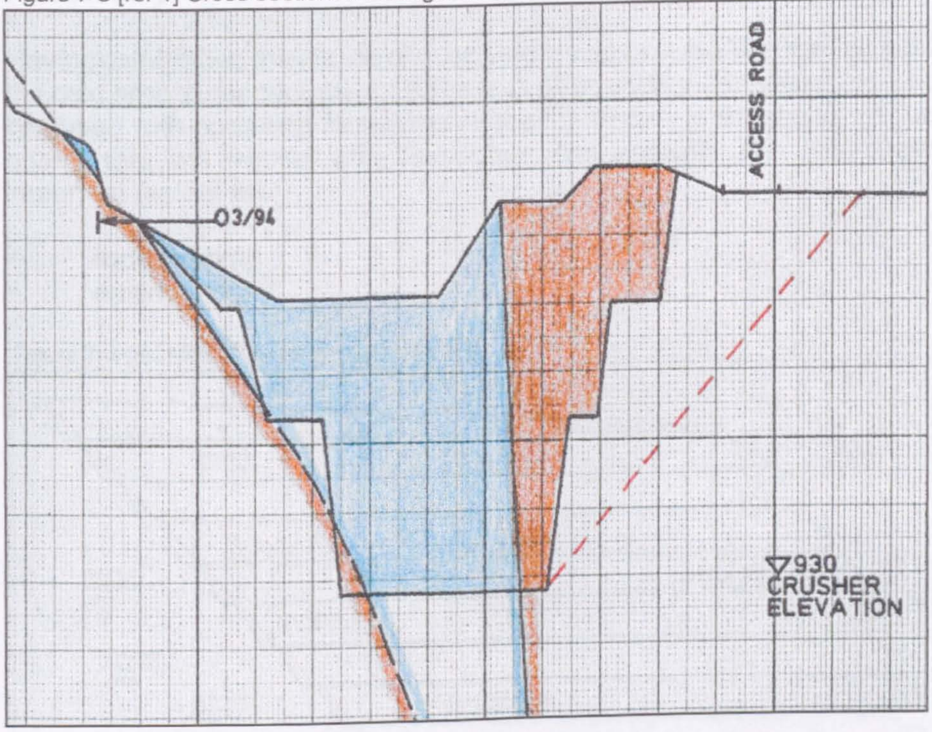
7.2.2 Conversion from resource to a reserve

To convert a resource to a technical reserve, (but not necessarily an economical reserve) will require the identification of the final pit boundary and the development of a preliminary mining plan. Rock strength and other factors will suggest the amount of material to be retained on the walls of the benches and a decision made to either mine within the deposit and leave some material or to quarry outside of the deposit and take all of the deposit and some waste. The level of the phreatic surface often dictates the maximum practical depth of the workings, as the deeper into the water table, the greater the water inflow and pressure on the quarry walls and therefore risk of collapse, however, for this project, the water table has been identified as below the base level of the quarry.

Internal or external excavation

The hand drawing on the next page was made recently by Anglo Alpha and shows a vertical section through the Changalume deposit, the major grid represents 50 metres. The limestone is shown in blue and the waste igneous rock shown in brown. The contact boundary of the two rocks is seen on the right hand side to be almost vertical. Quarrying this profile calls for either the limestone or the waste to be benched. The deposit is already marginal in respect to its economic volume and in order to maximise the resource, Anglo Alpha have recommended that benching is

Figure 7-3 [ref 1] Cross section of Changalume



made outside of the limestone and into the waste, should the decision have been made to only quarry the limestone, the reserve would have been reduced by fifty percent. Where the contact between the useful deposit and the waste are close to vertical, calculations need to be made regarding the cost of excavating and storing the waste versus leaving good material in place, this is a simple calculation and often results in a compromise. A factor that must be considered is the strength and stability of the different rocks, for example, the limestone may support a boundary wall which is almost vertical and the waste may require an angle of forty-five degrees or vice-versa.

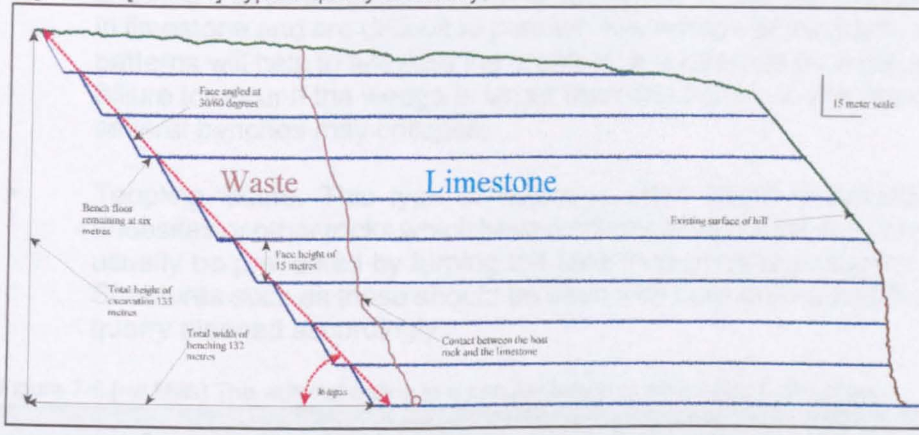
A further complication, that should be considered is the effect upon cash flow, whereby the waste to product ratio, is usually at its least cost effective at the beginning of a project and improves towards the end, thus resulting in an 'S' curve distribution of revenue. Careful quarry planning can help reduce the impact on cash flow by optimising the extraction to allow a progressive excavation of the waste which is as close as possible to being in line with production on an even distribution basis. This may involve operating from several areas of a single reserve. The experience of the writer with regard to feasibility studies on quarries has shown that the over concentration of activities with regard to production, instead of the timely exposure of saleable product (advance quarrying) is the biggest cause of financial failure in quarries.

Pit boundary

Having established the choice of quarrying inside or outside of the deposit, the next area to concentrate on is the final pit boundary, this should not be confused with operating faces, the final pit boundary is the profile of the quarry that will remain after extraction has ceased. The two most important factors are;

- rock strength
- environment

Figure 7-4 [ref Mills] Typical quarry boundary



Details of rock strength will provide the steepest angle at which the wall can remain stable, generally the steeper the wall, the more cost effective it is, however, most new projects require that the profile of the mine, especially if it is operated on an existing slope feature, leave the final slope close to the original value. To resolve this problem a compromise must be reached between environmental costs and production.

Rock mechanics

The strength of rocks and the study of rock mechanics have a profound effect on the design of an excavation and ultimately the volume of reserves that can be extracted. Rock may be weak because it is a sediment that has not been cemented or well consolidated. Many limestones of the cretaceous and tertiary age have this characteristic, or because it is weathered or intensively fractured, as in major fault zones. If the rock is incompetent it may not always be possible to operate to close tolerances, and the structure could collapse if the stresses exceed the rock strength. This is especially true of limestone and marble where the structural characteristics of the material can change in a few metres from hard marble, to calcite crystal, to breccia, each material chemically the same but with very different strengths. The most common types of rock failure which may cause a bench to collapse are;

- Circular or rotary failure. This is in section, a semicircular failure of material, usually found in shallow waste tips containing soils which have problems with water saturation, lack of compaction and a clearly defined boundary from the old surface below. It is simply a matter of the weight of the material pushing down on a base material which has insufficient cohesion and strength to support the weight of the material placed above it. Circular failures can be readily identified and apart from their bulk, are easily dealt with, they tend to be on a large scale and man made.

- Wedge failure. This is where discontinuities intersect the rock face allowing a double wedge of material to fall out. These can happen in limestone and are difficult to plan for. Knowledge of the fracture patterns will help to alleviate the problem. It is possible for a major failure to occur if the wedge is larger than one bench, in this case, several benches may collapse.

- Toppling failure. This type of failure is often found in basalts, andesites or other rocks which have a columnar structure, they can usually be prevented by turning the face through ninety degrees. Structures such as these should be seen with core drilling and the quarry planned accordingly.

Figure 7-5 [ref Mills] The writer standing in a circular failure of about 500,000 tonnes.

- Plane failure. Usually identified as forces tending to cause deformation of a material by slippage along a plane or planes parallel to the imposed stress. The resultant shear is of great importance in nature, being intimately related to the downslope movement of earth materials and to earthquakes. In quarrying this is made worse where the angle of the face does not match the angle of the bedding plane, the most common rocks displaying these features are slates, sandstones, basalts and other rocks with distinct bedding planes. The problem can sometimes be resolved by turning the face.

- Laminar failure, or creep. This is generally a man made feature which occurs on waste dumps, whereby the waste is dumped on an area which has a slope similar to the natural angle of repose of the dumped material. Different levels of compaction during dumping cause the waste to be layered. Water seeping through the waste will eventually flow at the interface of the original ground surface and the dumped material. This will reduce the friction between the two surfaces and in time, gravity will cause the various levels of the waste to slide. The rate of slide will vary according to its degree of saturation. As the layers are more saturated at their bases, the slippage through the layers will occur with the levels nearest the base of the dump moving faster and further from their origins.

The picture shows a planer type rock failure in a limestone anticline, the failure extends upwards at 20 degrees from the vertical for some 200 metres. In colder climates than central Africa, care must be taken to prevent water from entering the perimeter face, as frost heave will soon cause the face to scale and fail. The following are reference tables of "cohesive strengths" and "friction angles" of various materials. The wide variations, for example schist at 26 to 70 show that the science and calculations must be viewed and modified with experience and common sense. One of the most important aspect to consider when determining rock strength is the effect of ground water, Water pressure in the joints and fissures will often provide uplift on the potential sliding surfaces, reducing the friction and shearing resistance. In limestone, water can have a significant chemical effect (dissolution) on the rock, especially if the water has a low ph. Often, the phreatic surface close to a rock face be modified by drilling drain holes.

Figure 7-6 [ref Mills] Upwards shot of the strata. (Mexico)

Figure 7-7 [ref 13 et al] Rock strengths
Source, Cohesive strengths for intact soils and rocks (Robinson 1971). Friction angles in degrees for a variety of intact materials (Hoek 1970) [Waters) 1978.

Material	angle in degrees	Material	kg/m²
andesite	45	very soft soil	170
basalt	48 to 50	soft soil	340
chalk	35 to 41	firm soil	880
diorite	53 to 55	stiff soil	2,200
graywacke	45 to 50	very stiff soil	7,800
limestone	30 to 60	very soft rock	17,000
monzonite	48 to 65	soft rock	56,000
porphyry	30 to 40	hard rock	170,000
quartzite	64	very hard rock	560,000
sandstone	45 to 50	extremely hard rock	1,000,000
schist	26 to 70	Moh's Harness scale	
shale	45 to 64	talc	1.0
siltstone	50	gypsum	2.0
slate	45 to 60	calcite	3.0
clay	10 to 20	fluorspar	4.0
calcite	20 to 27	apatite	5.0
faulted shale	14 to 27	feldspar	6.0
breccia	22 to 30	quartz	7.0
compacted rock	40	topaz	8.0
dry sand	18	corundum	9.0
rock fill	38	diamond	10.0

Deformation and slope stability

Production faces in quarries require only short term stability, however when the excavation reaches the pit boundary, the face may be required to remain permanently. Excavation in a direction that is obtuse to the strike of the bedding and sets of major fractures can create a more stable slope than for faces advanced in other directions. Ground pressures will usually change the shape of an

Figure 7-8 [ref 90] Typical final bench detail in hard stable rock

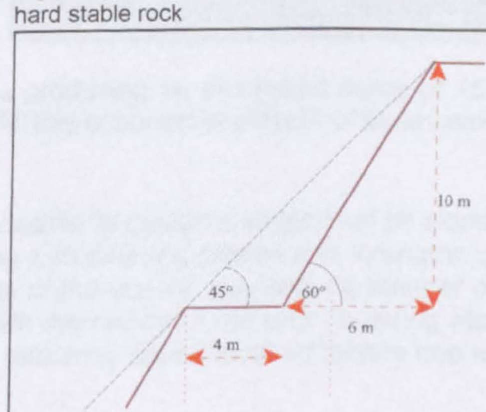
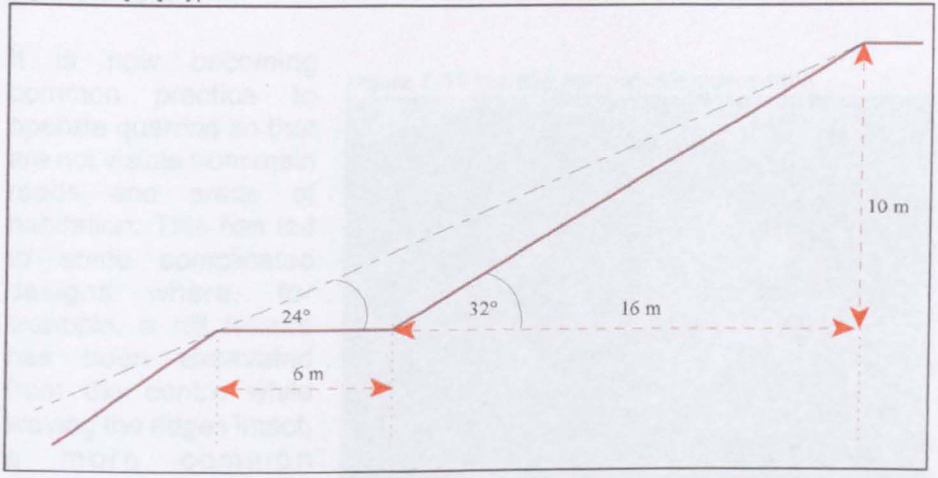


Figure 7-9 [90] Typical final bench detail in unstable conditions



excavation and if deformation is excessive, the slope can fail. An indication of the way the ground responds to pressure can be seen in the structure of valleys that represent natural excavations caused by the process of glacial erosion. Natural excavations indicate that the sides of a man made excavation will tend to move inwards and if the excavation is sufficiently wide, the floor will move upwards. To demonstrate this, is the example of the floor of a thickly bedded ordovecian limestone quarry having an excavated area of 300 by 600 metres, that developed a crack 100 metres long. Within a few minutes the rock on either side of the crack had risen 2.4 metres producing an elongated dome of 150 metres long and 30 metres wide. All this occurred at a depth of excavation of 15 metres.

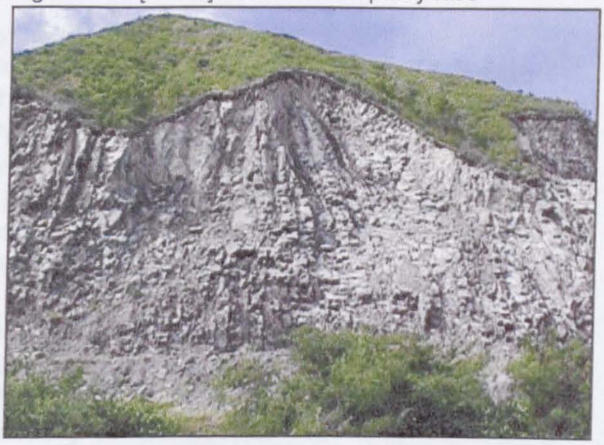
Figure 7-10 [ref 88] Vertical jointing

The writer believes that it is not possible to design a single final pit slope. This is especially so when working with differing grades and strengths of marble. Commonly different parts of the quarry may require steeper or shallower slopes to safely deal with the nature of the rock (bedding etc) and the availability of high grade rock may cause local variations due to selective quarrying.

Environment

It is now becoming common practice to operate quarries so that are not visible from main roads and areas of habitation. This has led to some complicated designs where, for example, a hill feature has been excavated from the centre while leaving the edges intact, a more common requirement is to leave the final slope, close to the original slope value.

Figure 7-11 [ref 88] An unstable quarry face



The line drawings above and to the right show typical final designs. In other instances, the walls have been kept to a steep angle and after production has ceased, a programme of naturalisation has been implemented whereby a series of holes have been drilled towards the face and the crest of the face blasted to give both a reduced slope value and a reasonable drainage for re-growth of vegetation.

Summary

Only when the final pit boundary, and the maximum practical working depth has been established, together with the economic decision of where to cut the waste can a deposit be considered as being a reserve. Of the case studies, probably the best one is the most recent report on the Chilanga deposit, even this report however, does not consider the practicality of actually quarrying the deposit to the recommended depth, has not addressed the problems of rock stability nor has it addressed the economics of quarrying the waste.

7.3.0 CHILANGA

7.3.1 Survey [ref 86]

Until August 1993 surveying of the quarry was carried out by ZCCM, however they decided that they no longer wanted to carry out this work and recommended that the company should use Terrain Surveys and Associates. Since January 1995 the surveying has been carried out by Petbon Surveying Services who have produced an accurate 1:1000 scale topographical map, that is periodically updated as the quarry is developed and more information becomes available. The new map has shown that all the previous maps were very inaccurate.

Detailed on the map are seven truncated concrete pyramids. They mark the mining licence area boundary. The pyramids are known as beacons and are marked from A through to G. The height datum, is the top of Beacon "A" which was arbitrarily set at a level of 100.00 metres and it is from this beacon that all local heights are derived. The local vertical interval (contour) is one metre. A local grid line has been included on the map to help in both development of the quarry and to help in documenting any core drilling programme that may be carried out. Insufficient data is available to plot the collaring of the existing core drilling exercises.

Due to large amounts of material being found which are not mentioned in any reports, the writer is confident that the information accrued and collated by both Weller and ZCCM is inaccurate. Because the results calculated in the recently written report by United Nations Industrial Development Organisation (UNIDO) are based on the same information it is probable they are also inaccurate. Development work carried out in the north, south and east of the quarry has proven that much of the information collated and detailed by ZCCM is speculative.

7.3.2 Estimated reserves (Weller) [ref 132]

Weller in his Summary Report on Geological Investigation for Limestone in the Chilanga area states;

"The northern sector consists of high grade limestone with total carbonates in excess of 90% and $MgCO_3$ below 2%. Over the remainder of the hill feature total carbonates are between 80 and 90% with $MgCO_3$ below 4%. Where the deposit extends beneath the flat area east of the hill the grades are variable within the hill feature range. The conglomeritic limestone is low in carbonates, often below 70%, but the $MgCO_3$ content is usually below 4%. Total proved reserves (excluding conglomeritic limestone) are estimated at 10.5 million tonnes of which 7.7 million tonnes occur beneath the hill feature".

7.3.3 Estimated reserve (ZCCM) [ref 140]

ZCCM in their 1992 report state;

"From the geological reserve calculations, RP3 mining area contains 10.27 million tonnes of limestone at 84.9% $CaCO_3$ and 3.45% $MgCO_3$ on average. The reserves in this area have been calculated from mid-benches 85-65 RL, average thickness of 30m and an S.G. of 2.75. The remaining reserves above the 90m RL and resources below 60m RL and the less than 77% $CaCO_3$ material were not included in the calculation, but may represent an addition to the above-mentioned figure. The total area underlain by lamprophyre dykes and lenses has also been subtracted from the calculated reserves".

The comments from Weller are reasonably concise and state that the RP3 deposit contains 10.5 million tonnes of limestone, of which 7.7 million tonnes is beneath the hill feature. As the hill has now been removed, assuming that the total reserve contains 7.7 million tonnes would be reasonable. The comments made by ZCCM are far from clear regarding either context or syntax. The first sentence does suggest that the reserve contains 10.27 million tonnes.

7.3.4 Estimated reserve (UNIDO) [ref 128]

" The total volume of limestone is 3,527,000 cubic metres, ie 9,284,000 tonnes of raw material suitable for cement production. It is necessary to emphasise that the above mentioned reserves calculation is considerably influenced by the management of the previous geological survey. With regard to the high variability of chemical and technological properties of the deposit body, the drill holes density is insufficient. Because of the missing drill holes a more exajct determination of the lithological boundaries in the carbonate sedimentary deposit is not possible. There is little information on the geological structure of the marginal deposit parts.

We suppose it is possible to secure some additional parts of the RP3 deposit (under the 60 metre level) and also on its north-eastern continuation. The following possibility depends on determination of geomechanical properties of the deposit rocks aiming to make an accurate mathematical analyses of final slope stability and to calculate the more exact value of its inclination. However, it is necessary to carry out a supplementary, more detailed drilling investigation and qualifiably documented and evaluated geological survey with professional management."

7.3.5 Estimated reserve (Writer) 1996

Recent mapping of the known areas containing useable limestone has shown that approximately 2,000,000 tonnes of material are available for every 10 metres depth excavated. The limestone in the karstic area has been calculated at 50% and the gritstone area has been excluded from the computation. The depth of the reserve is unknown, however, it would be unreasonable to assume that the material extended to a depth of less than forty metres, The actual depth of the limestone can be established by the methods shown in the last chapter.

Until the depth of the deposit is properly established and a final pit boundary is designed, a preliminary computation of the reserve suggests that 8,000,000 tonnes of material are available for abstraction.

7.3.6 <u>RESOURCE EVALUATION (1998 Report)</u> [ref 137]

This is a report that was published by ZAMBEZI EXPLORATION CONSULTANTS (PVT) LIMITED IN 1998.

PREVIOUS RESOURCE EVALUATIONS:

Weller (1968) records that surface exploration, including trenching, was conducted during 1965 and 1966. Following this a diamond drilling programme consisting of 30 boreholes was undertaken in 1968. The exploration conducted is reported to have established that cement quality carbonate underlay an area of approximately 12 hectares. Based on these investigations Weller (1968) concluded that, excluding the horizon of psephitic marble in the north-west of the deposit, *measured resources* of "medium grade stone" totalling ±9.5 million tonnes had been established to a depth of 27.4 metres below the base of the hill.

Humphreys (1983) records that a further seven drillholes, totalling 310 metres, were sunk during 1981. However, Mills (1996) contends that eight not seven boreholes were completed during these investigations, and reports that an additional 21 drillholes, sunk to a depth of 35 metres, were completed during 1987.

In 1991 the Technical Services Division of Zambia Consolidated Copper Mines Limited were engaged to undertake the geological evaluation and mine planning of the RP3 Quarry. Utilising the records available of the drilling undertaken in 1968, 1981 and 1987, supported by the site investigations undertaken, it was determined that exploration had established resources to a depth of 60 metres below surface. The drilling conducted in 1968 under the supervision of Weller, during which thirty boreholes were sunk, was reported by Molak and Siddiqui (1991) to have formed the prime data source for this assessment. The locations, lengths and azimuths of these drill holes were scaled off plans, while the $CaCO_3$ contents for the 1968 and 1987 drilling campaigns were calculated from the total carbonate and $MgCO_3$ results reported: $\%CaCO_3 = \%\text{Total Carbonate} - (\%MgCO_3 \times 1.182)$.

Utilising this data Molak and Siddiqui (1991) concluded, employing a specific gravity of 2.75, that the RP3 deposit contained reserves totalling some 10.3 million tonnes with an average composition of 84.9% $CaCO_3$ and 3.5% $MgCO_3$. However, Molak and Siddiqui (1991[a]) reported that of the 49 boreholes used in the evaluation only specific samples from the 1968 drilling campaign, generally with unusual characteristics, contained data from which alumina and silica moduli could be determined. Consequently, based on available information, the alumina and silica moduli were calculated at 1.21 and 1.69 respectively. These lie below the target values of MA 1.8 - 2.0 and Ms 2.6, and it was suggested that the alumina and silica moduli could be improved by the addition of 38.4 kilograms of material, containing approximately 85% SiO_2 and 15% Al_2O_3, per tonne of mill feed. Drilling to obtain more information on the Al_2O_3, Fe_2O_3 and SiO_2 contents of the deposit was not recommended, with it being proposed that the alumina and silica moduli could be controlled by enhanced grade control in the quarry involving the:

- Pre-planning of drilling and blasting based on accurate survey control.
- Correct sampling of blast hole cuttings.
- Rapid and accurate sample analysis.
- Inclusion of all data in mining block assessments.
- Critical evaluation of ore to waste separation and/or blending.

Unfortunately, only a portion of the data on which the assessment completed by the Technical Services Division of Zambia Consolidated Copper Mines Limited was based remains available for re-evaluation. Despite this Mills (1996) managed to estimated *proven reserves* at 2 million tonnes per 10 metre mining depth which, excluding the area composed of schist in the east of the Quarry and allowing for 50% waste in surface areas effected by Karstic weathering, were taken to total 8 million tonnes.

Measured resource Estimation

Quarry development, as emphasised by Mills (1996), established that the exploration completed up to 1987 failed to adequately delineate significant geological developments, examples of which are listed below, that have or will adversely effect mining operations:

- Karstic Weathering: Such weathering, which has been established to extend to a depth of >20 metres below surface, resulted in some 100,000 cubic metres of material being removed and dumped as waste. Areas reportedly notably effected were Chilanga Cement's RP3 Mining Blocks 4, 5, 11, 12 and 14.

- Melanocratic Igneous Intrusives: A significant intrusive body immediately west of the main haulage route near the northern boundary of the Quarry.

- Psammite Beds: The extent of the schist present in the east of the deposit to the north-west of Beacon A.

The quarry area has been largely cleared of overburden. However, site inspection early in 1997 established that re-vegetation, compounded by the stockpiling of >30,000 tonnes of oversize blocks from the quarry awaiting reduction, extensively masks exposure away from the working face.

The preliminary site investigation and perusal of the surviving records completed determined that further exploration was required to establish measured resources in accordance with the Australasian Code For Reporting Of Identified Mineral Resources And Ore Reserves (1992). Consequently, taking cognisance of the pertinent surviving information, it was recommended that detailed geologic mapping, together with core and percussion drilling based on a 65 metre exploration grid designed to optimise utilisation of the available geological data, be undertaken, FIGURE 1. Altogether a total of 9 diamond and 33 percussion holes were drilled. The samples taken from these boreholes were analysed employing classical chemical methods in the laboratories of Chilanga Cement Limited at Chilanga and Ndola, APPENDIX D.

The resource modelling of the Dream Hill, Outpost Hill and RP3 Quarry deposits was undertaken with Dr. J. Gray and S. Black of Techbase Europe Limited utilising the Techbase suite of engineering software. All three deposits were found to contain a statistically wide variety of populations for the compounds analysed. The relationship of these populations to lithology is uncertain, with the deposits having been effected by a number of deformational events rendering correlation problematic. Normal distributions were not obvious in the upper levels of the marble, at depths of commonly <5 metres, due to the effects of weathering and the infilling of dissolution cavities with soil. However, a progressive increase of quality occurs with depth. Additionally, confirming that percussion hole samples are more susceptible to contamination, significant improvements in distribution quality was observed when the analyses obtained on the core from diamond drillholes were evaluated separately. This does not detract however from the value of utilising percussion holes to cost effectively obtain information for resource estimation, establishing geological continuity and/or defining deposit limits.

After several statistical studies of the assayed data it was determined that a resource estimate could be achieved employing an inverse distance algorithm. This method, which is commonly applied to industrial mineral deposits, is dependent on the original data having a normal distribution or on the application of a cut-off grade to a log-normal distribution. However, with log-normally distributed populations the application of a cut-off grade introduces a bias towards achieving a favourable result. Despite this, especially when considering that poorer grade material can be either stockpiled for blending or discarded, it constitutes an effective method for calculating resource tonnages. Additionally, inverse distance possesses the advantage over simpler methods, such as polygonal estimation, in that the mining software can also use the block model created to control blending and grade, predict revenues, design the open pit and schedule extraction.

The analytical results obtained during the 1997 and three earlier drilling campaigns at RP3 Quarry were utilised during modelling, with the collar elevations of the latter being estimated taking into account the effects of overburden removal and mining activity. Both raw and composited data showed calcium oxide to be modelled with population over 35%, whilst magnesium oxide was again log-normal. Resource tonnages were calculated from surface down to both the water table and 60 metre mine datum level without any filters, to determine the total tonnage with the measured resource polygon, and filtered on $CaCO_3/MgCO_3$, $SiO_2/Al_2O_3/Fe_2O_3$ and the Ma/Ms (Aluminium and Silica Modulii) to delineate feed capable of meeting the chemical requirements for Portland Cement in Zambia TABLE 6. This involved:

Employing the triangulation algorithm to model the topographic surfaces using the survey data supplied by Chilanga Cement Limited.

Using the minimum curvature - biharmonic spline algorithm on the downhole measurements obtained to model the water table.

Compositing the downhole data and locating these values within polygons assigned as containing either indicated or measured resources, as defined in TABLE 5, taking into consideration surface geology, borehole information and assay data. Where possible the boreholes were given half distance estimated locations, while in areas controlled by geological constraints the estimated polygon boundary was established with reference to the dip and strike of the controlling feature.

Modelling of the data employing the inverse distance method delimited by topography. All searches of the exploration grid were conducted using a 100 x 100 x 20 metre ellipse, with the shortest axis orientated downhole, on the criteria of a maximum of 25 and minimum of 4 samples, whilst for comparison, in order to judge the possibility of the results from boreholes situated on the edge of defined polygons being ignored, the minimum number of samples was reduced to three.

Figure 7-12 [ref 137] Filters employed

CaO (%)	MgO (%)	Al_2O_3 (%)	Fe_2O_3 (%)	SiO_2 (%)	Ma (%)	Ms (%)
45.0 – 55.0	0.0 – 3.5	0.0 – 3.0	0.0 – 3.0	0.0 – 10.0	0.0 – 2.6	0.0 – 2.6

The measured resources of potential carbonate cement feed estimated to occur within the area defined at RP3 Quarry, utilising the inverse distance method and employing the criteria outlined, are listed in the table below. Deducting twenty per cent for material loss due to geological factors, such as igneous intrusives, and on mining, it is considered that by efficient blending a tonnage approaching that obtained when no filters were applied to the 60 metre mine datum level, 9.38 million tonnes, can be produced from the deposit.

Figure 7-13 [ref 137] RP3 Quarry resource tonnages estimates

MINING DEPTH		RESOURCE TONNAGE FILTERS APPLIED (MMT)				
		None	CaO/MgO	Si/Al/Fe	Ma/Ms	All
Above Water Table	Total	9.05	6.28	6.28	8.22	4.95
	20% Deducted	7.24	5.02	5.02	6.58	3.96
60m Mine Datum	Total	11.73	8.11	8.12	10.56	6.42
	20% Deducted	9.38	6.49	6.50	8.44	5.14

Chapter Eight

Mine Planning

8.1.0 PLANNING

8.1.1 General

The strategic planning of a quarry is little different from the planning of any other kind of physical operation. In Africa, one of the functions of the writer was to appraise the technical, logistical, environmental, commercial and financial aspects of several quarrying projects and plan them accordingly. On a green field site, this process often follows the satisfactory completion of a feasibility study. Such a study can do much to point a quarry development in the right direction, define its risks and achievable objectives. The study can also indicate that it may be necessary to abandon the project altogether. The correct approach to project planning is to identify risks by undertaking work or operations in a systematic order, with the work being divided into a number of stages.

8.1.2 Sequence of works

Often the preliminary works will begin with a closure and restoration scheme and design accordingly, to achieve this end, the sequence of production is as follows;

- Exploration and evaluation
- Development
- Extraction
- Processing
- Saleable products
- Transportation and distribution
- Closure and restoration

The sequence above will be incorporated and form the skeleton for the quarry plan and can be set according to;

- The occurrence of specific events within the quarry development that are easily recognised as they materialise
- The application of a time limit for each stage
- Budgetary restrictions for each stage or
- a combination of any of the above

Project planners frequently face the task of controlling operations that contain unknown and unpredictable factors. There are procedures that allow for probabilities or alternative options to be built into initial project planning, so that the project can facilitate uncertainty.

Financial appraisal

In most instances, and as is true of the case studies, a significant level of expenditure will be required at the outset. At this stage of development, all activities and economic costs must be identified and assessed, and will fall within some or all of the following (although financial appraisal is carried out by a separate department the writer for completeness, includes a discussion of these items);

- An initial description of the project, with its required performance characteristics quantified in simple terms
- The total expenditure estimated to carry out the project and bring the product into commercial use
- The anticipated dates when the product will be brought into commercial supply
- Forecast of operating maintenance costs for all existing plant that would be superceded by the new project
- Forecast of operating maintenance cost for new plant within the project
- Forecast of operating and maintenance costs associated with production
- Scrap or resale value expected from disposal from the superceded plant or structures
- The economic working life of the project, also to include de-commissioning and restoration
- Forecast of scrap resale value or negative value expected at the end of the working life of the new plant
- Sale of the land, with either positive or negative value
- Forecast of the costs of financing over the development period to include, borrowing rates, inflation trends and international exchange rate trends
- Fiscal considerations to include taxes, financial incentives and penalties to be expected by central and local government
- Cash flow, discounted at the developers required rate of return (profit)
- Identification of all inflows and outflows with calculated net present value and internal rate of return (percentage rate at which the development will earn money) [ref 58]

The project team will be required to make a decision as to whether a project will go ahead. The final decision will be dependant on a range of factors including the answers to such questions as;

- Can the project be achieved technically?
- Are the reports of engineers, geologists and other experts accurate?
- What are the environmental implications?
- Are output calculations realistic?
- Is there sufficient demand for the product?
- What price should the product be fixed at?
- Will the project be completed within a specified timescale?
- How much will the project cost and are these costing based on

realistic assumptions?
- How will finance be raised?
- Is the rate of return satisfactory?

Discounted cash flow schedule [ref 117]

This is a principal tool for effective project management, where all future items of income and liabilities are discounted to a common date to enable realistic development appraisal. These are essential where finance is raised externally and the rate of return can be calculated with ease. The cash flow schedule permits a more sophisticated approach for project planning. Such schedules have the virtue of enabling many relevant items to be included in calculations when they occur, in a format that allows ease of understanding. These will include, the cost of finance, taxation, inflation, royalties and cost of production. When reasonable assumptions can be made about future events such as, the capital cost of new plant, these can also be incorporated in the schedule when they are expected to occur.

Net present value method (NPV) [ref 117]

When analysing profits or the producers required rate of return (profit) it is necessary to discount all future values to the present day. The function of discounting is that for example, £100.00 invested today will not have the same value in one years time, this can be due to the effects of inflation, conversely is £100.00 is invested in the project today with a required rate of return of 20%, the producer will require a gross sum of £120.00. Today's £100.00 is called the discounted or net present value of the future £120.00. The discounting rate for a particular project is a matter for management discretion, and will certainly be judged to be related to prevailing interest rates and inflation, and will be assessed by a centralised accounting section. Where the NPV of a project (final balance total) is greater than zero following discounting at the developers required rate of return the project is said to be financially viable. Any sums above zero are calculated profits over and above the "opportunity costs" (an alternative investment return) to the producer of investing in an operation.

Funding

There are several options available to finance a quarry development on a long term basis;

- Cash reserves
- Sale of assets
- Borrowing from a finance house
- Issuing debentures or loan stock, (internal finance)
- Securitisation, such as commercial mortgage indemnity

8.1.3 <u>General planning</u> [ref 117]

Introduction

Within the detailed quarrying plan it is advisable to establish a timescale for development to provide an indication of the relationship between the time allowed and the time needed for completion. A safe assumption is that a plan is required that systematically communicates each step of the project and any relationships between activities to demonstrate when each sub project should be finished in order to complete the whole project efficiently within a required timescale. This must be understood by all participants in the project. There are several methods for timescale planning that have been adapted to quarry development.

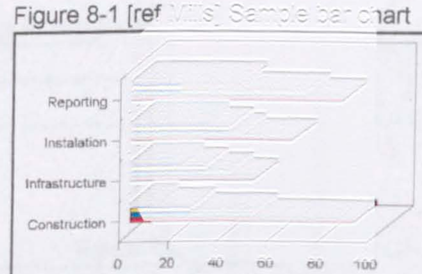
- Timetables

This is the most simple form of project planning, where the planning team identifies tasks and provides a target date for completion. The timetable can usually be managed through a series of progress meetings. While this method can be ideal for small projects it is too simple for planning on a large scale. Timetable plans may be written down with insufficient care and thought, and be ineffective for day to day progress, monitoring and control as they lack adequate detail.

- Bar charts

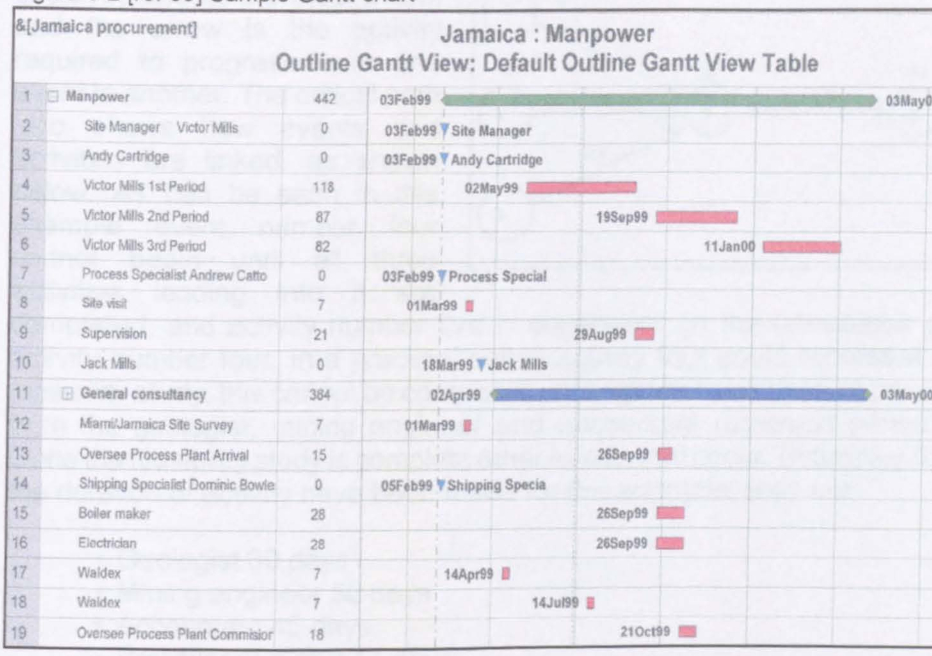
These display the timescale for development more effectively than simple timetables. The plan is drawn up on a scale where the horizontal axis is directly proportional to time (days, months, and years). As can be seen in the sample show each horizontal bar represents a project task, its length scaled according to its expected duration. A more sophisticated bar chart, known as a Gantt chart in addition to the horizontal bars as indicated, the name or description is displayed on the same row, at the left edge of the chart. Gantt charts are widely used, so named after there originator Henry Gantt (1861 to 1919) they are valuable planning aids and have been incorporated in many computer packages as standard, such as "Microsoft Project" or "Turboproject" a sample is shown below. Gantt charts are simple to construct and interpret and are commonly displayed as wall charts in the form of coded bar charts. All that is required is that the number of bar charts for a particular code are added that fall within each time column to aggregate the resources needed for a particular planning unit. Bar charts have their drawbacks, reorganisation of the schedule can

Figure 8-1 [ref Mills] Sample bar chart



be difficult, particularly for complex Gantt charts.

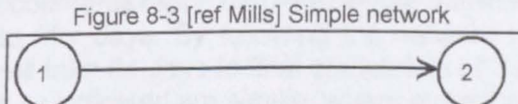
Figure 8-2 [ref 89] Sample Gantt chart



- Critical path network analysis

This is a general term for a number of project planning methods. The best known of these are critical path analysis.

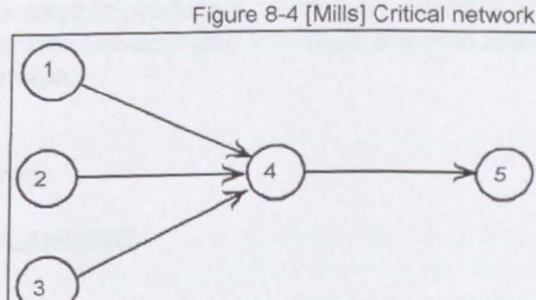
Figure 8-3 [ref Mills] Simple network



- Critical path analysis

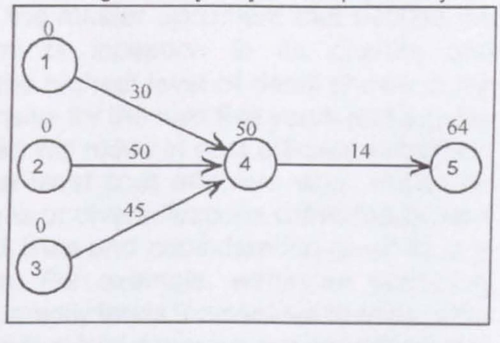
This is essentially an "activity on arrow" system (these are often called arrow networks), and can also be called pert diagrams. They are a technique for controlling and coordinating the various activities necessary in completing a major project and utilize a chart that consists essentially of a series of circles, each of which represents a particular part of a project, and arrows representing the activities that link these parts together. The critical path is the minimum time that a project can take, represented by the greatest of the times that are obtained by totalling the individual activities

Figure 8-4 [Mills] Critical network



on any path from start to finish. In the example shown above each circle represents a project event, and the arrow is the activity required to progress from one event to another. The critical path also shows how events and activities are linked, as shown below. As can be seen in this example event number four cannot begin until all three activities leading into it are completed, and activity number five is dependent on the completion of activity number four. In a practical sense activity four could represent a feasibility study, this cannot be completed until reports have been obtained from the geologist, mining engineer and accountant (amongst others). Once the feasibility study is complete other events can occur. Estimates for the duration of activity have been made for this example, they are;

Figure 8-5 [Mills] Critical path analysis



- Geologist 30 days
- Mining engineer 50 days
- Accountant 45 days
- Preliminary report 14 days

When the durations are applied the network is as shown. The critical path will be the longest time that the preliminary report will take to complete. It is clear that the geologists and accountants report can be of longer duration and be completed anytime up to fifty days. By following the network to event five it can be seen that it will take 64 days to final completion of the preliminary report. The examples as indicated are simple, where more that one pathway exists the longest and shortest times must be show and in all cases the longest pathway chosen. The identification of critical tasks enables the allocation of resources to their most effective use. Suppose as in the example shown, sixty-four days to produce a preliminary report is not acceptable, the project manager must re-appraise to reduce the time scale for the network path by for example;

- Increasing man hours
- allocating more resources

8.2.0 PHYSICAL QUARRY PLANNING

8.2.1 <u>Introduction</u>

Once finance has been arranged and timescale planning is complete, management will require a quarry plan. The function of the quarry plan is to systematically control the process of development and extraction so that it meets the required level of output within a framework of defined costs and quality objectives as defined in the feasibility study. The plan is not merely one of extraction, it is also the master document that defines the development of the quarry from its inception to its closure and reinstatement. The plan will have the highest level of detail shown in the first year, be reasonably comprehensive for the next five years and a guide thereafter. A high quality quarry plan will result in cost efficient extraction as resources will be worked in the most cost effective way. Particular emphasis will be paid to any changes or diversifications within the project and industry with regard to product lines and consideration given to any potential expansions of production. For example, within an operating limestone quarry, available markets readily lends themselves to expansion into the cement and lime industry, ready mixed concrete, pre-cast concrete, aggregates and asphalt. The plan can provide for controlled expansion as too rapid expansion can burden a producer with excess costs and inefficient operations, high capital liabilities and eventually insolvency. Conversely, too little economic planning can make it difficult and expensive to increase output at a later date. This can place a product at a significant cost disadvantage if other competitors with larger facilities generate a product at a lower cost or with more consistent quality. A producer with an appropriate level of facilities can respond quickly to an increase in demand for a product by the incorporation of market research and therefore knowledge of future market projections.

8.2.2 Planning

The quarry plan is a long term policy framework for operational development that is often presented as short, intermediate and long term. The plan logically progresses by acquiring a databank of knowledge from a team of experts (or sometimes an individual), this will usually consist of;

- Owner
- Accountant
- Mining engineer
- Surveyor
- Geologist
- Environmentalist

It is likely that the whole project will be consolidated by a qualified mining engineer.

- The owner will set the life of the project, funding and investment levels, establish a required rate of return, direct the experts to the operational standards that are required, establish a safety policy and mode of practice. This information will form the basis of the financial development and in some cases the practical development of the project.

- The accountant will consider project expenditure, produce forecasts, estimate fixed and variable costs and set preliminary budgets for the required periods. Reporting will consist of a financial framework within which the team can operate.

- The surveyor will physically appraise the topography and shape of the site, establish fixed survey stations and carry out a detailed survey. Reporting will consist of charts at 1:1,000 scale or less, vertical cross sections through two axis, definition of the selected contours (aligned with bench development), calculate volumes.

- The geologist will carry out an investigation using core holes and other sampling systems on an accumulative progressive basis, the immediate area of extraction being analysed in the greatest detail which will include any changes in the dip and strike of the deposit, any changes to the thickness of the bed, any folding, jointing with details of any master joints, any Karstic activity, the contact (groundwater table) between the Phreatic zone (groundwater zone) and the Vadose zone (overlying unsaturated zone). Reporting, will consist of a sub surface survey and geological mapping, showing thicknesses of beds, deviations in quality, recommendations for mining and any other abnormalities that may be of consequence.

- Integral to the planning process will be an environmental impact statement, to ensure a minimum of pollution and disruption, this document should address all areas affected by the quarry. The environmentalist will input sufficient information to the planning team to enable the design and placement of drains and temporary waste dumps to be constructed in an environmentally acceptable location, and plan accordingly reduction of environmental impact schedules to include continuance of restoration scheme, mitigation of impacts from noise, vibrations dust, emissions, traffic, waste, visual effects, landscaping, water pollution, soil, and ecology.

- The mining engineer collate all the reports, carry out a document review (lease, mining acts etc) with this information the engineer will formulate a preliminary plan for the whole site from cradle to grave.

In the production of the preliminary plan, the following aspects will have been fully considered and evaluated;

- funding
- geological data
- overburden stripping
- environmental requirements
- health and safety
- legislative compliance
- provision of infrastructure
- availability of finance

- environmental impact
- general arrangement of the quarry
- working programme
- overburden removal
- waste dump development and maintenance
- water control and drainage
- bench details and development
- road location specification and routes
- type of plant with expected working hours
- any reinstatement and landscaping
- guidelines for social impact
- Lateral extent, shape and thickness of deposit
- Geological structure of deposit
- Internal variation of deposit
- Depth and characteristic of overburden
- Phreatic surface
- Water pressures and flow rates
- Overburden and storage
- Semi permanent roads
- Semi permanent drains
- Compliance with environmental mitigation program
- Compliance with the long term landscaping measures

Having considered the above, the preliminary quarry document will be tabled for approval and finalisation to the team, and it may at this time be necessary for presentation to the legislative authorities for their approval. Once approved, this will become the master document.

From this master document each phase of development will be identified, often these phases are described as initial development, short, medium and long term plans and closure. All but the initial development are rolling, or ongoing plans, that advance on a time basis. For example, the one year plan, on expiry will be replaced by a further one year plan.

The long term quarry plan will usually have a viability of ten years. Because of the lengthy time span there will be little true quarrying data and it will be more of a financial document, being of more use to the company accountants than the quarry manager. For example, included in this plan will be recommendations made in allocating rates of increase to the various kinds of expenditures made on available goods and services, capital plant and other investments and long term strategies. The site specific geological data will be acquired as the project proceeds and legislation concerning re-use of the land and environmental concerns may be significantly changed from when the plan was conceived. In addition, global pressures may force changes onto the original plan. The plan should be part of an integrated framework taking into account details of final quarry design and any progressive reconstruction, because of this, the design must remain flexible and take into account any increased knowledge of the deposit. The planners should not be forced into an isolated reactive mode, this usually being a result of the quarry operators not adhering to the plan.

The intermediate plan of duration five years, is more detailed than the long term plan and provides a level of information sufficient to facilitate forward development of the site. The level of information in the five year plan will include;

- Means of excavation, the machinery, plant and methods employed in excavation operations
- The method of excavation, the system of working required to ensure continuous product supply
- Phased plans of working for overburden removal, drilling and blasting and excavation
- Disposal and storage of waste
- Methods of dealing with surface and ground water
- Methods for ensuring safety and stability of quarry faces

Details in the intermediate plan to show;

- The correct equipment is available when required, within the investment schedule and financial framework
- A sequence of working is generated that maximise quarry efficiency and minimises the cost of moving materials
- Training of personnel and a scheme to replace retirees
- Health and safety initiatives are in place

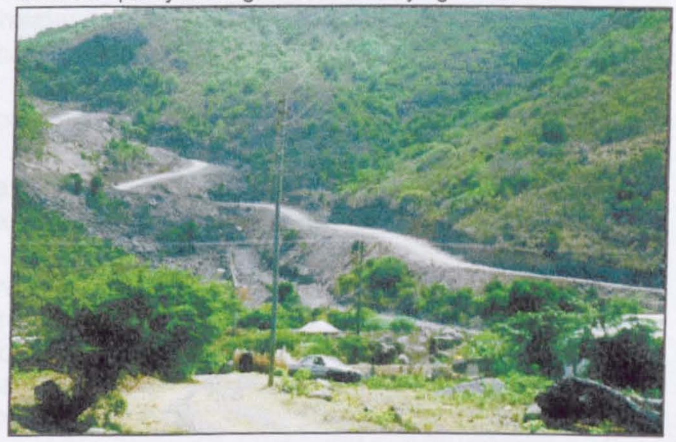
The short term physical plan provides the highest level of detail, of duration one year and is immediately associated with production. Typically a short term plan will provide specific details of road construction, bench development, infrastructure and immediate financial requirements. The following are examples of the detail that would be found in a short term plan;

Roads

Before the quarry can advance there must be access, this may consist of a few tracks cut by a dozer, or it may involve the construction of a complete road network. Usually, a quarry will have a multiple road network consisting of; a permanent road system, a long term road system and on going temporary road development and closure. The road may be built by the quarry, or alternatively contractors may be employed, whichever labour is used, it is probable that a professional team of civil engineers will be called upon to provide the detailed design. In the image shown below, the quarry only provided the most general of detail and left the rest to the writers own judgement. Typically, the facility will begin with a series of coordinates, together with specifications and information on the required construction, such as;

- routing — follow the natural contours *elevation not to exceed* 1:12
- width — not less than 15 metres (50-tonne trucks have 4.5 metres width)
- drainage — drainage on the high banking and super-elevation with culverts
- safety barriers — ARMCO barriers where required signing, clearly legible road signs conforming to country standard
- surfacing — concrete at turning points and asphalt throughout
- road marking — to conform with local standard
- priorities — to be clearly marked

Figure 8-6 [Mills] The writer took over construction of this road after the quarry manager was killed trying to build it.



The intermediate road system will connect to various feeder roads serving the quarry benches. During the life of the quarry and to adapt to the changing locations of the active benches, the feeder roads will be redesigned and rerouted several times. These roads need not be built to as high a standard as the permanent road network. To achieve acceptable inclines looping should be considered, in this case, attention must be paid to the arc of visibility and where possible, all the bends must be horizontal. Efforts should be made to ensure that the *road is designed* to have a minimal visual impact, both during construction and use, this can often be found by constructing as much of the road as is possible beneath exposed features, such as in a valley or beneath the rim of the quarry. Dust will be controlled by the application of a water spray. Adequate drainage will be provided to prevent flooding. The permanent road can be screened by planting screens of leafy trees, and this will reduce the nuisances of dust and noise.

Control of ground water

Quarrying operations interfere with natural water levels. An excavation below the phreatic level must be protected against unacceptable inflows of water, this can be achieved by excluding it from the site, or by abstracting it from the ground within and around a site. To control the ground water flowing into an excavation it is necessary to know the expected rate of flow so that calculations can be made on the size of drains and pumps. Such data should be available from hydrogeological or hydrological sources.

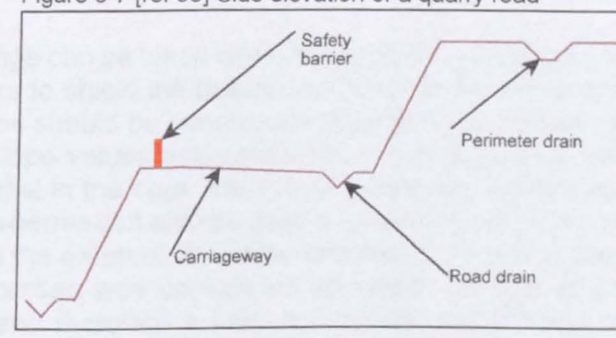
Ground water flow is sustained by the drainage of water stored in voids within the ground and from hydrogeological boundaries that recharge water to the ground. Such water may be intercepted before it reaches an excavation, this can be achieved by de-watering techniques. Rivers around such areas should be diverted before they are able to recharge the surface water reservoirs. Drains will also be constructed.

Drain construction

Operating in wet conditions causes problems with,

- drilling, clogging and collapse of the bore holes
- blasting, desensitisation of ANFO
- face loading, with lack of grip and excessive tyre failure through cuts
- haulage, with heavy dumpers sliding and tyre slippage
- general reduction in performance

Figure 8-7 [ref 90] Side elevation of a quarry road



Should the quarry be sited on the side of a hill, the problem is often one of keeping the haul roads dry, whereas, if the quarry is below ground level, the problem is one of avoiding the normal ingress of water from the surrounding area and removing the water that enters as rain. The problem will be increased if the quarry is operating below the water table. Road drainage is not complicated, but often it is neglected, the principle is, to first ensure that the road is higher than the surrounding land, and then provide channels at each side of the carriageway to prevent water from entering the road. When the road is climbing or descending the side of a hill, it is normal and important for safety reasons, and in order to prevent erosion, to provide the carriageway with a single elevation that will drain the water into a channel running continuously between the hillside and the road. The channel should have the capacity to contain and transport any water that is flowing down the hillside, together with the water that has flowed from the carriageway to a suitable point where a culvert can be employed to safely dispose of the water without it crossing above the road. The amount of water entering a quarry can be minimised by excavating a drain around the perimeter of the site and using this to redirect the water away from the site in the direction of the natural drainage. Should the quarry be operating sub water level, the perimeter drain can often be used as a recipient for quarry pumping, it should be noted that settling ponds may be required to facilitate the mechanical removal of solids.

Overburden stripping

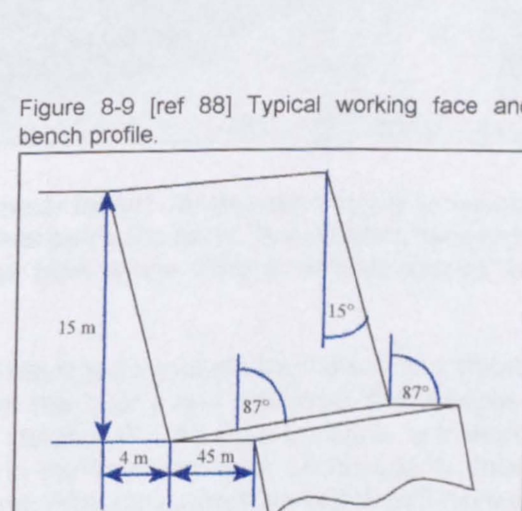
This process can either be carried out using quarry equipment and be an ongoing operation that takes place as the quarry advances, or it can be on a campaign basis where it is planned and priced for tender and a contract negotiated for the work. Unless there are particular difficulties, this part of the operation is straightforward. Advantage can be taken when stripping the overburden to construct berms or banks to shield the quarry and mitigate the visual and other impacts. The berms should be constructed to appear as natural as possible with minimal slope values and constructed in a sequence that places the rock fill material in the core, the sub soil next and the top soil close to the surface. The berms can also be used to provide a barrier to re-direct surface water into the external drainage network. Contrary to past beliefs where the overburden was considered as waste product to be removed from the site and therefore a financial liability, the storage of overburden has become a major part of the environmental restoration process.

Figure 8-8 [ref Mills] Moving topsoil (Tanzania)

Bench development

The long term plant will give the overall shape of the quarry and within this, the benches can be designed. Most quarries, whether they are a hole in the ground or cutting into the side of a hill will operate a series of benches. A bench is a step or level cut into the side of the rock, one bench consists of a floor and a face, with the floor being the horizontal section and the face

Figure 8-9 [ref 88] Typical working face and bench profile.



being the vertical section. The bottom of the vertical face is known as the toe, and the top of the face being known as the crest. To assist in stability, the face can be angled, this inclination is usually described in quarrying terms as degrees from the vertical, this is different from most other applications, where the angle is measured from the horizontal. Care should be taken when dealing with this subject to ensure that the same criteria is being applied by all parties. Typically, the angles applied to working faces, (as opposed to final perimeter faces) range from vertical to twenty degrees with five to fifteen degrees being the norm. In a modern hard rock quarry bench heights will range from range from a vertical interval of between five to fifteen metres.

Figure 8-10 [ref 71] Bench development at Changalume in 1983.

Figure 8-11 [ref Mills] After ten years of unplanned working

The final perimeter bench will be designed to enable the maximum amount of material to be recovered from the quarry and therefore, the steepest slope angle, while still leaving a stable wall. The main principle, is to work as closely as safety will permit to the final perimeter of the quarry, thus leaving a minimum of rock behind. Although a working bench will have a floor width of at least three times the height of the face, the floor left behind on the perimeter bench will be one third or less of the face height.

The sole purposes for leaving any floor remaining in place is;

- for it to act as a rock trap to prevent any material falling onto the benches operating below
- so that the legislative authorities do not class the wall as one high bench (which will make it illegal)

As the lower working benches approach the outer limit of the quarry they will be designed and developed to remain as a perimeter bench. This involves using a greater face angle than the fifteen degrees (from the vertical) which would normally be used in a working bench. An overall face angle of thirty degrees (from the vertical) would be considered satisfactory for the final bench, this to be achieved by using a none-disruptive blasting technique known as smooth blasting. With a bench floor remaining of six metres, a face height of fifteen metres and a face angle of thirty degrees, the overall angle of excavation (pit slope) will be forty-six degrees from the horizontal. The floor of the bench should incorporate both a slight back slope and a longitudinal slope each of approximately three degrees from the horizontal, the purpose of this being to control the flow of water and direct it to a main drop channel.

Drilling and blasting

Appropriate planning and control of the drilling and blasting programme is vital if the quarry benches are to be operated effectively, the areas directly affected by blasting techniques are: -

- final pit boundary, with regard to face angles and rock stability
- environment, with regard to noise, dust and vibration
- type of loaders eg, face shovel, back hoe, front end wheeled loader etc.
- type and size and of dump trucks
- type, size and capacity of crushers
- residence time of material in the primary grinding circuit, ie throughput

As a result of extreme tectonic activity, the limestones found in central Africa have been extensively folded and faulted and bench stability will be compromised if the bedding is tilted or if there is pronounced jointing. The bedding of sedimentary rock can vary within a few metres and the physical properties of the rock can be markedly different. The correct use of pre-splitting or smooth blasting techniques will minimise the risks associated with having high abandoned faces. Besides making the limestone difficult to drill, the jointing causes the gas products from the explosive, which would normally heave the rock is often released through the cracks, causing the heaving of the blast to be unsatisfactory. It is sometimes found that the fissures in the deposit are aligned in a particular direction, in this case, to obtain the best results, the face should where possible be oriented in a direction which has been proven by experimentation to give best blasting results.

Fragmentation can largely be controlled through effective management of blast design and the proper selection and use of explosives. To a large extent the degree of fragmentation will dictate the rate and cost of production by reduced power consumption at the crusher and less wear and maintenance on the other equipment. The capacity of any type of crusher is wholly dependent on the size of material it is required to crush, and good fragmentation will increase crusher throughput.

The amount of throw and looseness of the blasted rock will influence both the type of loading machine and the rate at which it will operate. Wheeled front end loaders operate best with low blast profiles, whereas face shovels and excavators are best served by blasting to a high profile. In some quarries, an excavator will be required to operate from the top of the rock pile, in this instance care should be taken to ensure that the base of the rock pile is both within reach of the excavator and stable. Effective sub level blasting to clear the toes and leave a smooth floor will reduce maintenance costs for both the primary loader and dump trucks. Excessive sub level blasting will have little effect on the floor and will be environmentally unacceptable because of high ground vibration levels. A reasonable depth of sub drilling is one third of the burden.

Waste management

Waste management should be incorporated into the plan to control the following;

- The occupation of space
- The creation of dust
- Contamination of the ground/water through surface water run-off.

Within a quarry the main sources of waste are:

- Overburden (permanent)
- Slurry from processing
- Oil spillages
- Derelict plant and machinery

Some commonly used methods of mitigating the effect of waste on the environment are:

- Where possible keep waste out of site within the area worked
- Locate as far as practicable away from water sources

- Only temporary disposal to stockpiles
- Overburden to be used for restoration purposes
- Dispose of derelict plant and machinery off site
- Encapsulate areas where oil spillages commonly occur
- Use stockpiles as screening/noise barriers
- Waste heaps to have drains installed to control surface water run-off
- Direct replacement of overburden, as the preferred method
- Waste heaps grassed and landscaped

Restoration

This will feature in all of the phases of development and use, and will therefore be mentioned in all the quarry plans. Most quarries operate a policy of progressive rehabilitation, towards a pre-determined end use. The aim of a restoration scheme is to improve an otherwise despoiled quarry site by creating areas of natural regeneration, and occasionally to introduce a new use onto the site, such as:

- leisure (such as a boating lake)
- recreational facilities (such as climbing)
- nature conservation (such as a bird sanctuary)
- agriculture
- forestry
- industrial
- housing

These uses are highly likely to be introduced in the UK due to strict planning and in particular section 106 agreements, in Africa such schemes are now becoming a mandatory prerequisite to the permission of operations. A detailed post construction landscape and management plan should include:

- Perimeter planting around the site boundaries
- Ongoing soil restoration and soil making activities
- The planting of indigenous plant and trees
- The introduction of new species in the interests of bio-diversity
- Planting in such a way that low level structures are screened within the facility, and from the nearest residential property
- All structures finished in neutral colours
- Wildlife opportunities stabilised and promoted
- Waste heaps formed similar to surrounding contour lines
- Unworked areas to be left untouched
- Where possible "wet" areas left insitu to attract wildlife

8.3.0 MINE PLAN OF CHILANGA RP3 QUARRY

8.3.1 Introduction

This is an extract from a comprehensive mining plan that was produced by the writer [ref 86] in 1995 for Chilanga Cement Company. The full document was both a financial and physical plan, however, for this case study, an abbreviated version of the physical plan only has been provided. The plan demonstrates the method of identifying blocks of material by both their lateral extent and by their vertical extent, gives a timescale of operation and calculates the advancement through each year. The original drawing were prepared by Petbon Surveying services using an Autocad CAD system and printed on A0 size sheets, for this document, a small part of the drawings showing only the internal quarry workings has been abstracted.

8.3.2 Mining Operation

External water management

A surface water collection and diversion trench has recently been cut to the north of the mine heading in an east to westerly direction. The purpose of the trench, is to direct any rainwater away from the mine excavation to discharge to the west of the hill feature. The trench must be maintained and improved by cutting the sides back to 60 degrees. Where possible the sides and bottom of the trench should be buttressed with a layer of minus 100 mm rocks. Recently an access road has been constructed around the mine. The road generally follows the boundaries of the geological limits as suggested by ZCCM. A rainwater drain has been excavated on the outer side of the road. During construction, care has been taken to ensure that the elevation and contour of the road will cause any surface water to flow away from the mine excavation. This method of drainage must be maintained and should the road require repositioning the rainwater drain must be reconstructed.

Internal water management

As the mine develops, effective control of surface drainage will become more important. Ideally, the benches should be developed to maintain a steady fall of about 2% towards the north. However, because of incorrect development of the mine the fall will now have to be to the south where the topography will allow gravity drainage away from the active benches during the early stages of mine development. During the rainy season it is assumed that abstraction from lower bench will cease and the excavation will be used as a sump for the mine. Depending on the surface water quality, developing a temporary sedimentation pond to allow solids in suspension to settle out before allowing the water to discharge to the sump may be necessary.

Overburden

The expression "overburden" describes material, whether consolidated or not which has to be stripped before the mineral can be worked. The overburden should be removed in a timely manner prior to extraction of limestone.

Four types of overburden are found at RP3;

- lateritic soil
- dolomite
- grit-stone
- lateritic in-fill

The surface lateritic soil can be easily removed either by an excavator and truck, or by using a dozer, wheel loader and truck. Any dolomite that may be encountered must be drilled and blasted before it can be removed, it should be used for drainage and as road building material. The gritstone can be easily ripped by a dozer and loaded by wheeled loader. As lateritic in-fill is infiltrated into the karstic limestone, it will be difficult to remove and will often require that the limestone must first be blasted. Apart from the difficulties encountered in drilling this material, the result of the blasting is poor and causes the limestone to mix with the laterite, resulting in high losses of useable material.

An earthmoving contractor was employed to remove the overburden, this material has been used in road construction and the remainder stored in a temporary waste dump. At the same time, some lateritic soil and gritstone was removed. The lateritic soil is to be hauled by truck to a tip for disposal as waste and the gritstone being a useful product, to be used in road construction and maintenance. Once the contractors have removed as much material as they can, the area is drilled by a team of men using hand drills and a mobile compressor. The holes are blasted and the material is cleared. Where possible, an excavator is used, together with a rock breaker to reduce the material. Any boulders that cannot be removed are drilled and further reduced by blasting.

Drilling

Once the bench is cleared of blasting debris, blast hole drilling takes place using a drifter type drill and mobile air compressor. The preferred drill diameter is 79 mm, this size will be maintained throughout the life of the plan.. Because of the inability of the drills effectively to produce holes to a greater depth, and to conform to mining regulations the bench height will be operated at a height of seven metres. A bench height of ten to fifteen metres would be more cost effective to operate and when new equipment arrives, the operating height of the lower bench will be increased.

Although designed with the capability to angle drill, the rigs are not mechanically able to maintain a steady angle or azimuth, besides this, the operators do not have the skills required to produce angle holes. If these problems did not exist, consideration could be given to drilling the face at an angle of up to 15 degrees from vertical. The purpose of angling the face is to improve rock stability and to achieve a slight improvement in toe breakage. During the period of this mine plan, the holes will be drilled vertically.

Experimentation has shown that when using drill holes of 79 mm diameter, a burden and spacing of 2.5 metres has provided excellent fragmentation and throw with a minimum of over-break, because of this past experience, the square pattern of 2.5 metres will be maintained. A sub drilling factor of 0.83 metres will be incorporated, this will help in controlling the new quarry floor. Any projections will be removed by the hydraulic rock hammer.

Blasting

To achieve the relatively high tonnages that are required to ensure adequate blending, and taking into consideration the blast height limitations which are enforced by legislation, standard practice will be to fire between 200 and 300 holes per blast. Advantage will be taken of the NONEL system to time the blast. Blending is achieved by, using a chevron timing pattern to heave the rock into the centre of the blast where it is effectively mixed. The use of gelignite has been discontinued and the drill holes will now now be loaded with a base charge of aluminised slurry and a column charge of ANFO. Some experimentation has been carried out regarding loading densities and a full column charge of ANFO working a burden and spacing of 2.5 metres, loaded to within 1.5 metres from the collar of the hole has proven to give satisfactory fragmentation and heave.

The details of hole loading are as follows;

- depth of hole = 7.5 metres
- primer/base charge length 0.83 metres
- column charge length = 5.17 metres
- subdrill = 0.83 metres
- specific charge = 30 kg
- volume of rock = 41.69 cubic metres
- mass of rock = 106.73 tonnes

The practice of using detonating cord to fire a primer in the hole has been ended and the NONEL Unidet 500 millisecond delay system of down the hole detonators will be used. The Unidet detonators are positioned directly into the slurry which acts as a primer for the ANFO. A delay of 500 milliseconds is incorporated into the detonators to enable all of the surface initiation to take place before any of the column charges are initiated, the delay is known as the "burning front" and the method of delay is known as "advance initiation". The NONEL Snapline surface connector system will be used to delay the individual lines. This recently introduced system is available in the following delay times; zero, 17, 25, 42, 67, 109 and 179 milliseconds. The system has been introduced at RP3 and experimentation has shown it to be effective. The preferred firing pattern is a wide chevron or V shaped pattern, this has been found to give the best fragmentation (caused by head on collisions from the material ejected from opposite sides of the chevrons) and throw.

To achieve a chevron pattern, the holes are drilled with an equal burden and spacing and loaded with a standard column charge, two 500 millisecond delay detonators are installed in the slurry base charge. The centre of the front row of the blast is established and as the holes each side of the centre line are only connected by the initiation detonator they can virtually be treated as separate blasts.

Eastern half. Starting from the centre line, and excluding the number one hole, which is fitted with a zero delay connector, the holes on the front row and outer sides of the blast are joined outwards from the centre to each other with 25 millisecond snapline connectors. From the delay detonators the remainder of the holes are joined with zero delay connectors to form diagonal lines radiating outwards from the centre.

Western side. Starting from the centre line, the process is a mirror image of the eastern side, except for the number one hole which is fitted with a 17 millisecond delay connector. When all the holes are connected and checked the zero and 17 millisecond delays on the front row can be coupled to the initiation detonator. The reason for using a 17 millisecond delay at the first hole on the western side it to cause the rows of holes on each side of the blast to fire out of sequence. The resulting reduction in specific charge will lessen vibration.

Initiation is by safety fuse and a "number six" power detonator. The use of safety fuses is, to the best belief of the writer restricted to Zambia, their use in most countries has been prohibited for some time. The reason for this being, that from lighting the fuse until the blast fires (about seven minutes) the operation is effectively out of control. Unfortunately, the obsolete blasting legislation which still prevails in Zambia recommends the use of this method of initiation. Whichever method of firing the blast is used it is important that the procedure for blasting operations includes a determination of the danger zone and failsafe methods for the withdrawal of personnel. These procedures are laid out in the Mine Managers rules for blasting.

Face loading

Once blasted, the raised rock pile will be dozed to ensure that its height is in accordance with mining legislation. The Caterpillar 988B front end loader will be used to load the rock into 35 tonne dump trucks. Because of the geological structure of the limestone, to ensure satisfactory breakage at the toe of the face the floor may need to be ripped or subjected to further blasting.

Haulage

The Cat 769C dump trucks will continue to haul the to the primary crusher. After being hauled to the crusher the material will be either tipped directly into the receiving hopper or stored in a "ready for use" stockpile to be used as required. The stockpile has a capacity more than 20,000 tonnes. It is important that the road is kept is good condition, to achieve this, the grader will operate at all times and as required, material will be hauled from the quarry to maintain the road surface. There will be no haulage during heavy rains, if crushing is required during these periods, material will be used from the stockpiles.

Secondary Breaking

Boulders that are too large for the crusher to handle are carried to a suitable area within the mine for further reduction. It remains common practice to drill the oversize boulders and blast them to reduce their size. This practice has become unacceptable for the following reasons;

- high labour content
- high maintenance requirement for hand drills and small compressors
- high cost of suitable explosives
- unavoidable risk of fly rock

It has been proven that throwing the boulders away is a more economical option than secondary blasting them. A more acceptable method of secondary breaking is, by using the hydraulic excavator and hammer.

Waste tips

Most of the areas between the mine and the plant have for many years been used as a location for tipping reject material. This practice is environmentally unacceptable and will be discontinued in favour of using a designated tipping area. The most satisfactory method of tipping is to build the tip in layers of less than one metre, this allows the material to be compacted and consolidated. To prevent fluidisation and lubrication of the tips, drainage channels will be constructed to carry any rainwater to an area of native and undisturbed ground. To ensure safe operation of waste tips, their design must obey the principles of soil mechanics;

Such structures must be founded on ground that is sufficiently strong to carry their weight without failing and they should not be sited on zones of natural ground water discharge without adequate provision being made for the control and drainage of surface water.

Two methods of tipping can be recommended;

- The layer method; is to build the tip in benches of one metre, this allows the material to be compacted and consolidated. The resulting tip is structurally sound. A disadvantage of this method, being that a dozer must be constantly employed to spread and compact the material.

- The side tipping method; calls for the material to be discharged over the edge of the tip, extending the area both upwards and outwards in a spiral. Because the material is tipped over the side it will not be effectively compacted and the tip will probably be structurally unsafe. A disadvantage of this method of tipping is that the tip will not be consolidated also there is a risk of the truck falling over the edge when tipping.

8.3.3 Mine Development and Mining Plan

Historical data

It should be taken into consideration that the ore body at RP3 is geologically complex and because of this, a very large amount of data is required to produce a comprehensive and specific mining plan. It would be normal when preparing a mining plan to refer to any historical information that may be available and update the plan with data that has, more recently come to light. For reasons already described, the recommendations found in the Pit Design Report as presented in March 1992 by ZCCM have been disregarded. As much of the geological data is suspected of being inaccurate, formulating a definitive long term mining plan extending below the present bench height is almost impossible. This document will discuss, mining the areas that are either visible and therefore known, or where a reasonable estimate can be made of the geology and structure of the material. It is believed that sufficient information is available to produce a sequence of mining which will be valid for the years, 1996, through to 2000.

Traditionally, only one bench has been operated, now however as the material is abstracted, a second level will begin to be excavated. Development of the lower bench has begun and a new access road has been constructed. The upper bench will, when fully developed ideally consist of one long face, retreating southwards with a north west to south east alignment. This arrangement is simplified by the topography of the mine. For blending purposes It will allow maximum access to the various grades of material. The second bench will follow as closely as possible, the development of the primary bench. To maximise the blending and grading of product, it is important that the two benches are worked simultaneously and separated by a bench width of not less than twenty metres.

Sequence of development

The orderly development of a long term mine excavation on this site requires that mining continues from the extreme northern limit of the known limestone deposit and proceeds by developing two benches aligned in a north west to south east direction and advancing to the south.

Drawings of the mine show grid lines drawn across the mine, separating the area into discreet blocks. One series of lines is numbered with the other being lettered. The blocks are designated as A1, B1, C1 etc. and the sub levels are designated as A1S, B1S, C1S etc. A nominal bench height of seven metres from the existing floor levels has been used to calculate the volume of the upper blocks and a bench height of ten metres has been used for the lower blocks. Throughout the operation of the two benches it is assumed that access to the upper benches will be maintained by a haul road that will be routed along the eastern boundary of the seven metre bench, close to the karstic area. If the demand for limestone is consistent; the following years development will be;

1996, at the seven metre bench, blocks B4, B5, C3, C4 and C5 will be worked and 80,000 cubic metres removed. At the ten metre bench, block A2 will be worked with 19,000 cubic metres being removed.

1997, at the seven metre bench, blocks B5, C3, C4, C5, D3, D4 and D5 will be worked and 73,200 cubic metres will be removed. At the ten metre bench, blocks B2S and B3S will be worked with 26,800 cubic metres being removed.

1998, at the seven metre bench, blocks B5, C5, D3, D4 and D5 will be worked and 63,800 cubic metres removed. At the ten metre bench, blocks B2S, B3S, C2S and C3S will be worked with 33,500 cubic metres being removed.

1999, at the seven metre bench, blocks D3, D4 and D5 will be worked and 72,000 cubic metres removed. At the ten metre bench, blocks B3S and C3S will be worked with 27,000 cubic metres being removed.

2000, during the first six months of this year, blocks B3S, B4S, C3S and C4S at the ten metre bench will be worked and 50,000 cubic metres will be removed.

Figure 8-12 [ref 86] Block quantities

Projected limestone block quantities and reserves at February 1996					
Block number	Volume at 7m bench	Volume at 10m bench	Combined volume	Abstracted 7m bench	Abstracted 10m bench
A2	0.0	26,800.0	26,800.0	0.0	0.0
A3	0.0	32,600.0	32,600.0	0.0	0.0
A4	0.0	15,600.0	15,600.0	0.0	0.0
B2	0.0	28,600.0	28,600.0	0.0	0.0
B3	0.0	50,000.0	50,000.0	0.0	0.0
B4	7,000.0	*50,000.0*	*57,000.0*	0.0	0.0
B5	33,500.0	50,000.0	83,500.0	0.0	0.0
C2	0.0	4,700.0	4,700.0	0.0	0.0
C3	35,000.0	50,000.0	85,000.0	0.0	0.0
C4	35,000.0	50,000.0	85,000.0	0.0	0.0
C5	35,000.0	50,000.0	85,000.0	0.0	0.0
D3	35,000.0	50,000.0	85,000.0	0.0	0.0
D4	35,000.0	50,000.0	85,000.0	0.0	0.0
D5	35,000.0	50,000.0	85,000.0	0.0	0.0
E3	39,000.0	50,000.0	89,000.0	0.0	0.0
E4	35,000.0	50,000.0	85,000.0	0.0	0.0
E5	35,000.0	50,000.0	85,000.0	0.0	0.0
F3	45,000.0	50,000.0	95,000.0	0.0	0.0
F4	35,000.0	50,000.0	85,000.0	0.0	0.0
F5	35,000.0	50,000.0	85,000.0	0.0	0.0
F6	27,500.0	35,000.0	62,500.0	0.0	0.0
G3	35,000.0	50,000.0	85,000.0	0.0	0.0
G4	37,500.0	50,000.0	87,500.0	0.0	0.0
G5	35,000.0	50,000.0	85,000.0	0.0	0.0
H4	55,000.0	50,000.0	105,000.0	0.0	0.0
H5	55,000.0	50,000.0	105,000.0	0.0	0.0
J4	35,000.0	50,000.0	85,000.0	0.0	0.0
TOTALS	**754,500.0**	**1,193,300.0**	**1,947,800.0**	**0.0**	**0.0**

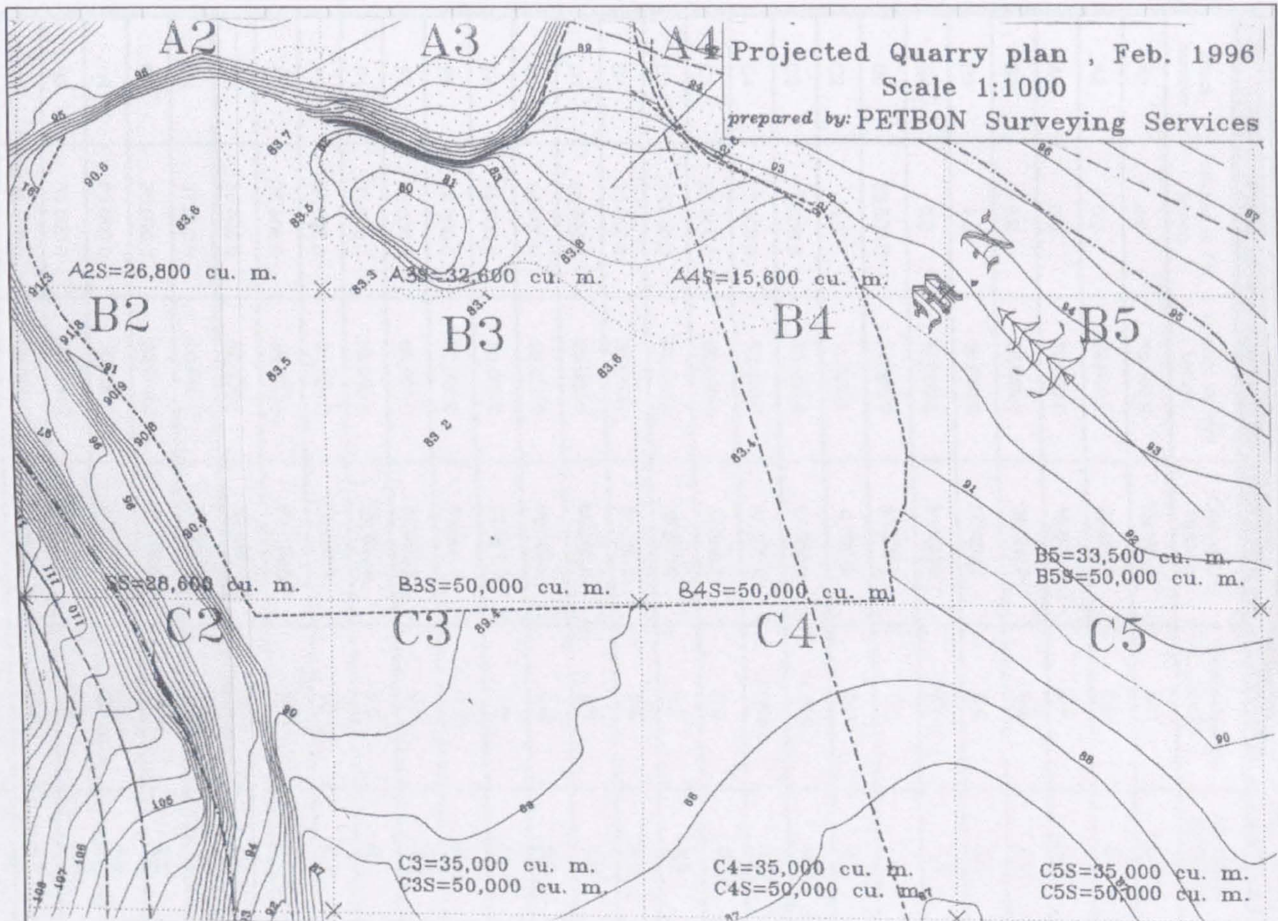


Figure 8-13 [ref 86] Block diagram

Figure 8-14 [ref 86] Block quantities

Projected limestone block quantities and reserves at June 1996					
Block number	Volume at 7m bench	Volume at 10m bench	Combined volume	Abstracted 7m bench	Abstracted 10m bench
A2	0.0	19,100.0	19,100.0	0.0	7,700.0
A3	0.0	32,600.0	32,600.0	0.0	0.0
A4	0.0	15,600.0	15,600.0	0.0	0.0
B2	0.0	28,600.0	28,600.0	0.0	0.0
B3	0.0	50,000.0	50,000.0	0.0	0.0
B4	0.0	50,000.0	50,000.0	7,000.0	0.0
B5	33,500.0	50,000.0	83,500.0	0.0	0.0
C2	0.0	4,700.0	4,700.0	0.0	0.0
C3	17,500.0	50,000.0	67,500.0	17,500.0	0.0
C4	17,500.0	50,000.0	67,500.0	17,500.0	0.0
C5	35,000.0	50,000.0	85,000.0	0.0	0.0
D3	35,000.0	50,000.0	85,000.0	0.0	0.0
D4	35,000.0	50,000.0	85,000.0	0.0	0.0
D5	35,000.0	50,000.0	85,000.0	0.0	0.0
E3	39,000.0	50,000.0	89,000.0	0.0	0.0
E4	35,000.0	50,000.0	85,000.0	0.0	0.0
E5	35,000.0	50,000.0	85,000.0	0.0	0.0
F3	45,000.0	50,000.0	95,000.0	0.0	0.0
F4	35,000.0	50,000.0	85,000.0	0.0	0.0
F5	35,000.0	50,000.0	85,000.0	0.0	0.0
F6	27,500.0	35,000.0	62,500.0	0.0	0.0
G3	35,000.0	50,000.0	85,000.0	0.0	0.0
G4	37,500.0	50,000.0	87,500.0	0.0	0.0
G5	35,000.0	50,000.0	85,000.0	0.0	0.0
H4	55,000.0	50,000.0	105,000.0	0.0	0.0
H5	55,000.0	50,000.0	105,000.0	0.0	0.0
J4	35,000.0	50,000.0	85,000.0	0.0	0.0
TOTALS	**712,500.0**	**1,185,600.0**	**1,898,100.0**	**42,000.0**	**7,700.0**

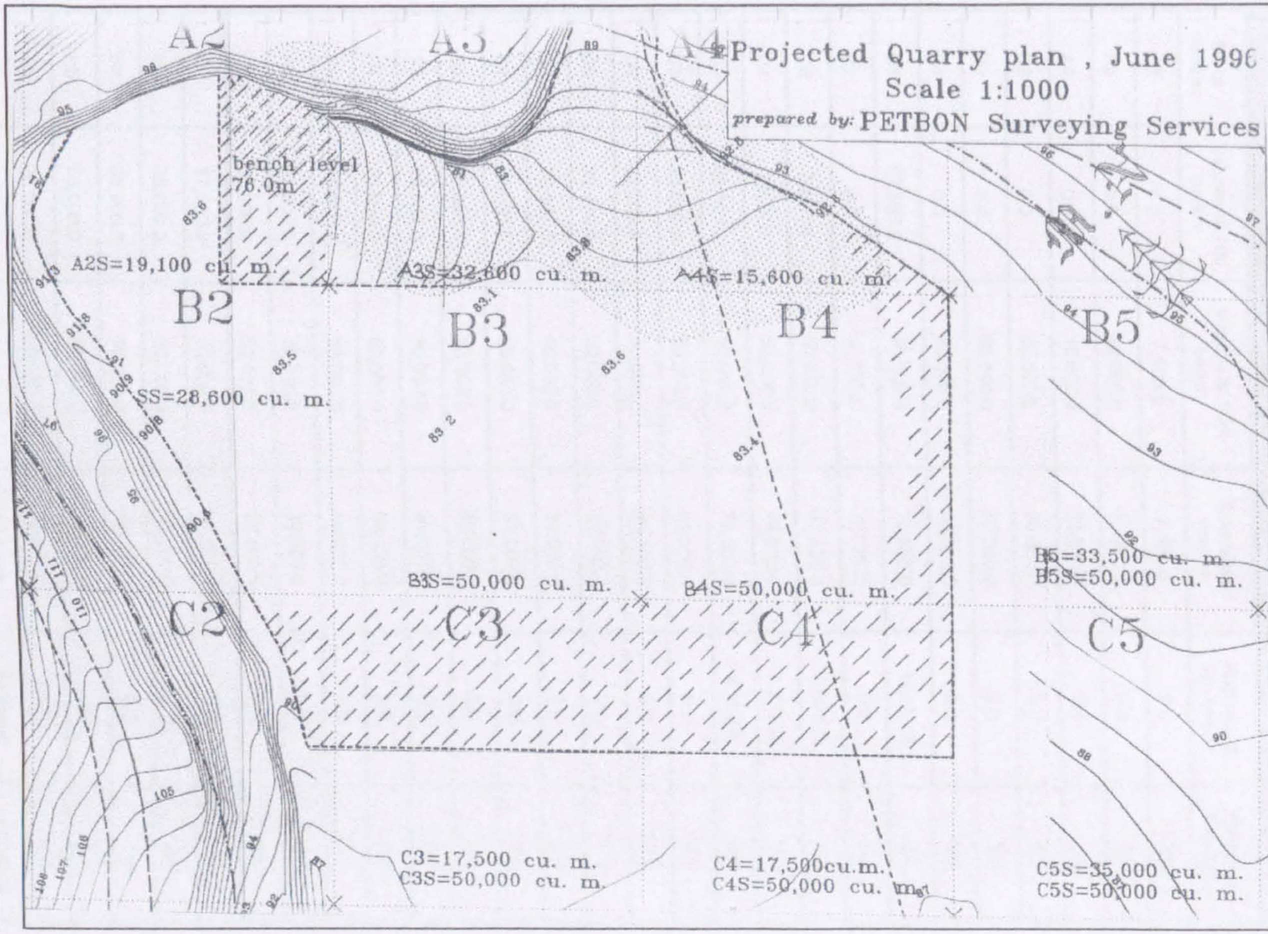


Figure 8-15 [ref 86] Block diagram

Figure 8-16 [ref 86] Block quantities

Projected limestone block quantities and reserves at January 1997					
Block number	Volume at 7m bench	Volume at 10m bench	Combined volume	Abstracted 7m bench	Abstracted 10m bench
A2	0.0	7,800.0	7,800.0	0.0	11,300.0
A3	0.0	32,600.0	32,600.0	0.0	0.0
A4	0.0	15,600.0	15,600.0	0.0	0.0
B2	0.0	28,600.0	28,600.0	0.0	0.0
B3	0.0	50,000.0	50,000.0	0.0	0.0
B4	0.0	50,000.0	50,000.0	0.0	0.0
B5	22,650.0	50,000.0	72,650.0	10,850.0	0.0
C2	0.0	4,700.0	4,700.0	0.0	0.0
C3	7,825.0	50,000.0	57,825.0	9,675.0	0.0
C4	7,825.0	50,000.0	57,825.0	9,675.0	0.0
C5	26,500.0	50,000.0	76,500.0	8,500.0	0.0
D3	35,000.0	50,000.0	85,000.0	0.0	0.0
D4	35,000.0	50,000.0	85,000.0	0.0	0.0
D5	35,000.0	50,000.0	85,000.0	0.0	0.0
E3	39,000.0	50,000.0	89,000.0	0.0	0.0
E4	35,000.0	50,000.0	85,000.0	0.0	0.0
E5	35,000.0	50,000.0	85,000.0	0.0	0.0
F3	45,000.0	50,000.0	95,000.0	0.0	0.0
F4	35,000.0	50,000.0	85,000.0	0.0	0.0
F5	35,000.0	50,000.0	85,000.0	0.0	0.0
F6	27,500.0	35,000.0	62,500.0	0.0	0.0
G3	35,000.0	50,000.0	85,000.0	0.0	0.0
G4	37,500.0	50,000.0	87,500.0	0.0	0.0
G5	35,000.0	50,000.0	85,000.0	0.0	0.0
H4	55,000.0	50,000.0	105,000.0	0.0	0.0
H5	55,000.0	50,000.0	105,000.0	0.0	0.0
J4	35,000.0	50,000.0	85,000.0	0.0	0.0
TOTALS	673,800.0	1,174,300.0	1,848,100.0	38,700.0	11,300.0

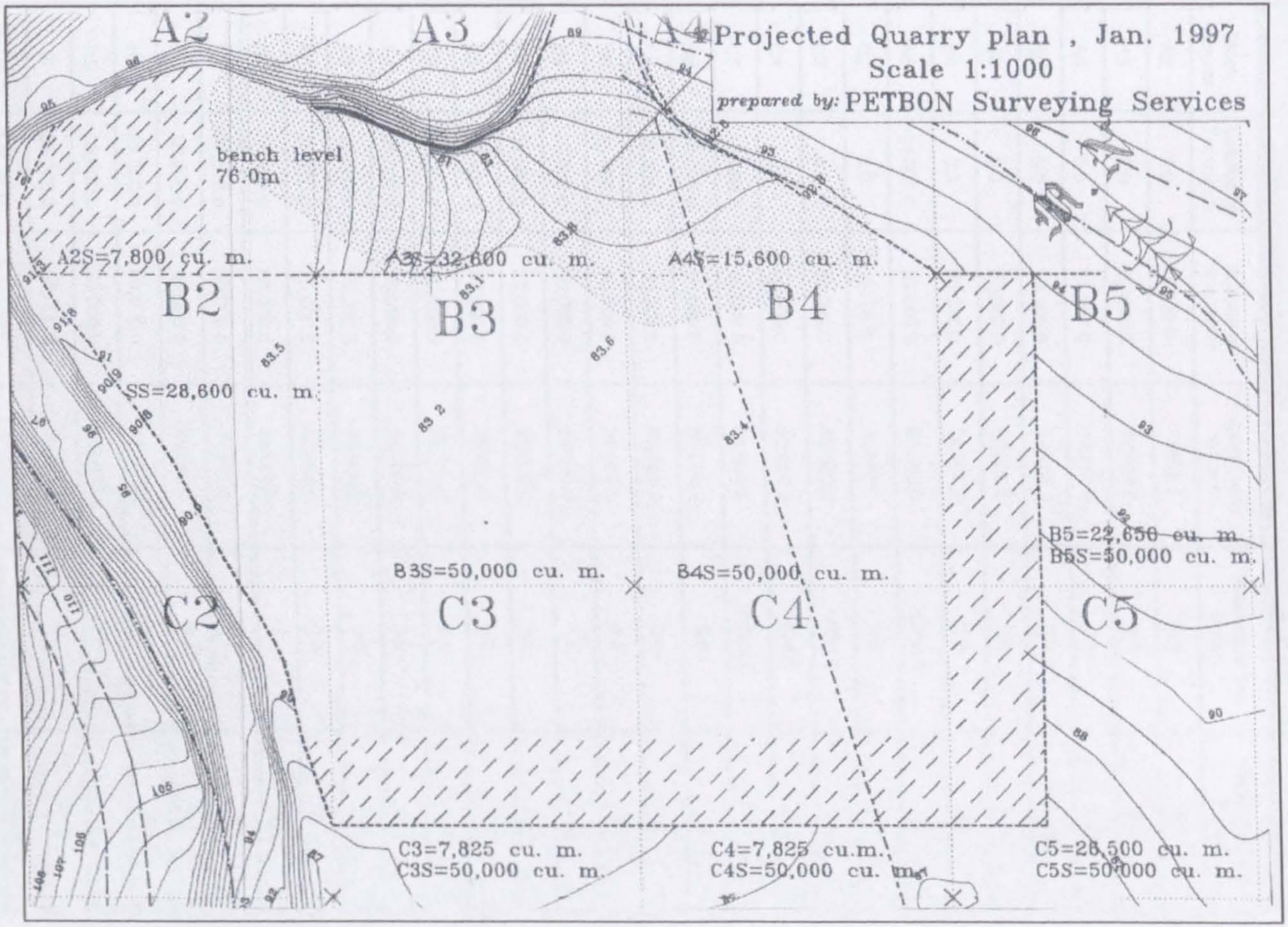


Figure 8-17 [ref 86] Block diagram

Figure 8-18 [ref 86] Block quantities

Projected limestone block quantities and reserves at June 1997					
Block number	Volume at 7m bench	Volume at 10m bench	Combined volume	Abstracted 7m bench	Abstracted 10m bench
A2	0.0	7,800.0	7,800.0	0.0	0.0
A3	0.0	32,600.0	32,600.0	0.0	0.0
A4	0.0	15,600.0	15,600.0	0.0	0.0
B2	0.0	13,100.0	13,100.0	0.0	15,500.0
B3	0.0	50,000.0	50,000.0	0.0	0.0
B4	0.0	50,000.0	50,000.0	0.0	0.0
B5	14,300.0	50,000.0	64,300.0	8,350.0	0.0
C2	0.0	4,700.0	4,700.0	0.0	0.0
C3	0.0	50,000.0	50,000.0	7,825.0	0.0
C4	0.0	50,000.0	50,000.0	7,825.0	0.0
C5	16,000.0	50,000.0	66,000.0	10,500.0	0.0
D3	35,000.0	50,000.0	85,000.0	0.0	0.0
D4	35,000.0	50,000.0	85,000.0	0.0	0.0
D5	35,000.0	50,000.0	85,000.0	0.0	0.0
E3	39,000.0	50,000.0	89,000.0	0.0	0.0
E4	35,000.0	50,000.0	85,000.0	0.0	0.0
E5	35,000.0	50,000.0	85,000.0	0.0	0.0
F3	45,000.0	50,000.0	95,000.0	0.0	0.0
F4	35,000.0	50,000.0	85,000.0	0.0	0.0
F5	35,000.0	50,000.0	85,000.0	0.0	0.0
F6	27,500.0	35,000.0	62,500.0	0.0	0.0
G3	35,000.0	50,000.0	85,000.0	0.0	0.0
G4	37,500.0	50,000.0	87,500.0	0.0	0.0
G5	35,000.0	50,000.0	85,000.0	0.0	0.0
H4	55,000.0	50,000.0	105,000.0	0.0	0.0
H5	55,000.0	50,000.0	105,000.0	0.0	0.0
J4	35,000.0	50,000.0	85,000.0	0.0	0.0
TOTALS	639,300.0	1,158,800.0	1,799,100.0	34,500.0	15,500.0

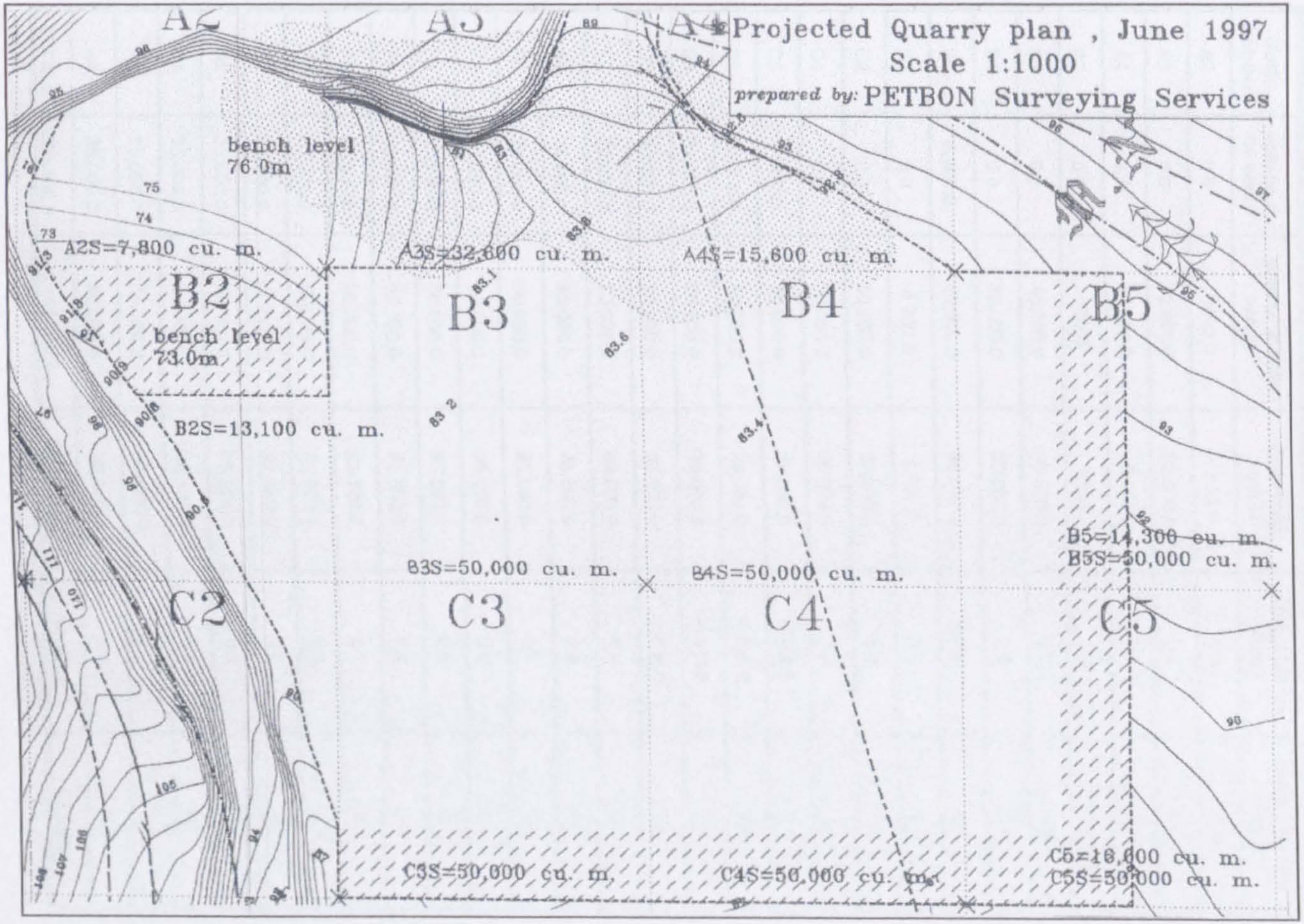


Figure 8-19 [ref 86] Block diagram

Figure 8-20 [ref 86] Block quantities

Projected limestone block quantities and reserves at January 1998					
Block number	Volume at 7m bench	Volume at 10m bench	Combined volume	Abstracted 7m bench	Abstracted 10m bench
A2	0.0	7,800.0	7,800.0	0.0	0.0
A3	0.0	32,600.0	32,600.0	0.0	0.0
A4	0.0	15,600.0	15,600.0	0.0	0.0
B2	0.0	100.0	100.0	0.0	13,000.0
B3	0.0	46,000.0	46,000.0	0.0	4,000.0
B4	0.0	50,000.0	50,000.0	0.0	0.0
B5	6,300.0	50,000.0	56,300.0	8,000.0	0.0
C2	0.0	4,700.0	4,700.0	0.0	0.0
C3	0.0	50,000.0	50,000.0	0.0	0.0
C4	0.0	50,000.0	50,000.0	0.0	0.0
C5	8,000.0	50,000.0	58,000.0	8,000.0	0.0
D3	29,000.0	50,000.0	79,000.0	6,000.0	0.0
D4	29,000.0	50,000.0	79,000.0	6,000.0	0.0
D5	30,000.0	50,000.0	80,000.0	5,000.0	0.0
E3	39,000.0	50,000.0	89,000.0	0.0	0.0
E4	35,000.0	50,000.0	85,000.0	0.0	0.0
E5	35,000.0	50,000.0	85,000.0	0.0	0.0
F3	45,000.0	50,000.0	95,000.0	0.0	0.0
F4	35,000.0	50,000.0	85,000.0	0.0	0.0
F5	35,000.0	50,000.0	85,000.0	0.0	0.0
F6	27,500.0	35,000.0	62,500.0	0.0	0.0
G3	35,000.0	50,000.0	85,000.0	0.0	0.0
G4	37,500.0	50,000.0	87,500.0	0.0	0.0
G5	35,000.0	50,000.0	85,000.0	0.0	0.0
H4	55,000.0	50,000.0	105,000.0	0.0	0.0
H5	55,000.0	50,000.0	105,000.0	0.0	0.0
J4	35,000.0	50,000.0	85,000.0	0.0	0.0
TOTALS	606,300.0	1,141,800.0	1,748,100.0	33,000.0	17,000.0

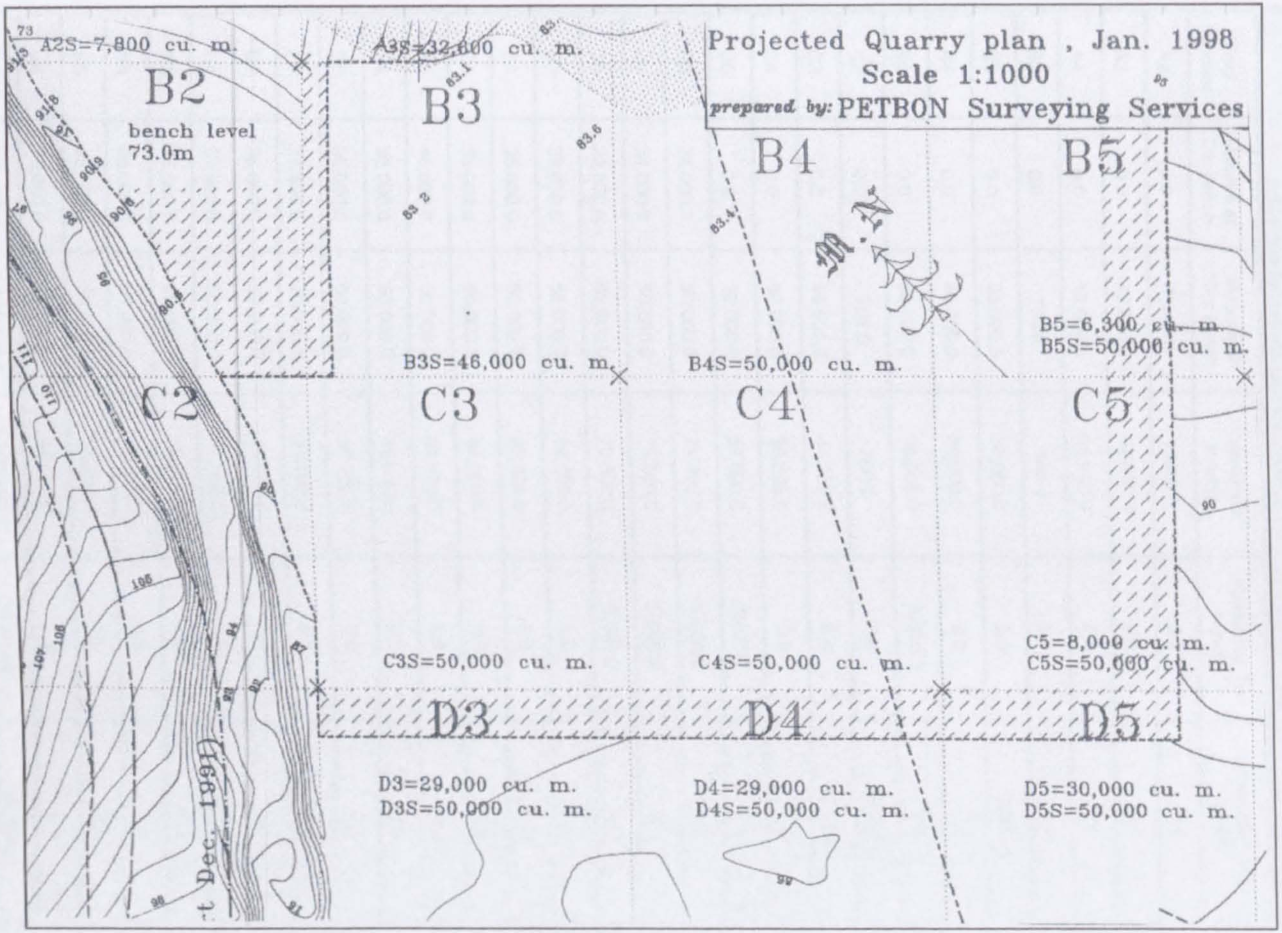


Figure 8-21 [ref 86] Block diagram

Figure 8-22 [ref 86] Block quantities

Projected limestone block quantities and reserves at June 1998					
Block number	Volume at 7m bench	Volume at 10m bench	Combined volume	Abstracted 7m bench	Abstracted 10m bench
A2	0.0	7,800.0	7,800.0	0.0	0.0
A3	0.0	32,600.0	32,600.0	0.0	0.0
A4	0.0	15,600.0	15,600.0	0.0	0.0
B2	0.0	100.0	100.0	0.0	0.0
B3	0.0	39,000.0	39,000.0	0.0	7,000.0
B4	0.0	50,000.0	50,000.0	0.0	0.0
B5	0.0	50,000.0	50,000.0	6,300.0	0.0
C2	0.0	700.0	700.0	0.0	4,000.0
C3	0.0	44,500.0	44,500.0	0.0	5,500.0
C4	0.0	50,000.0	50,000.0	0.0	0.0
C5	0.0	50,000.0	58,000.0	8,000.0	0.0
D3	24,000.0	50,000.0	74,000.0	5,000.0	0.0
D4	24,000.0	50,000.0	74,000.0	5,000.0	0.0
D5	23,500.0	50,000.0	73,500.0	6,500.0	0.0
E3	39,000.0	50,000.0	89,000.0	0.0	0.0
E4	35,000.0	50,000.0	85,000.0	0.0	0.0
E5	35,000.0	50,000.0	85,000.0	0.0	0.0
F3	45,000.0	50,000.0	95,000.0	0.0	0.0
F4	35,000.0	50,000.0	85,000.0	0.0	0.0
F5	35,000.0	50,000.0	85,000.0	0.0	0.0
F6	27,500.0	35,000.0	62,500.0	0.0	0.0
G3	35,000.0	50,000.0	85,000.0	0.0	0.0
G4	37,500.0	50,000.0	87,500.0	0.0	0.0
G5	35,000.0	50,000.0	85,000.0	0.0	0.0
H4	55,000.0	50,000.0	105,000.0	0.0	0.0
H5	55,000.0	50,000.0	105,000.0	0.0	0.0
J4	35,000.0	50,000.0	85,000.0	0.0	0.0
TOTALS	**575,500.0**	**1,125,300.0**	**1,700,800.0**	**30,800.0**	**16,500.0**

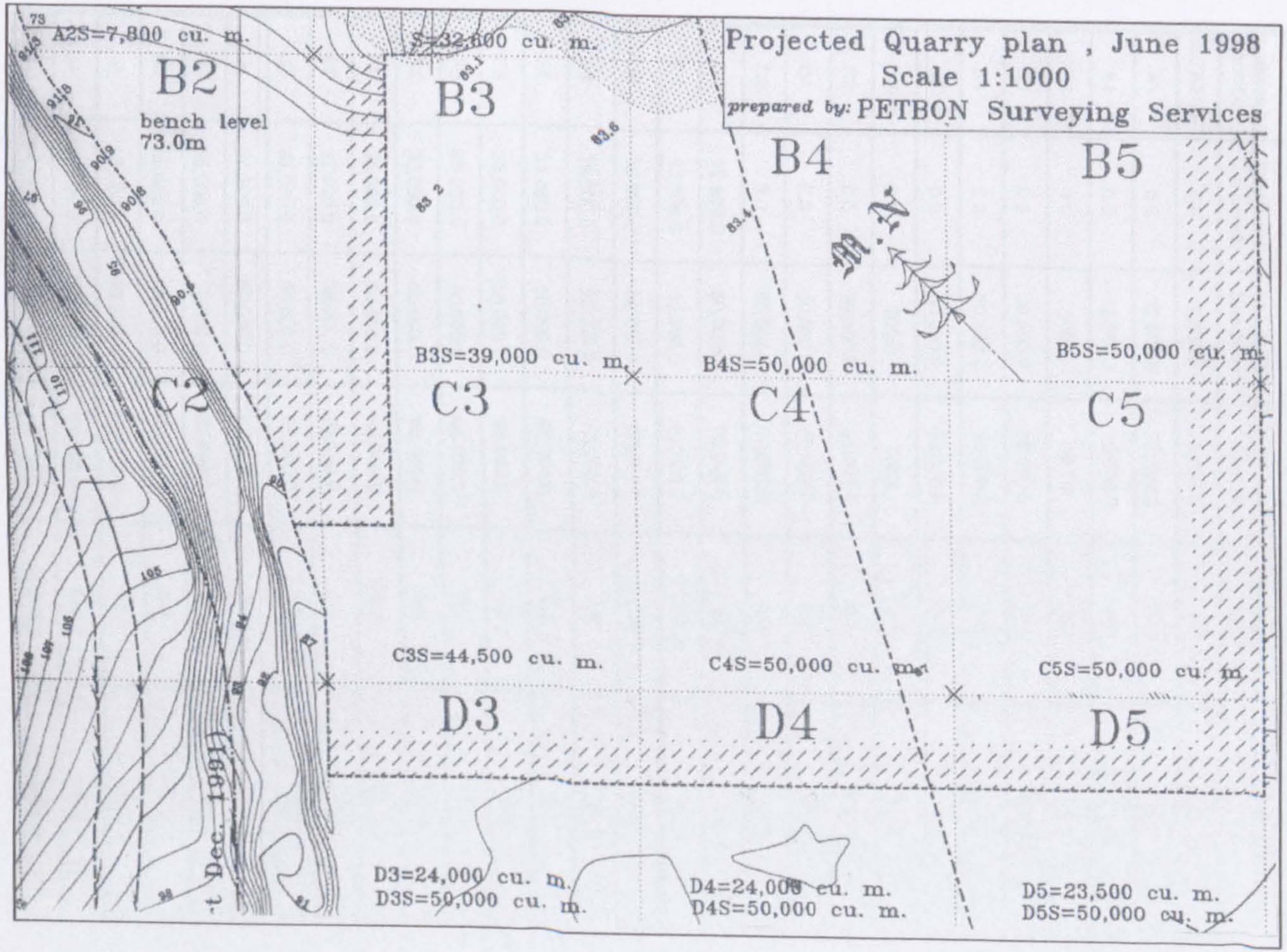


Figure 8-23 [ref 86] Block diagram

Figure 8-24 [ref 86] Block quantities

Projected limestone block quantities and reserves at January 1999					
Block number	Volume at 7m bench	Volume at 10m bench	Combined volume	Abstracted 7m bench	Abstracted 10m bench
A2	0.0	7,800.0	7,800.0	0.0	0.0
A3	0.0	32,600.0	32,600.0	0.0	0.0
A4	0.0	15,600.0	15,600.0	0.0	0.0
B2	0.0	100.0	100.0	0.0	0.0
B3	0.0	28,500.0	28,500.0	0.0	11,500.0
B4	0.0	50,000.0	50,000.0	0.0	0.0
B5	0.0	50,000.0	50,000.0	0.0	0.0
C2	0.0	700.0	700.0	0.0	0.0
C3	0.0	39,300.0	33,900.0	0.0	5,200.0
C4	0.0	50,000.0	50,000.0	0.0	0.0
C5	0.0	50,000.0	50,000.0	0.0	0.0
D3	12,900.0	50,000.0	62,900.0	11,100.0	0.0
D4	12,900.0	50,000.0	62,900.0	11,100.0	0.0
D5	12,900.0	50,000.0	62,900.0	11,100.0	0.0
E3	39,000.0	50,000.0	89,000.0	0.0	0.0
E4	35,000.0	50,000.0	85,000.0	0.0	0.0
E5	35,000.0	50,000.0	85,000.0	0.0	0.0
F3	45,000.0	50,000.0	95,000.0	0.0	0.0
F4	35,000.0	50,000.0	85,000.0	0.0	0.0
F5	35,000.0	50,000.0	85,000.0	0.0	0.0
F6	27,500.0	35,000.0	62,500.0	0.0	0.0
G3	35,000.0	50,000.0	85,000.0	0.0	0.0
G4	37,500.0	50,000.0	87,500.0	0.0	0.0
G5	35,000.0	50,000.0	85,000.0	0.0	0.0
H4	55,000.0	50,000.0	105,000.0	0.0	0.0
H5	55,000.0	50,000.0	105,000.0	0.0	0.0
J4	35,000.0	50,000.0	85,000.0	0.0	0.0
TOTALS	**542,700.0**	**1,109,600.0**	**1,652,300.0**	**33,300.0**	**16,700.0**

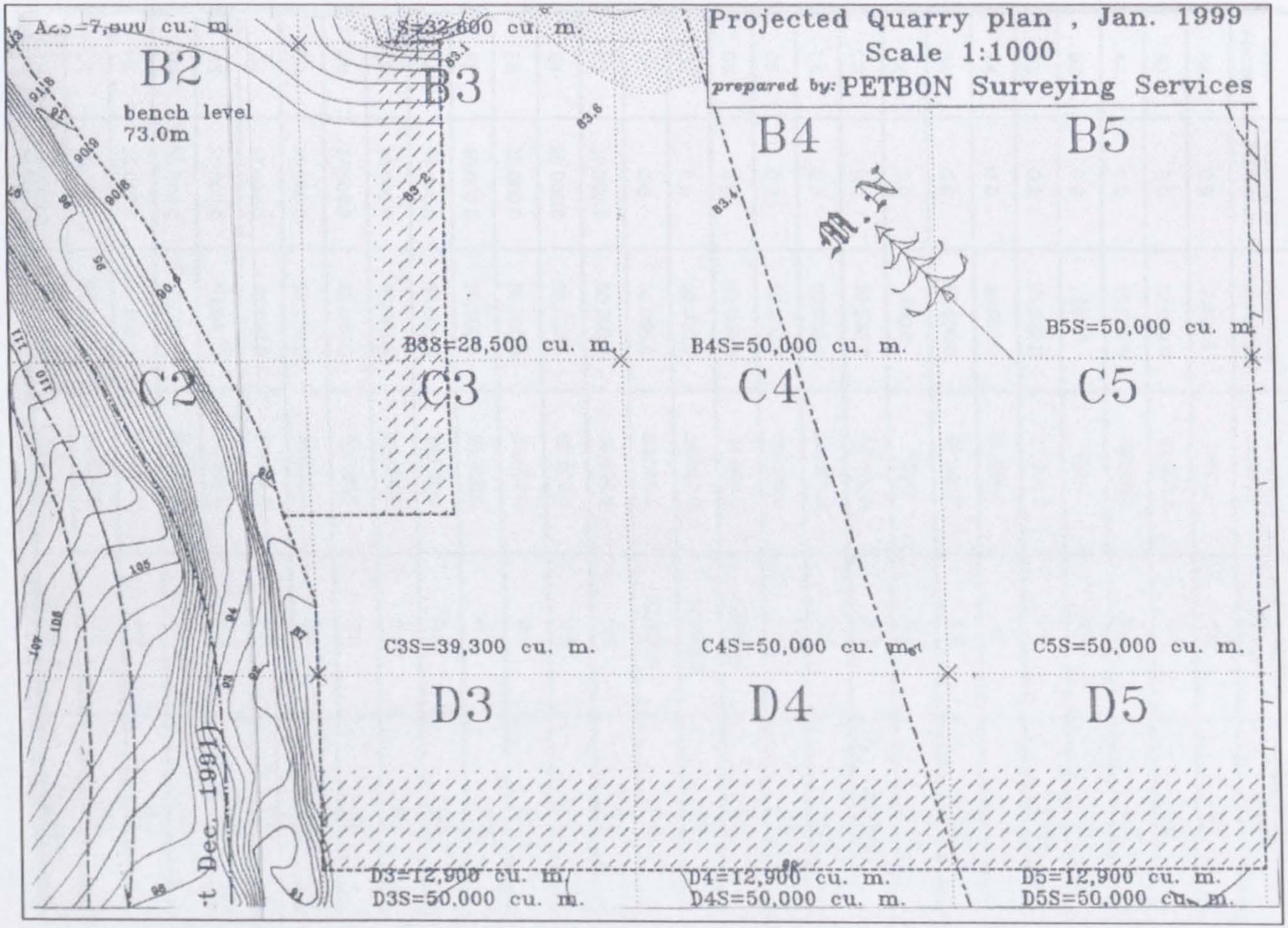


Figure 8-25 [ref 86] Block diagram

Figure 8-26 [ref 86] Block quantities

Projected limestone block quantities and reserves at June 1999					
Block number	Volume at 7m bench	Volume at 10m bench	Combined volume	Abstracted 7m bench	Abstracted 10m bench
A2	0.0	7,800.0	7,800.0	0.0	0.0
A3	0.0	32,600.0	32,600.0	0.0	0.0
A4	0.0	15,600.0	15,600.0	0.0	0.0
B2	0.0	100.0	100.0	0.0	0.0
B3	0.0	21,000.0	21,000.0	0.0	7,500.0
B4	0.0	50,000.0	50,000.0	0.0	0.0
B5	0.0	50,000.0	50,000.0	0.0	0.0
C2	0.0	700.0	700.0	0.0	0.0
C3	0.0	32,500.0	32,500.0	0.0	3,800.0
C4	0.0	50,000.0	50,000.0	0.0	0.0
C5	0.0	50,000.0	50,000.0	0.0	0.0
D3	0.0	50,000.0	50,000.0	12,900.0	0.0
D4	0.0	50,000.0	50,000.0	12,900.0	0.0
D5	0.0	50,000.0	50,000.0	12,900.0	0.0
E3	39,000.0	50,000.0	89,000.0	0.0	0.0
E4	35,000.0	50,000.0	85,000.0	0.0	0.0
E5	35,000.0	50,000.0	85,000.0	0.0	0.0
F3	45,000.0	50,000.0	95,000.0	0.0	0.0
F4	35,000.0	50,000.0	85,000.0	0.0	0.0
F5	35,000.0	50,000.0	85,000.0	0.0	0.0
F6	27,500.0	35,000.0	62,500.0	0.0	0.0
G3	35,000.0	50,000.0	85,000.0	0.0	0.0
G4	37,500.0	50,000.0	87,500.0	0.0	0.0
G5	35,000.0	50,000.0	85,000.0	0.0	0.0
H4	55,000.0	50,000.0	105,000.0	0.0	0.0
H5	55,000.0	50,000.0	105,000.0	0.0	0.0
J4	35,000.0	50,000.0	85,000.0	0.0	0.0
TOTALS	504,000.0	1,095,300.0	1,599,300.0	38,700.0	11,300.0

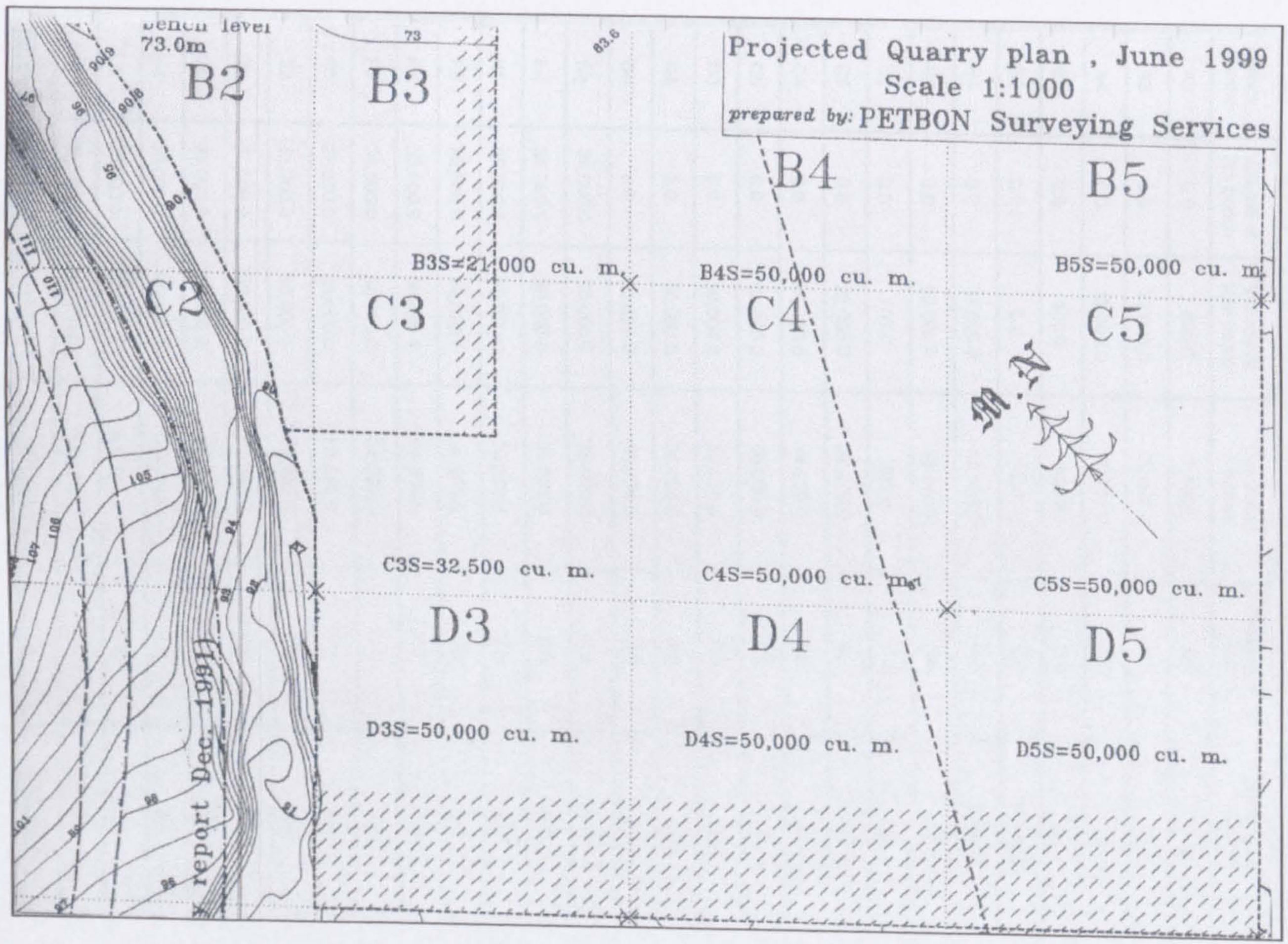


Figure 8-27 [ref 86] Block diagram

Figure 8-28 [ref 86] Block quantities

Projected limestone block quantities and reserves at January 2000					
Block number	Volume at 7m bench	Volume at 10m bench	Combined volume	Abstracted 7m bench	Abstracted 10m bench
A2	0.0	7,800.0	7,800.0	0.0	0.0
A3	0.0	32,600.0	32,600.0	0.0	0.0
A4	0.0	15,600.0	15,600.0	0.0	0.0
B2	0.0	100.0	100.0	0.0	0.0
B3	0.0	0.0	0.0	0.0	21,000.0
B4	0.0	37,500.0	37,500.0	0.0	12,500.0
B5	0.0	50,000.0	50,000.0	0.0	0.0
C2	0.0	700.0	700.0	0.0	0.0
C3	0.0	22,000.0	22,000.0	0.0	10,500.0
C4	0.0	44,000.0	44,000.0	0.0	6,000.0
C5	0.0	50,000.0	50,000.0	0.0	0.0
D3	0.0	50,000.0	50,000.0	0.0	0.0
D4	0.0	50,000.0	50,000.0	0.0	0.0
D5	0.0	50,000.0	50,000.0	0.0	0.0
E3	39,000.0	50,000.0	89,000.0	0.0	0.0
E4	35,000.0	50,000.0	85,000.0	0.0	0.0
E5	35,000.0	50,000.0	85,000.0	0.0	0.0
F3	45,000.0	50,000.0	95,000.0	0.0	0.0
F4	35,000.0	50,000.0	85,000.0	0.0	0.0
F5	35,000.0	50,000.0	85,000.0	0.0	0.0
F6	27,500.0	35,000.0	62,500.0	0.0	0.0
G3	35,000.0	50,000.0	85,000.0	0.0	0.0
G4	37,500.0	50,000.0	87,500.0	0.0	0.0
G5	35,000.0	50,000.0	85,000.0	0.0	0.0
H4	55,000.0	50,000.0	105,000.0	0.0	0.0
H5	55,000.0	50,000.0	105,000.0	0.0	0.0
J4	35,000.0	50,000.0	85,000.0	0.0	0.0
TOTALS	**504,000.0**	**1,045,300.0**	**1,549,300.0**	**0.0**	**50,000.0**

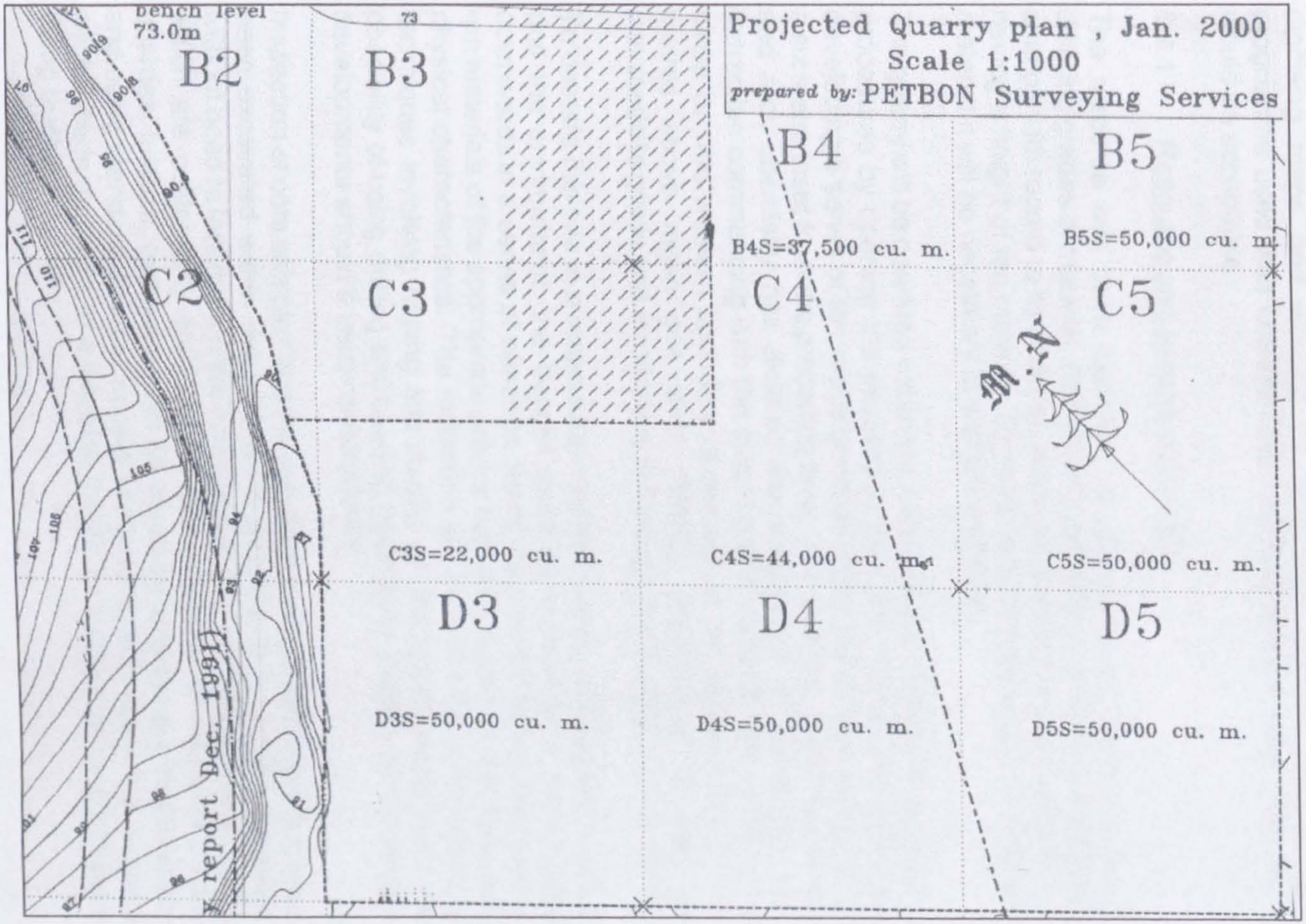


Figure 8-29 [ref 86] Block diagram

8.4.0 A SAMPLE PHYSICAL QUARRYING PLAN.

The following quarry plan was produced by the Writer, [ref 90] for a limestone quarry to serve a cement plant, the drawing were produced by digitising maps and working in "Computer Assisted Design", the programme used was Drawfix CAD, but any other similar programme would be acceptable.

8.4.1 Resource and general description

The resource has been identified as consisting of three chemically differing grades of material. Additionally the reserve contains horizons of change with regard to its bedding, these horizons have been identified as having a height of ten metres. To produce a homogenous run of quarry material it will be necessary to blend the grades.

The quarry will be operated within the conventional codes of practice and procedures by opening the excavation from the highest elevation and developing a series of ten metre benches. Each bench level being given a six metre inset from the preceding level. The relatively complex geology and rock chemistry has dictated the progression of extraction, with extraction commencing with the lowest grade material, this being found close to the western boundary of the site at its highest point of 135 metres above mean sea level (AMSL), progressing through the intermediate grade and terminating in the high grade at 45 metres AMSL.

To operate this site in a responsible manner, paying due regard to safety and the environment, the deposit must be worked from the surface downwards in a series of benches, taking into consideration the need to win materials of the appropriate grades both with regard to chemistry and physical characteristics. The extraction will consist of a combination of techniques involving ripping and dozing on the upper levels, with the possibility of using drilling and blasting techniques in parts of the deeper developments should it become necessary.

Inspection of core samples and the results of various trial pits which have been excavated within the site, show that the rock can be exploited without need to incorporate the advanced drilling and blasting techniques which are customarily employed in the operation of most hard rock quarries. Instead, excavation will be made by employing a heavy dozer and using standard downhill ripping and dozing techniques the material will be made available to a wheeled loader for loading into rigid chassis dump trucks.

Road construction

Before quarrying can begin, a road will be constructed to the area of operations. It is recommended that the road starts from the area found to the south east of the new clinker processing plant at grid reference 385,700 east 2,029,500 north and terminates at a convenient point within the extraction area, this has been identified as grid reference 384,600 east 2,029,900 north.

The first 500 metres of the road, that is, the road extending from the proposed plant site, will for the life of the quarry be permanent routing and because of this, it is recommended that it is constructed to a high standard with regard to ;

▸	routing	to follow the natural contours
▸	elevation	and gradients not to exceed 1:12
▸	width	not less than 15 metres
▸	drainage	drainage on high banking and super-elevation with culverts
▸	safety barriers	ARMCO barriers where required
▸	signing	clearly legible road signs conforming to country standard
▸	surfacing	concrete at turning points and asphalt throughout
▸	road marking	to conform with local standard
▸	priorities	to be clearly marked

This road will connect to various feeder roads. During the life of the quarry and to adapt to the changing locations of the active benches, the feeder roads will be redesigned and re-routed several times. These roads need not be built to as high a standard as the permanent road. To achieve an acceptable inclination, usually 1:12, the road follows natural contours, the rise of 55 metres and the short distance available, will not require that the length of the road is extended by looping. Should looping be considered, attention must be paid to the arc of visibility and all the bends to be horizontal.

Efforts should be made to ensure that the road is designed to have a minimal visual impact, both during construction and use. Dust will be controlled by the application of a water spray, adequate drainage will provided to prevent flooding. The permanent road can be screened by planting screens of leafy trees, this will reduce the nuisances of dust and noise.

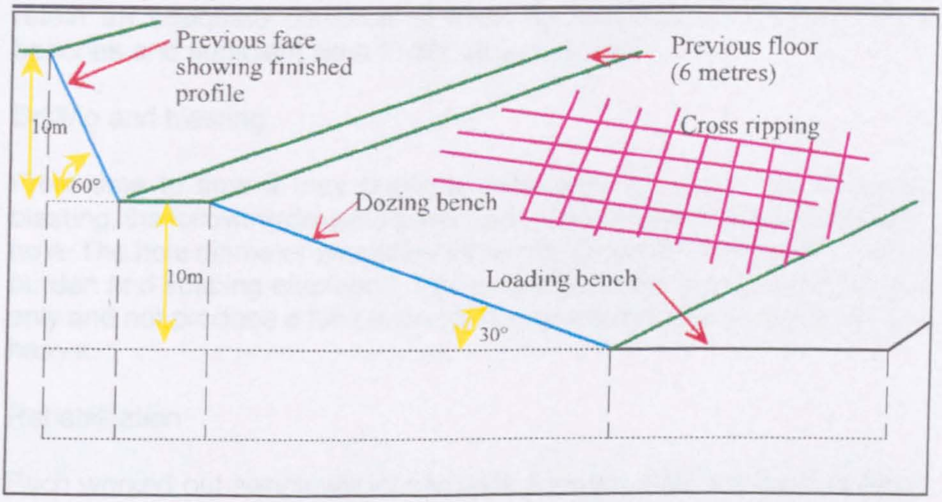
Bench development

Most quarries, whether they are a hole in the ground or cutting into the side of a hill will operate a series of benches. A bench is a step or level cut into the side of the rock, one bench consists of a floor and a face, with the floor being the horizontal section and the face being the vertical or angled section.

Bench height

The bottom of the vertical face is known as the toe, and the top is the crest. Typical bench heights in a modern quarry, range from five to fifteen metres. Within reason, the higher the face, the more cost effective is the operation, however, with enforced legislation the benches will be reduced to a minimum. The benches in this quarry have been chosen to be operated to a compromised vertical height of ten metres, this height is considered to be the minimum necessary in order to enable sufficient scope for blending of the materials.

Figure 8-30 [ref 90] Bench details



Bench inclination

To assist in stability the face is usually angled back from the vertical, this inclination is described in degrees from the vertical and ranges from vertical to twenty degrees with between five to fifteen degrees being the norm. In this mine, the operation will made by use of ripping and dozing and a shallow bench angle is required. To enable satisfactory blending, a face angle of sixty degrees from the vertical is recommended, this will result in a lateral dozing slope of 17 metres length.

Bench inclination (final perimeter)

As the working benches approach the outer limit of the quarry, they will be designed and developed to remain as a perimeter bench or wall. The angle of the face is usually kept as steep as the rules of rock mechanics allow. This is to allow the maximum amount of material to be quarried without having the lower benches encroach too much into the deposit. As this operation is one of dozing and not blasting, the perimeter bench will be excavated to remain at a steeper angle than the working bench and thirty degrees from vertical is considered satisfactory. The face can be accurately cut by using a hydraulic excavator.

Bench floor

It is likely that the chemistry of the rock will dictate the progression of the various bench levels. There is no particular requirement to operate the benches sequentially, however, development of the benches and advance drilling may suggest a local deviation from the main plan, resulting in several benches being worked in parallel. Although a working bench will have a floor width of at least sixty metres, the floor left behind on the perimeter bench will be six metres only. This is small enough to avoid leaving the hill with an obvious stepped appearance, but large enough to retain an adequate distance to allow for longitudinal draining of the benches and sufficient area to act as a rock trap.

Drilling and blasting

From time to time it may become necessary to loosen the rock with blasting, the following drawing gives approximate details of a charged drill-hole. The hole diameter should be 89 mm and a square drilling of 3 metres burden and spacing employed. The purpose of this, is to loosen the rock only and not produce a full bench blast with maximum fragmentation and heave.

Rehabilitation

Each worked out bench will incorporate a longitudinal downwards slope in the floor of three degrees. This is to direct water away from the main workings and into a surface drain. Settling ponds should be constructed within the drain to trap suspended solids and to provide a facility, if required to modify the PH of the water. With a bench floor remaining of six metres, a vertical face height of ten metres and a face angle of thirty degrees, the composite overall angle of the hill when excavations are complete will be approximately 45 degrees or 1:1. As each bench reaches the perimeter, it will have its top soil replaced and vegetation re-established, details of the recommended types of vegetation are given in the section on the environment.

Method of development

The type of limestone that has been identified in the deposit indicates that it can be mined with the use of a heavy dozer to first rip, then push the material to a loader. Specific types of dozers and loaders are detailed in the section titled Mobile Plant. Bench development will begin by excavating a road into the new bench at its floor level, the dozer will then cross rip at 45 degrees to a depth of one metre, on completion of ripping it will excavate the rock and push it to the road for loading. Development will progress from this area towards the bench perimeter, effectively retreat mining. The bench will be worked towards its floor level at a an angle of thirty degrees from the horizontal, this being a suitable angle for the operation of a heavy dozer. A hydraulic excavator will be needed to cut the final perimeter and produce the stable type of benches that are required for the faces to remain exposed after the cessation of quarrying.

8.4.2 Conceptual reserve calculation

The geological study has identified a physically consistent, young rock which is substantially without faulting, bedding planes or major jointing. *The rock has, however,* been found to have contain many voids, both small and large and much micro jointing *and fracturing.* The method of extraction that is envisaged *will enable* the whole of the identified deposit to be exploited. As a result of this, the volume of the *available resource,* can be simply calculated by area mapping and void calculation. For both social and physical environmental reasons, a 100 metre stand off has been made from the public roads and habitations. The reserve has been specifically calculated by identifying individual ten metre bench levels, the area, applying a fill factor (assuming that all the ten metres is not available and there are some losses) and calculating to reach the volume. A specific gravity of 1.8 has been employed to arrive at the mass (this being the approximate dry density of the rock) in tonnes and the volumes have been rounded off. The criteria are discussed in subsequent sections

Figure 8-31 [ref 90] Reserves

LIMESTONE	MINE				
Bench Floor level	Floor area in m^2	Fill factor	Volume in m^3	Density factor	Mass in tonnes
125 m	36,000.00	0.20	72,000.00	1.80	129,600.00
115 m	312,000.00	0.50	1,560,000.00	1.80	2,808,000.00
105 m	535,000.00	0.85	4,547,500.00	1.80	8,185,500.00
95 m	789,000.00	0.85	6,706,500.00	1.80	12,071,700.00
85 m	728,000.00	0.85	6,188,000.00	1.80	11,138,400.00
75 m	464,000.00	0.85	3,944,000.00	1.80	7,099,200.00
65 m	423,000.00	0.90	3,807,000.00	1.80	6,852,600.00
55 m	335,000.00	0.95	3,182,500.00	1.80	5,728,500.00
45 m	163,000.00	0.95	1,548,500.00	1.80	2,787,300.00
			31,556,000.00		56,800,800.00

Using the tables shown above, the total extractable limestone technical reserve is calculated at 56,800,800.00 tonnes and rounded to 57,000,000.

The usage factor is entirely subject to the final raw meal mix design.

The following pages show drawings produced by the writer for a feasibility study carried out for International Mining Consultants Limited of the UK.

The first drawing shows the grade of limestone with regard to calcium carbonate content.

The next series of drawings show the development of the quarry, bench by bench. The quantities that are shown in the main text were calculated from these drawings by using the cad facility to measure the top bench contour, the bottom bench contour and the vertical interval to calculate the volume. After arriving at a fill factor (the estimated filling between the two contours taking into account the topography) a reasonably accurate volume could be arrived at. As this volume was calculated bench by bench, it is a simple matter to log the progress of the mine by simply deducting the expected annual or monthly rate of extraction from the relevant bench level.

The last drawing is a composite image of each bench superimposed upon the previous bench.

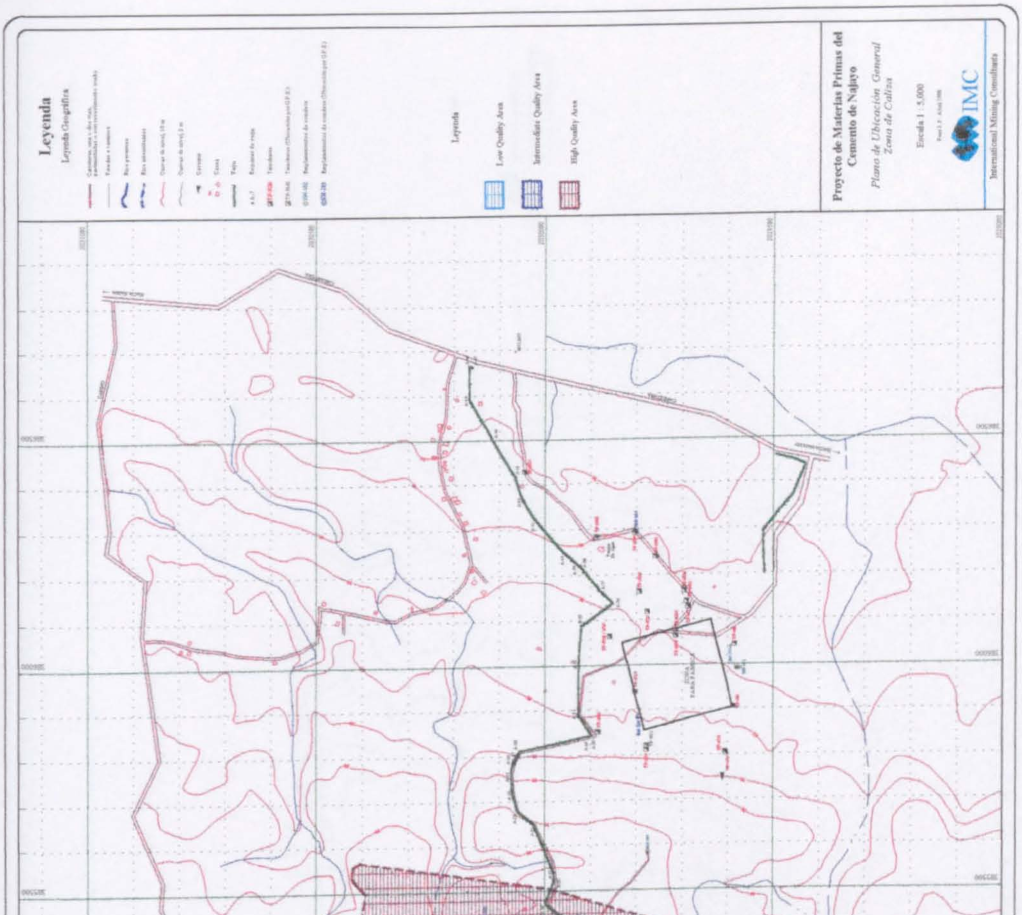


Figure 8-32 [ref 90] Grades of limestone

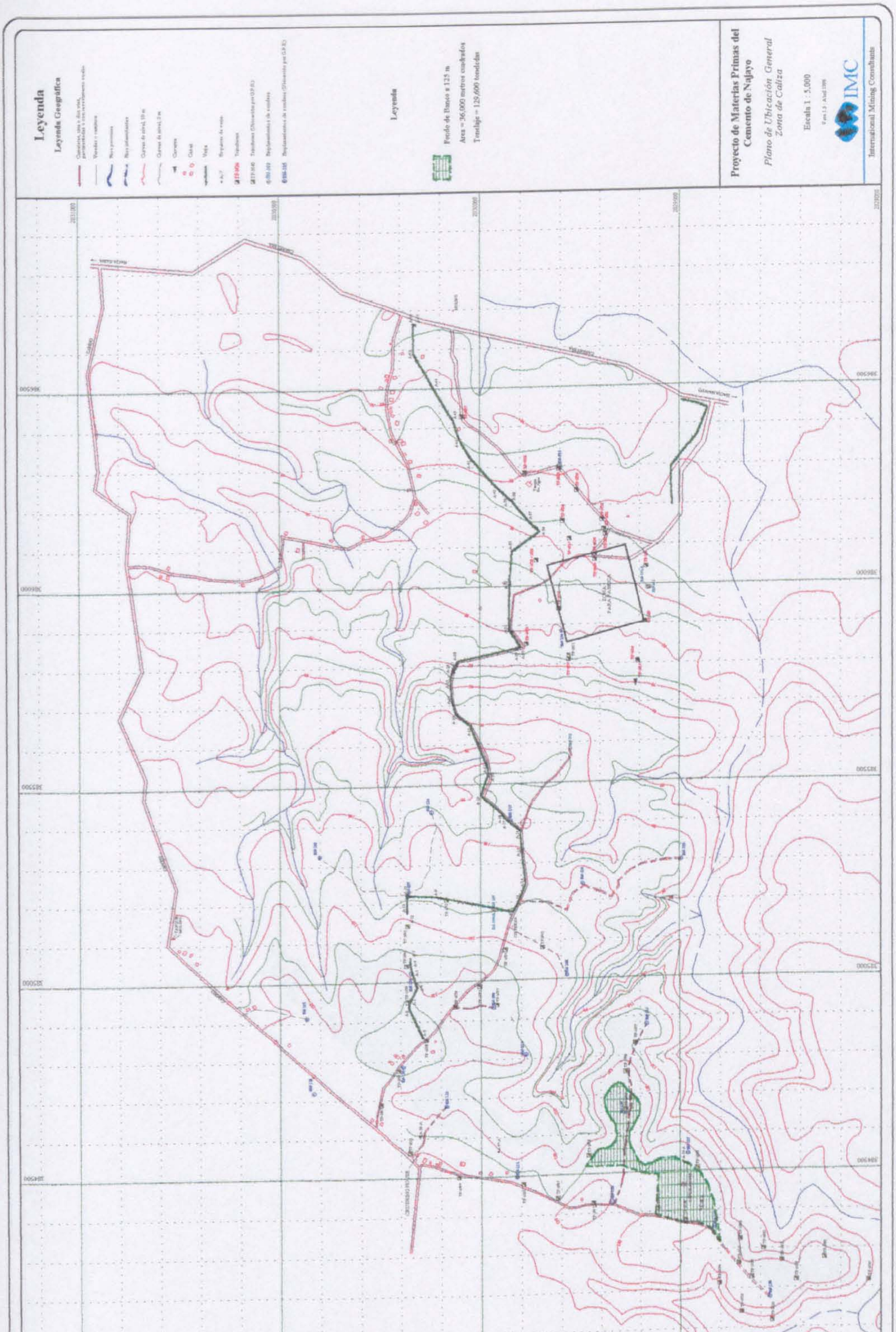


Figure 8-33 [ref 90] 125 metre bench

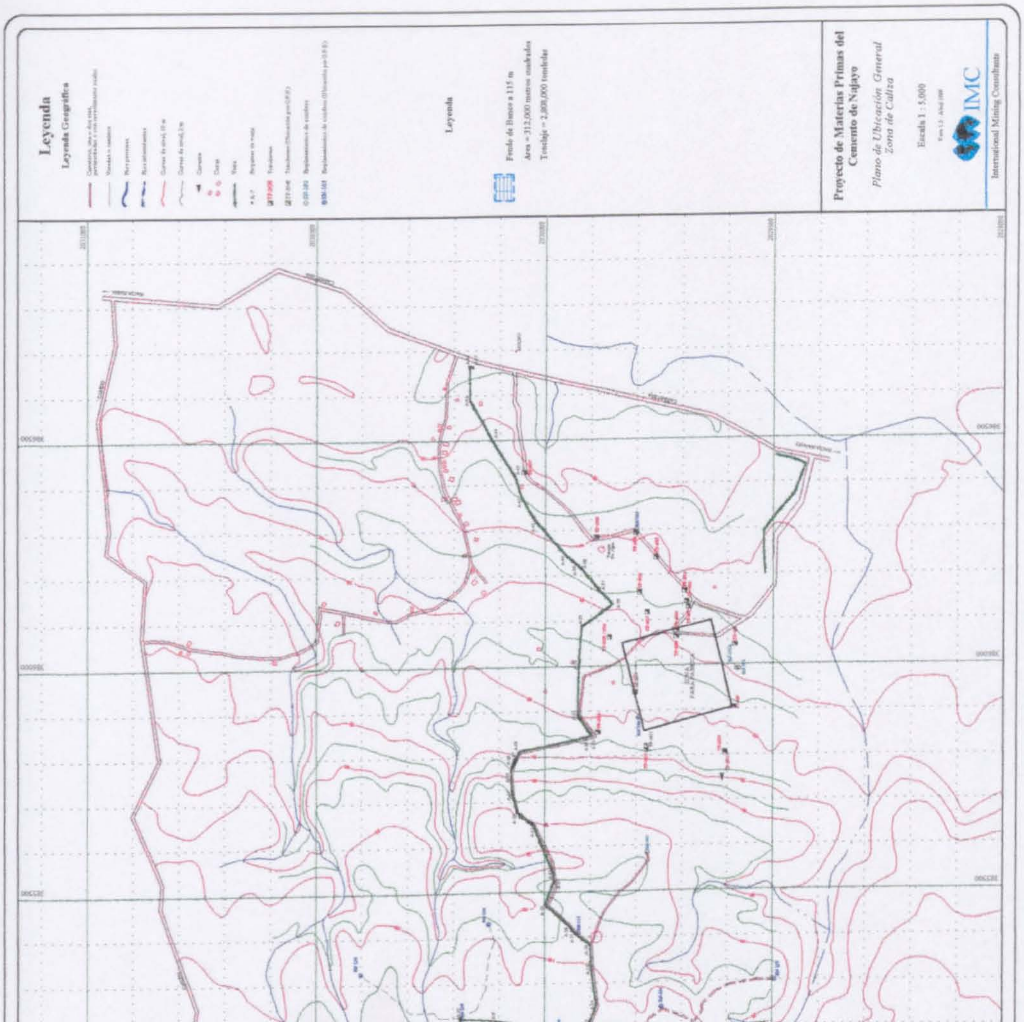


Figure 8-34 [ref 90] 115 metre bench

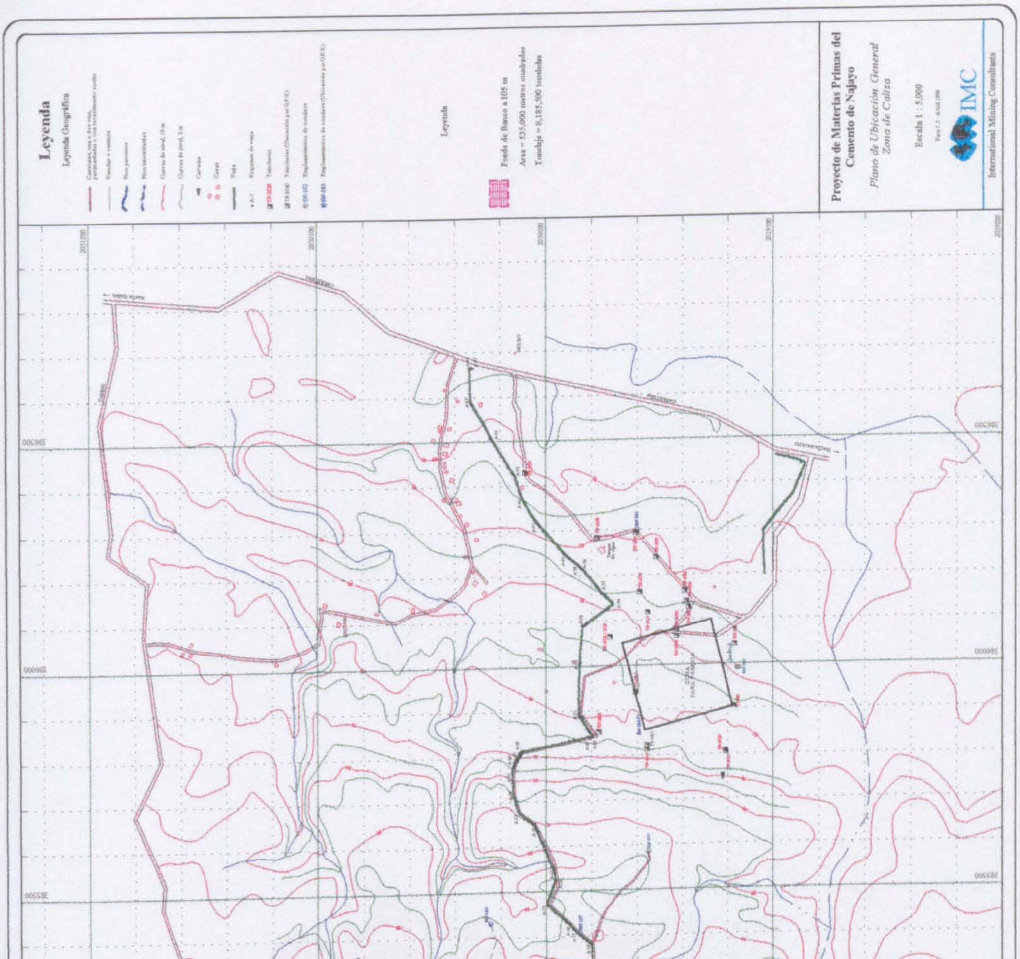


Figure 8-35 [ref 90] 105 metre bench

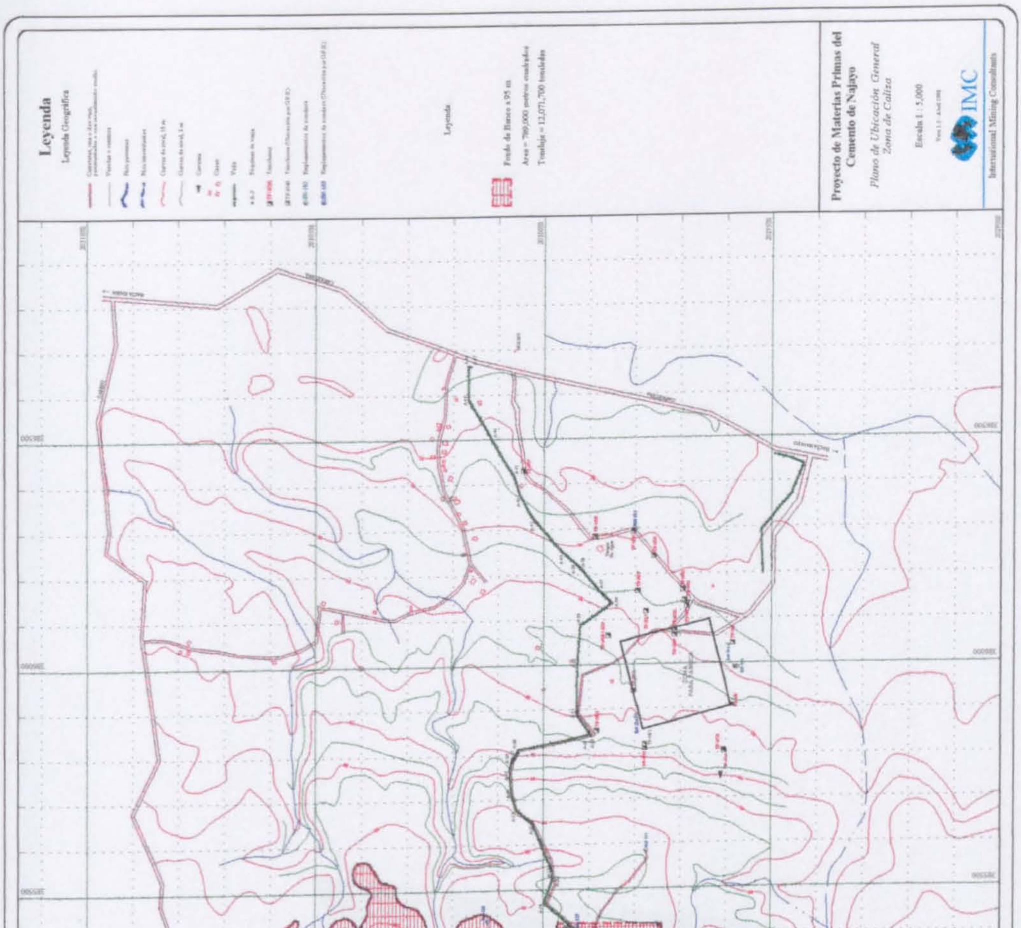


Figure 8-36 [ref 90] 95 metre bench

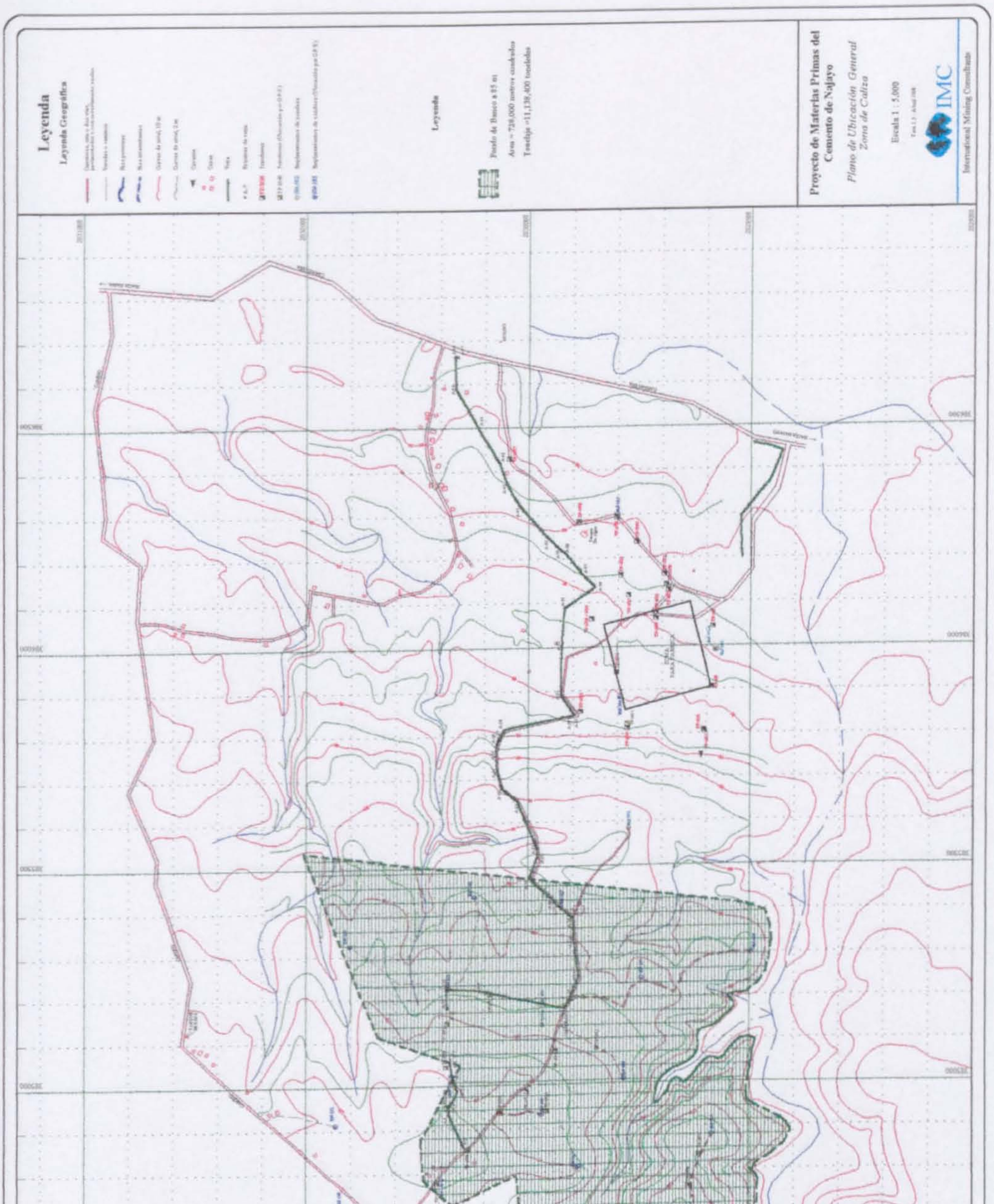


Figure 8-37 [ref 90] 85 metre bench

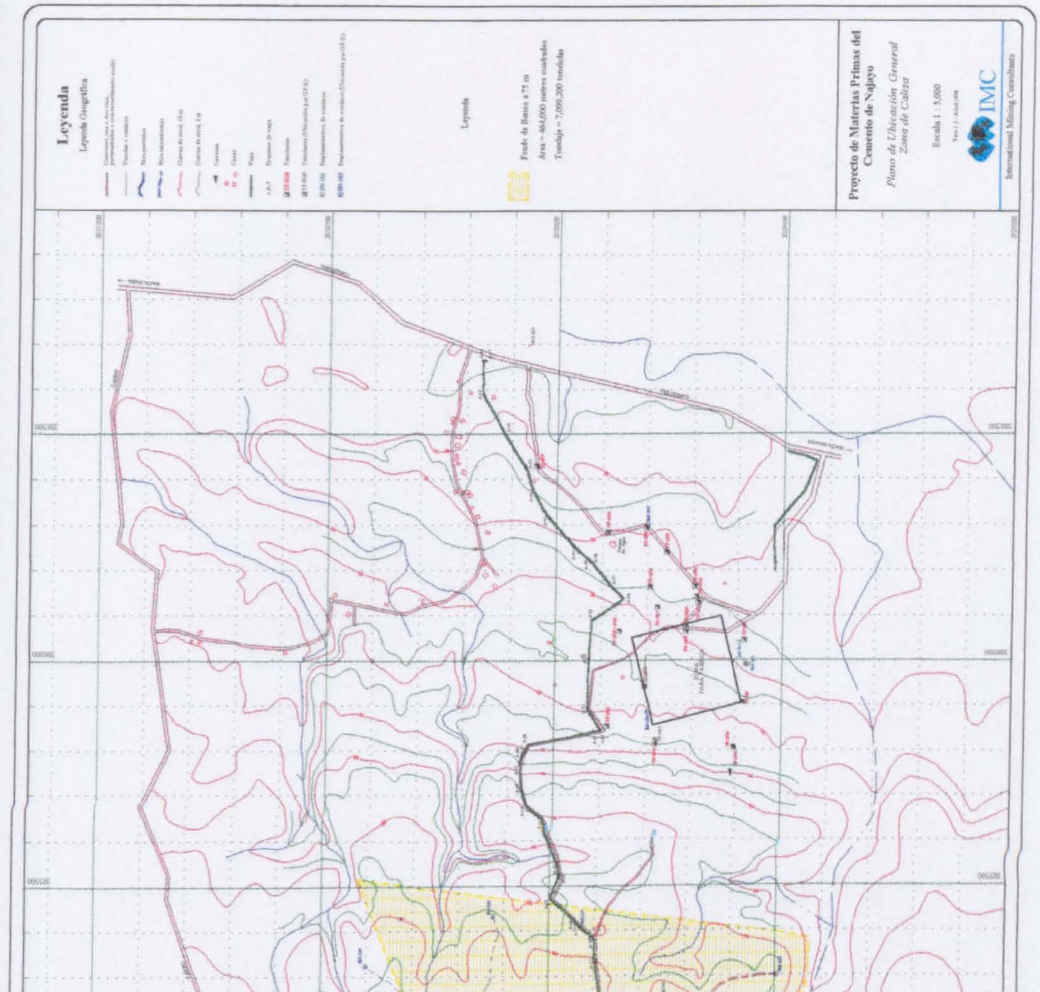


Figure 8-38 [ref 90] 75 metre bench

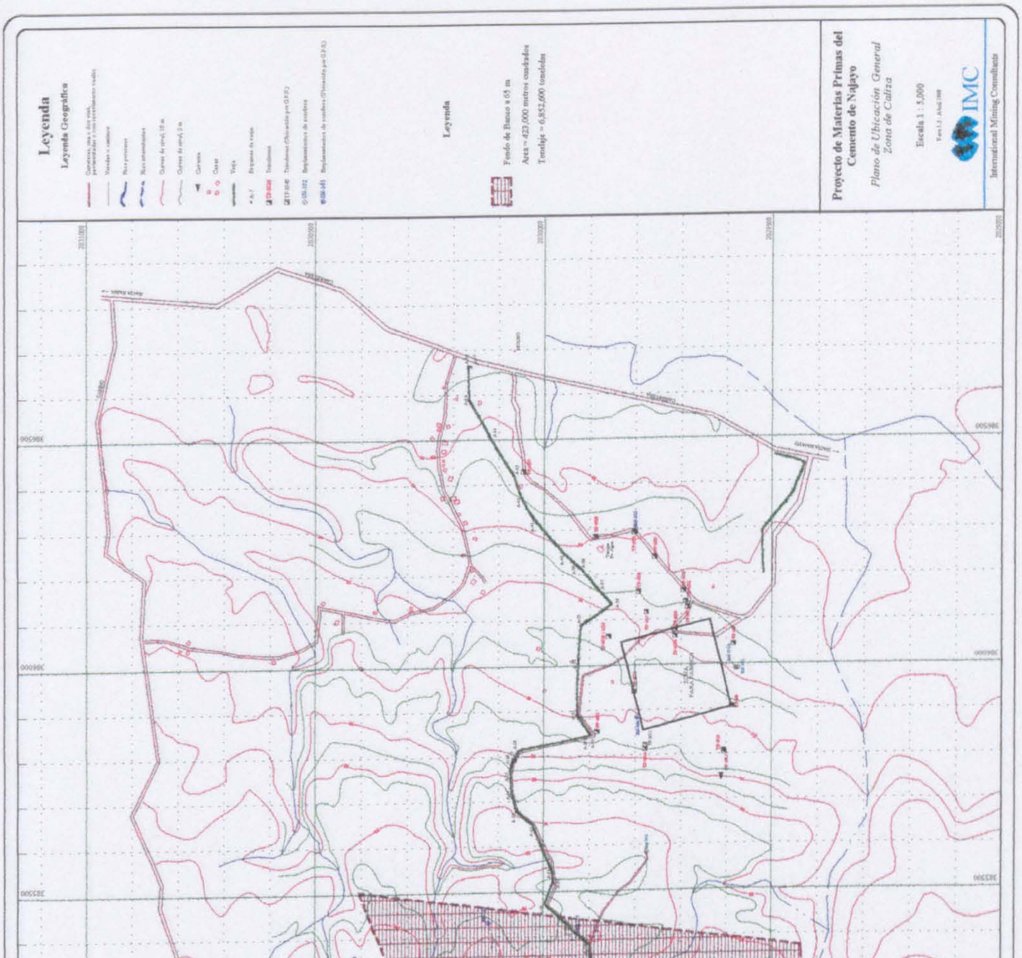


Figure 8-39 [ref 90] 65 metre bench

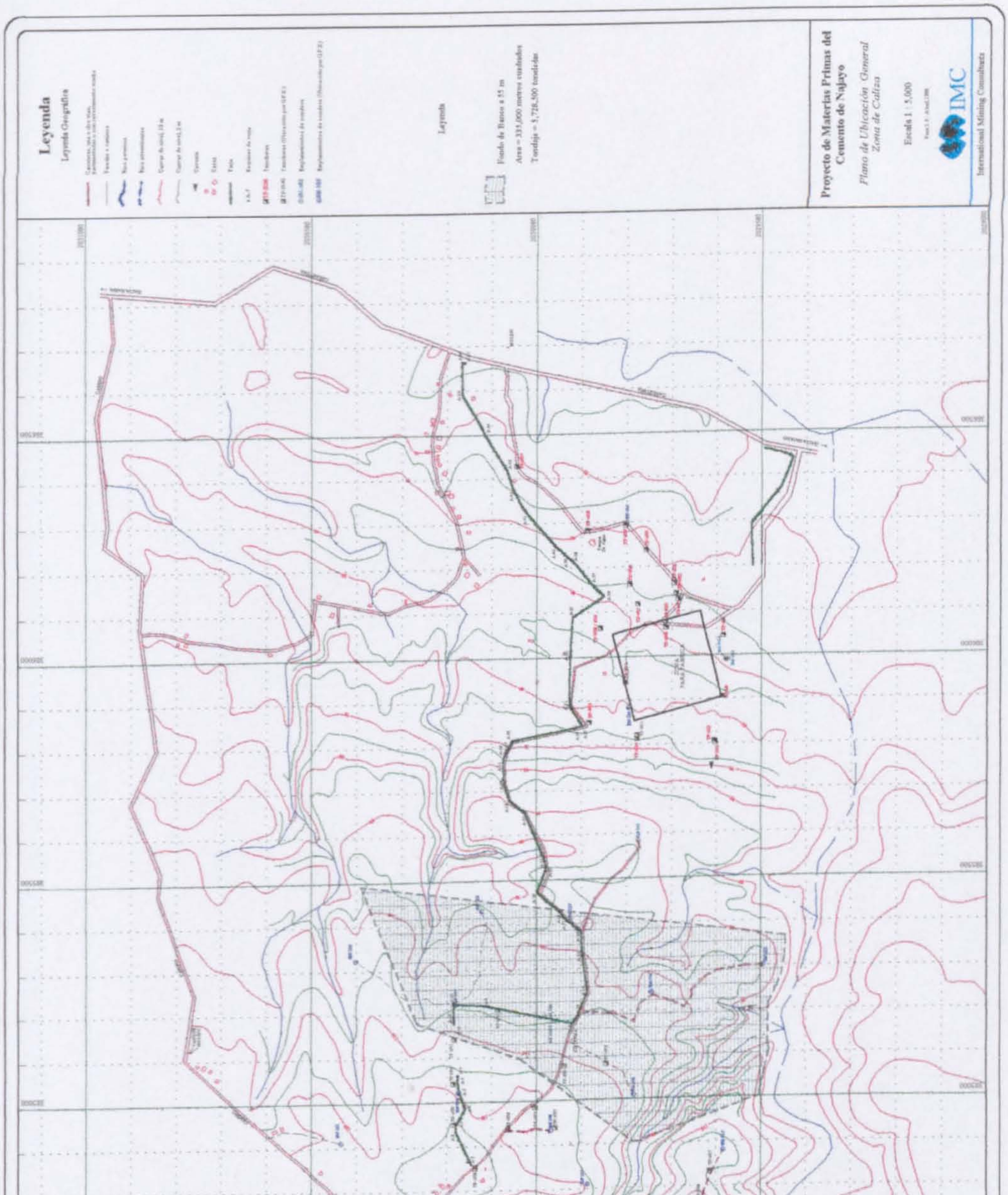


Figure 8-40 [ref 90] 55 metre bench

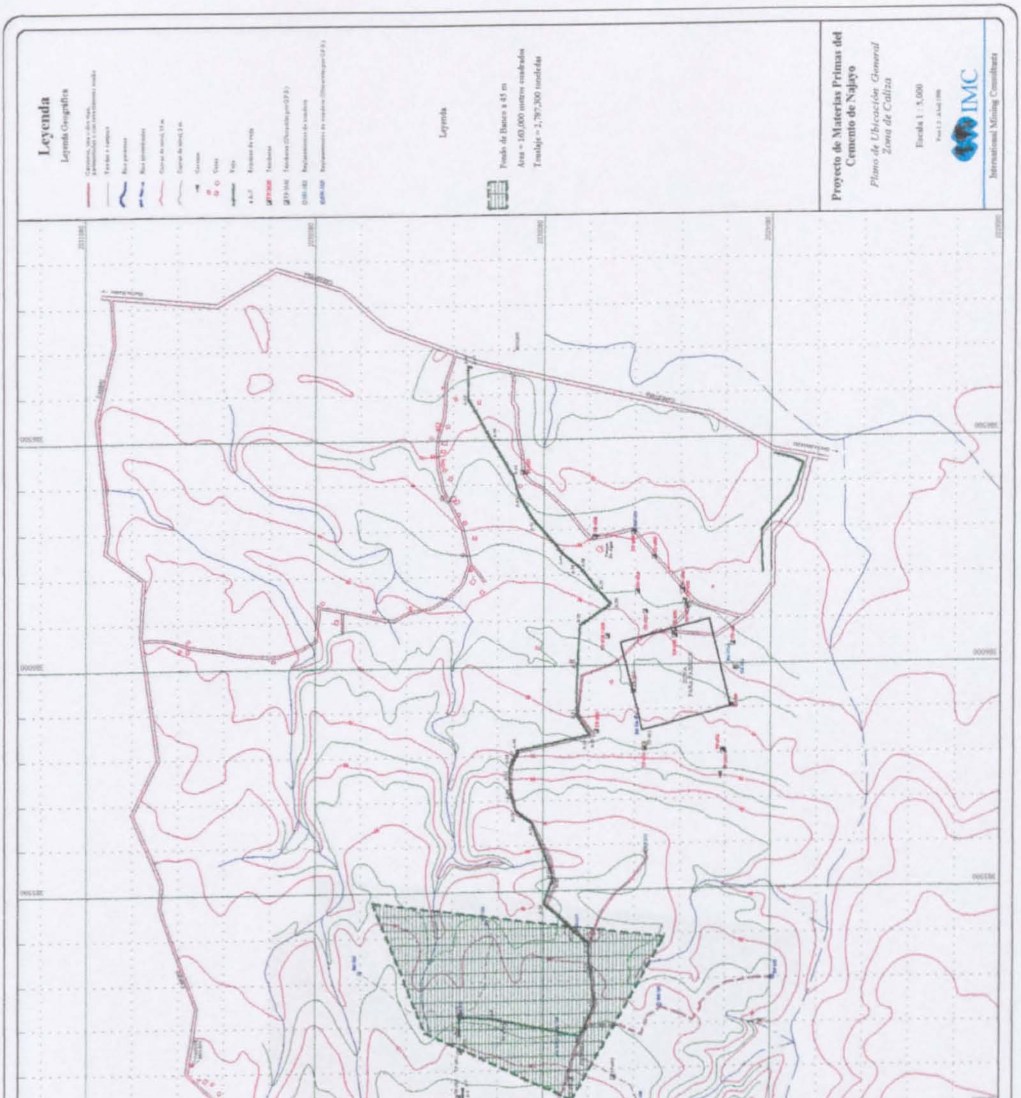


Figure 8-41 [ref 90] 45 metre bench

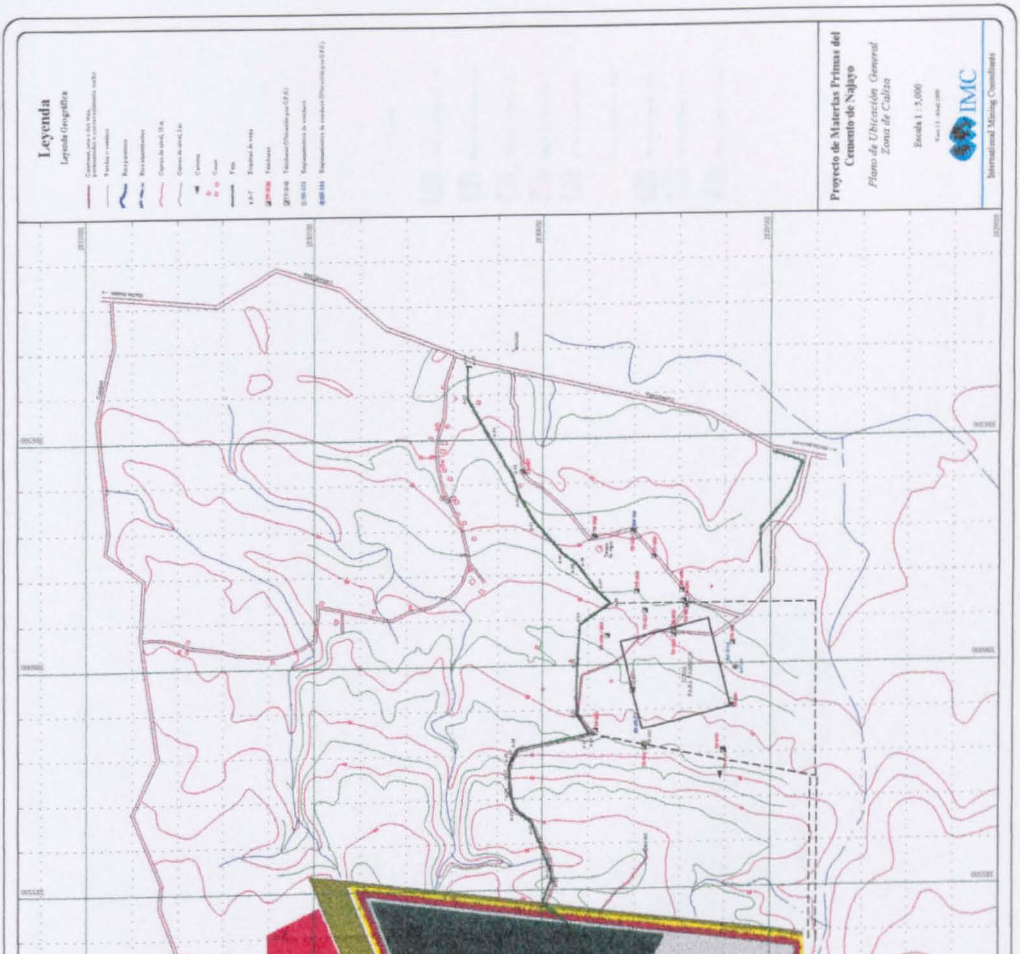


Figure 8-42 [ref 90] Composite view

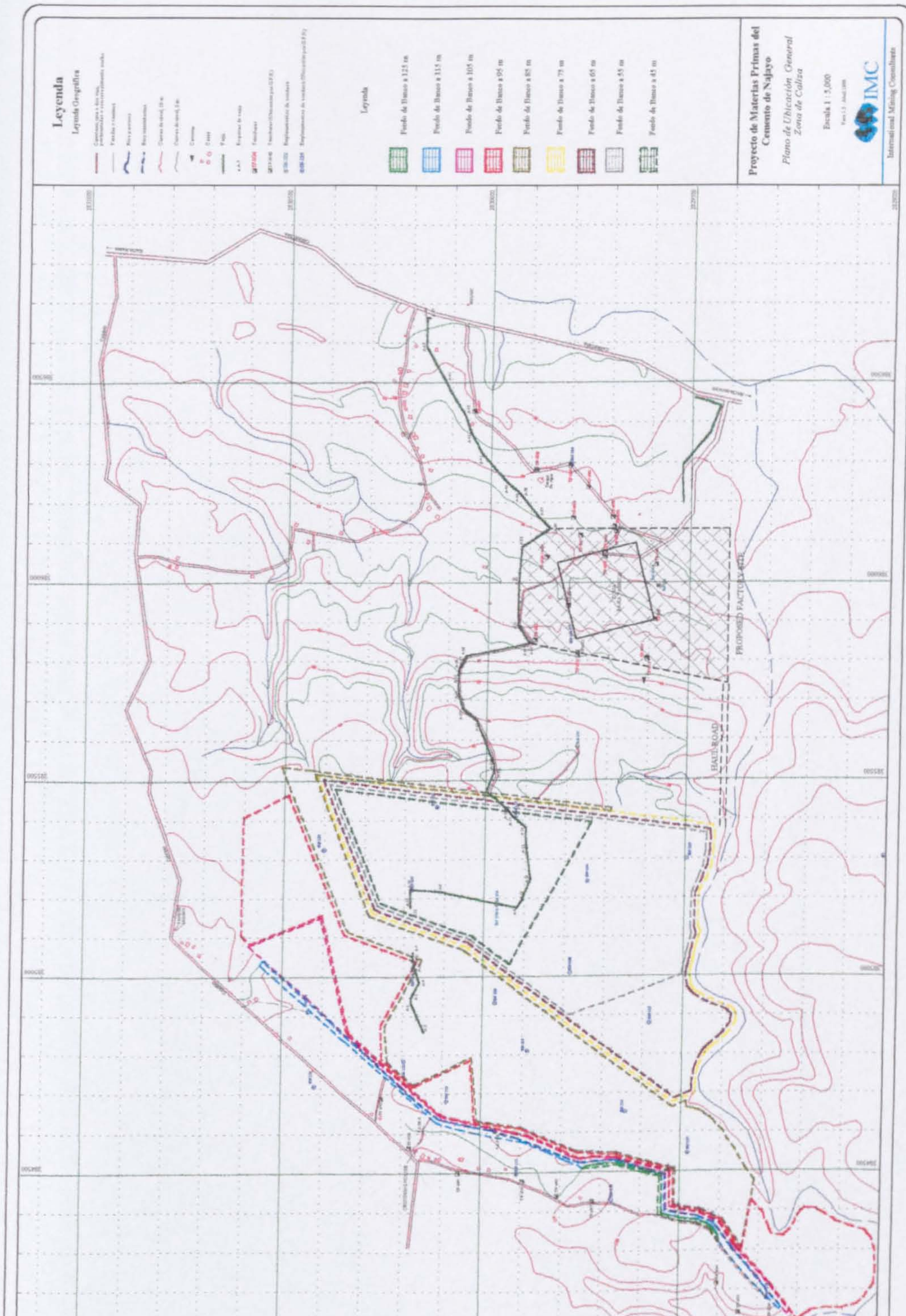


Figure 8-43 [ref 90] Composite bench view