Study the nature of the minerals in Quarried Limestone and Laterite to the Cement burning process

By
W.R. Kumara
(01/AS/022)

The thesis submitted in Partial fulfillment of the requirement for the degree of
Bachelor of Science
In
Natural Resources

Department of Natural Resources
Faculty of Applied Sciences
Sabaragamuwa University of Sri Lanka
Buttala, 91100

July 2005

Declarations

The work describe in this thesis was carried out by me at the Holcim Lanka (Ltd), under the supervision of Mr.W.A.S.A.G.Janz and Dr.A.L.T.Hewawasm. A report of this has not been submitted to any other university to any other degree.

W.Ruwan Kumara
(01/AS/022)
13/09/2005

Certified by,

External supervisor.
Mr.W.A.S.A.G.Janz,
The Quarry Manager,
Holcim Lanka (Ltd),
Puttalam,
13/09/2005.

Quarry Manager
HOLCIM (LANKA) LTD,
Aruwakkalu Quarry Site
Eluwankulam - Puttalam.

Internal supervisor,
Dr.A.L.T.Hewawasm,
Department of Natural resources,
Faculty of Applied Sciences,
Sabaragamuwa University of Sri Lanka,
Buttala.
13/09/2005

13/09/2005

Prof.M.S.Rupasinghe,
The Head of department,
Department of natural resources,
Faculty of Applied Sciences,
Sabaragamuwa University of Sri Lanka,
Buttala.
13/09/2005

10/10/2005

Acknowledgement

I would like to express my warm appreciation to my internal supervisor Dr.A.L.T.Hewawasm, The Lecturer, Department of Natural Resources, Faculty of Applied Sciences, Sabaragamuwa University of Sri Lanka, for his valuable guidance and supervision throughout the project.

I also wish my deepest thank to my external supervisor Mr. W.A.S.A.Janz, The Quarry Manager, Holcim Lanka (Ltd), Aruwakkalu, Puttalam, for his encouragement and assistance to continues support that was given me to complete this project successfully.

My deep sense of gratitude to Prof.M.S.Rupasinghe, the head of department, Department of Natural Resources, Faculty of Applied Sciences, Sabaragamuwa University of Sri Lanka, for the consultation given me.

My sincere thank goes to my colleagues who supported me during my project.

Abstract

All the cement raw materials contain constituents other than the main constituent. Sometime these unwanted minerals or impurities cause problems in cement manufacturing process. They cause negative effect on the reaction take place inside the kiln.

The clinker production rates have been reduced in August and September of year 2004, due to affect of those impurities of raw materials. Therefore, the quartz was identified as major impurity, which is affected to cement burning process.

The Quartz has some special characteristic like, highly chemical inertness, High melting point, Specific crystal structure and high hardness (7). Therefore, the quartz removing is very important to get quality clinker with low production cost. Several methods were introduced to minimize quartz in cement raw materials as removing of some quartz layers by optical identification, Better bed cleaning methods and planned material collection system.

A 3D model was prepared by analysis of large amount of representative samples to show the quartz variation of the quarry. Therefore, it will be very useful to future quarry planning without or minimum quartz in the cement raw materials and get quality clinker without burning problems.

Table of Content

Chapter 01

Chapter 02

Chapter 03

Chapter 04

Chapter 05

List of Tables **Page**

List of Figures **Page**

CHAPTER 01
INTRODUCTION AND OBJECTIVES

1.1 Introduction

1.1.1. The study area

1.1.1.1. Location

The Aruwakkalu Limestone Quarry is located in Wanatavillu Division, approximately 30 Km to the North of Puttalam in Northwestern Province. The Puttalam-Eluvankulam minor road is lying 5 km of East of the Quarry and in the western boundary lies the shore of the Puttalam Lagoon. The Kale Oya River delineates the northern part of Quarry.

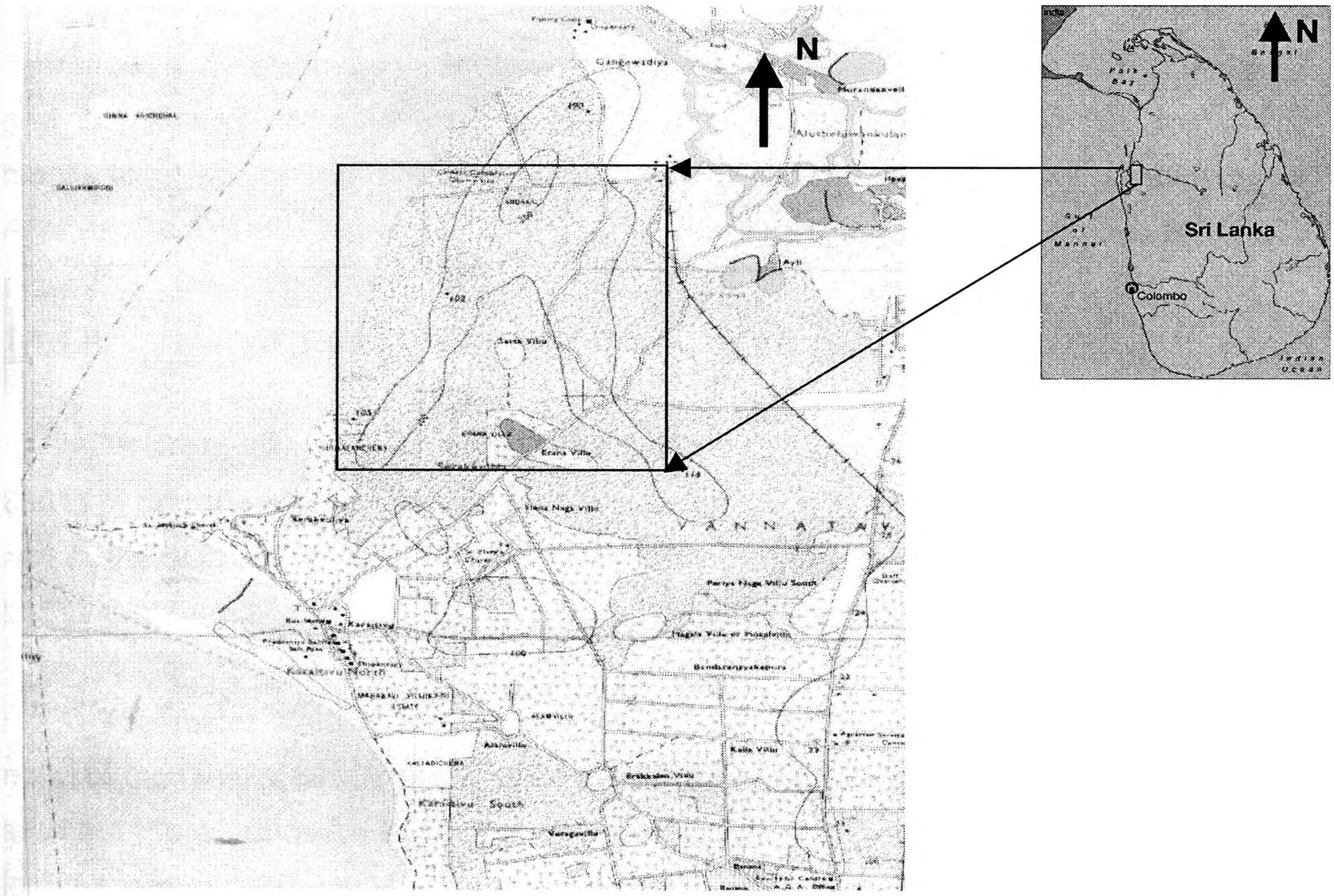


Figure 1.1. A photograph of the study area, Quarry site, Aruwakkalu. Showing the limestone deposit located beneath the dry evergreen forest cover.

1.1.1.2. Climate of the study area.

The area falls within the so-called Semi arid Zone of Sri Lanka, which is characterized by average annual rainfalls of between 500 mm - 650 mm. Most of rain falls during the northeast monsoon regime between October and February. In contrast the area suffers from drought during the southwest monsoon between May and September. The average temperatures for the year range from minimum of 24^0 C to a maximum of 30.6^0 C (Asesoria, 1991).

1.1.1.3. Vegetation and Land use of the study area

The Aruwakkaru Limestone Quarry is located within the Tropical Dry Mixed evergreen and deciduous forest types. The trees are usually less than 12 m in height and it is dense non-lofty scrubs characterized vegetation. The forest community mainly consists of (palu) *Manilkara hexandra.* Other common plant species are *Azadirachta indica, Chloroxylon switenia,* and *Amelocissus indica* (Asesoria, 1991).

1.1.1.4. Topography and Drainage of the study area

The Aruwakkalu Quarry traces between 343000 N - 336794 N and 94400 E - 98611 E and the highest elevation of more than 65 m is recorded at the Aruwakkalu Hill. At the southwest corner of the Quarry, topography is drops away to less than 5m just in land from the shores of the Puttalam Lagoon (Asesoria, 1991).

The major Kala Oya River discharges into the Puttalam Lagoon just to the north of the Quarry boundary. There are no other permanent streams noted in Quarry area but there are in lower lying areas, which appear only in wet season. These are located around Periya Naga Villu South, Erana Villu and Seta Villu shows as marshes (Asesoria, 1991).

1.1.1.5. Geology and Hydrology of the study area

In this area under reference, Limestone formations of Miocene age occur below a cover of red earth of Pliestoncene to recent age. The thickness of soil cover, as revealed from borehole data, varies from a few meters to over 35 m. The soil, which is sandy in nature, consist of Brick-red Sands, which are generally uniform and consist predominantly of grains of Quartz with Heavy minerals principally Ilmanite and fine Ferruginous Clay. Colouration of the grains is imparted by Hematite, which appears to have formed a coating on them. The Limestone is fine to medium grained, loosely compacted and cavernous. On the basis of physical and chemical characteristic, the Limestone is classified in to Limestone, Siliceous Limestone and Calcareous Sandstone. Being shallow water deposition, frequent changes in physical and chemical characteristics of Limestone are observed in the form of Bands. The Limestone is often marked with the occurrence of Clay bands. The typical Limestone is hard, partly granular, compact, indistinctly bedded and cream coloured. The Limestone is massive in places but some layers are richly fossliferous and weathered into a honeycombed mass. Thin Sandy beds are interlayered within the Limestone body. These calcareous formations are nearly flat with 2^0 - 5^0 dips towards West (Lagoon Side). Under the influence of structural deposition, part of the Limestone deposit extends below the Lagoon. Due to the sub-surface water percolation, formation of cavities in the Limestone is quite pronounced especially in the upper-part Red Earth, occurring over it, has percolated with water and subsequently deposited in the spaces (Cooray, 1995).

In this coastal area, under the influence of Puttlam Lagoon, the water table is governed by the sea level and the water is saline in nature. In the area under reference, especially in the Limestone terrains adjoining the sea, the water table is has been observed to be affected by tidal conditions (Asesoria, 1991).

1.1.2. The limestone burning issue of the Puttalam cement plant.

1.1.2.1. Introduction of cement manufacturing process.

Cement is an ultra fine gray powder; bind Rock and Sand into mass or matrix of concrete. Limestone and Laterite are used as a major raw material to produce cement. Cement is an artificial Silicate consists of Silicon, Calcium, and Aluminum, which is taken from limestone, and Laterite.

C_2S - Dicalcium Silicate
C_3S - Tricalcium Silicate
C_3A - Tricalcium Aluminate
C_3AF - Tricalcium Alumino Ferrite

To form the above minerals Calcium is obtained from limestone while Aluminum, Iron and Silicon are mainly added from Laterite. Dolomite and some other minerals are added as additives to increase the quality of cement.

Limestone transported from the quarry are broken into small pieces of 2-3 cm at the crusher and mixed with Laterite to a special ratio. (Limestone-95%and Laterite-5%) The Ballmill powders this mixture approximately below 212um. Resulted powder is stored inside the Raw mill Silo until they are mixed to a ratio and transported through Cyclone preheated system. The heated raw meal enters to the Kiln. The chemical reactions to convert the raw material into above clinker minerals take place inside the kiln at a temperature of 1400 ^{0}C. The clinker is transported to cement mill where it ground with Gypsum and different types of final cement products to suit different uses

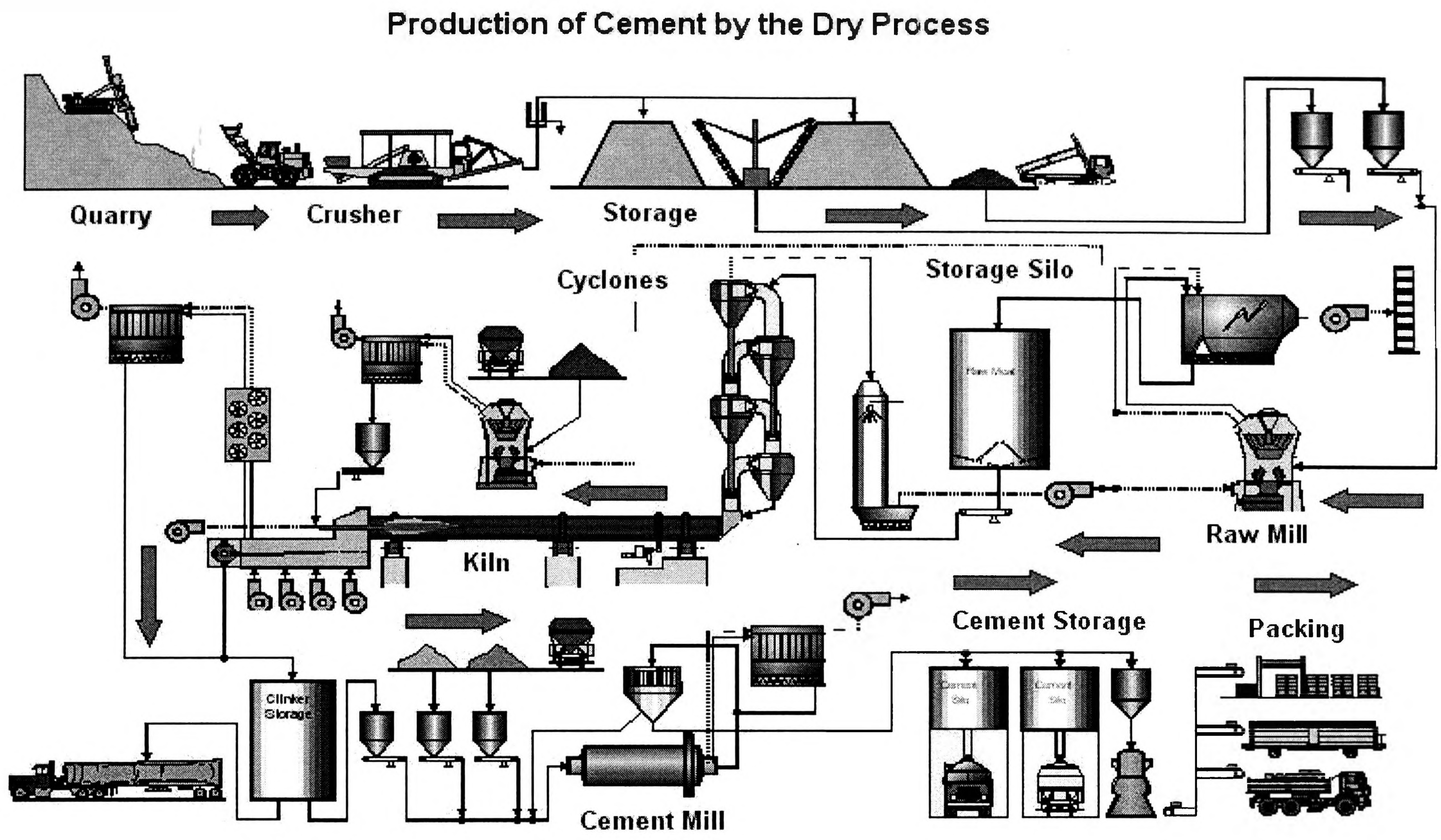


Figure 1.2. A flowchart of cement manufacturing process. Showing the whole process of cement production starting from raw materials.

1.1.2.2. Introduction of limestone burning issue of Puttalam cement plant.

All cement raw materials contains constituents other than the main constituent. Sometime these unwanted minerals or impurities cause problems in cement manufacturing process. They cause negative effect on the reaction take place inside the kiln. If these minerals effect the decomposition of raw materials at the normal kiln temperature, it takes longer time to complete the reaction. It results a lowering of kiln feed rate, which ultimately increase the cost of production.

At present, the rate of kiln feed drops time to time. It is interpreted the problem is cause by presence of relatively high amount of quartz in limestone. Quartz is a lightly resistant mineral it requires a higher temperature to break the structure of quartz. Therefore it remains nonreactor after the other raw materials complete reactions. The raw meal remains inside the kiln for a lager period to complete the reaction due to this reason. It leads to increase in fuel consumption and finally the production cost. This is identified as the burning issue at the plant

1.2.Objectives

1.2.1.Main objective

Achieve low cost, best quality product by using raw materials upgrading techniques and physically removing of issues creating materials from raw materials.

1.2.2.Specific objective.

a) Analyze the actual "minerals" or materials of limestone, which is affect to the burning issues.
b) Obtain detail information (like burnability) of above minerals or materials of limestone.
c) Compare all the properties of above minerals or materials with the properties of cement raw materials.
d) Study the properties of minerals or materials, which differ from properties of cement raw materials.

e) Selection a methods of physically removing of above minerals or materials by using above major differences.

Chapter 02

Literature review of the limestone burning issue and the study area

2.1. The sediments of the Aruwakkalu quarry site

Sediments are formed by weathering and erosion of bedrock or any other rock types by effecting different climate condition. Manly there are three types of sediments can be found in Sri Lanka. Those are:

a). Jurassic sediments
b). Tertiary sediments
c). Quaternary sediments

a). Jurassic Sediments

Occurrences of these sediments of Jurassic age were found at Tabbova, Andigama, Pallama, in northwest of Sri Lanka (Cooray, 1984).

b). Tertiary Sediments

Tertiary sediments of Miocene age, mostly Limestone, occur in the northwest and north coastal belt of Sri Lanka. The northern Jaffna peninsula and all the surrounding islands are underlain by Miocene Limestone that has flat or slightly west dipping beds. An assemblage of marine fossils were found in Jaffna limestone was used to date the sediments as cower Miocene age (Eames, 1950). These marine Miocene sediments now occur as Clifts 20-40meters above sea level, including some minor uplift since the Miocene.

c). Quaternary Sediments

The Quaternary sediments include Red earth, Beach sand, Logan clays and related unconsolidated deposits overlying the tertiary sediments and the crystalline rocks (Cooray, 1984).

2.2. The Sedimentary rocks of the Aruwakkalu quarry site

Sedimentary rock is a one of the three main rock types, which is form by cementation of deposited sediments and limestone can be seen as a major sedimentary rock in Aruwakkalu quarry area.

2.3. Limestone of the Aruwakkalu quarry site

Limestone have very variable colour: Whitish, Yellowish, light-brown and sometime also dark brown or almost black if it is contains bitumen's due to decomposition and transformation of the soft part of organism which have given rise to them. Limestone contains largely calcite, with secondary dolomite, and small quantities of Quartz and silicates especially clay minerals.

The Aruwakkalu limestone deposit was formed with the accumulation of calcareous skeletons of marine organism to be considered as autochthonous (Mathur-2001).

Cream coloured limestone occurs as a surface outcrop and as small boulders on the Wanatavillu division, about 10-km northwest of Puttalam town (Cooray-1995). The rock is rather gritty in appearance and has small concretions of chert as well as vugs and crevices with secondary silica. The limestone at Aruwakkalu is thought to belong to the Wanatavillu limestone series of lower Miocene age (Cooray-1965); it is the southern most occurrences of the Miocene limestone so far recorded. The limestone here forms a restricted inliers of tertiary rocks surround by later Quaternary formation. According to Davies and Herbert (1998), this is the Wanatavillu limestone unit, which is said to be 80-120 m thick.

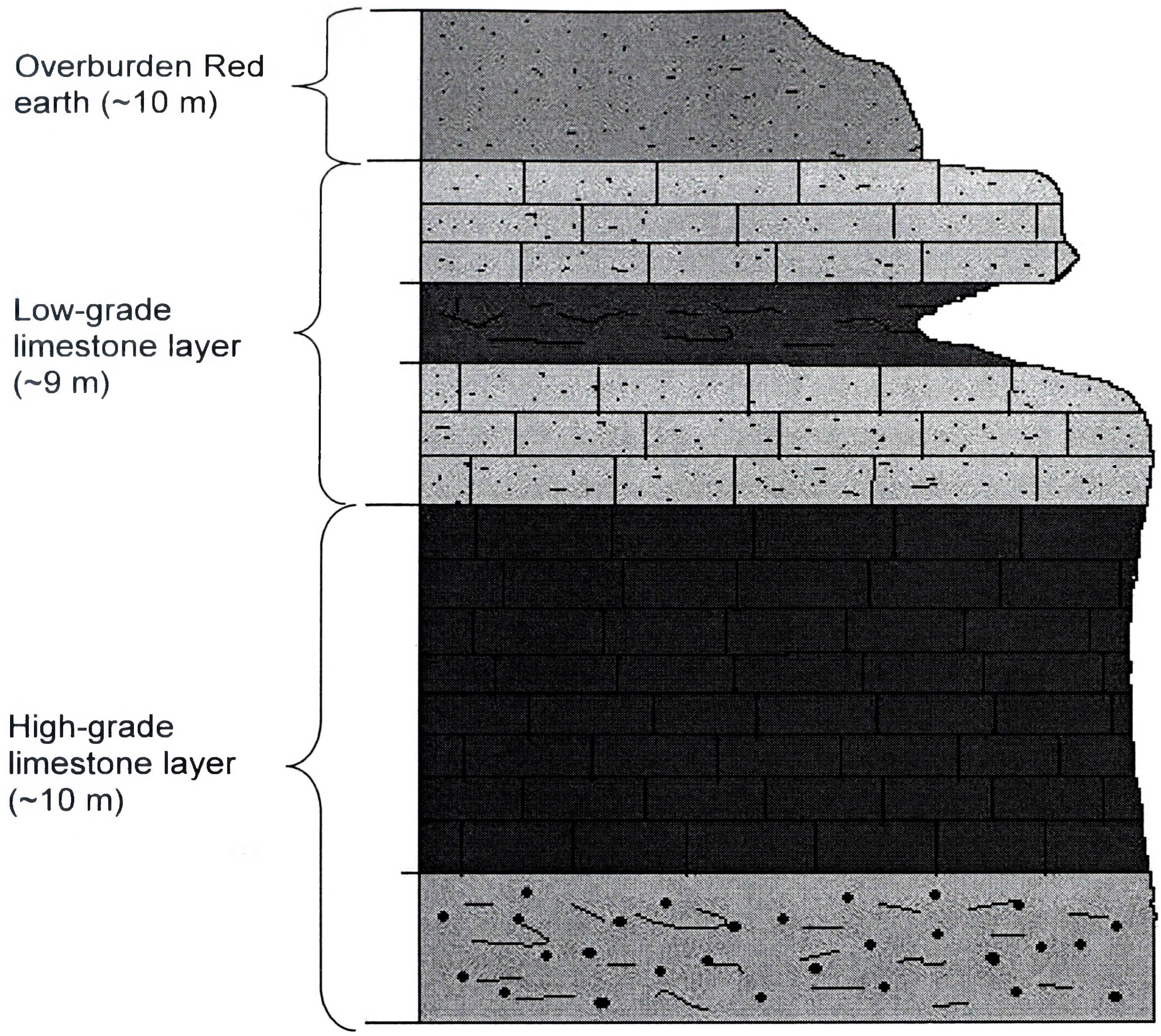


Figure 2.1. A photograph of the vertical section of Aruwakkalu limestone deposit. Showing the layer wise limestone deposition.

2.4. Laterite of the cement raw materials.

The main process of the Laterite formation is the relative or absolute enrichment of Al, Fe, Mn, and Cr. Such a weathering process occurring under tropical or sub-tropical climate conditions may lend to the formation of a range of products prominent among them in Sri Lanka being Fe-rich, Al-rich and Ni-rich Laterite (Dahanayake-1982).

Laterites occur extensively in the low land of Sri Lanka whereas these are observed as localized outcrops in the uplands and highlands. In lateritic weathering profiles, Al-rich zones are formed between and beneath harder Fe-rich layers. The processes of lateritisation and bauxitisation have produced residual products enriched in both Fe_2O_3 and Al_2O_3. In the lowlands and uplands the lateritisation processes have prevailed and the bauxitisation trend is more pronounced in the highlands (Dissanayake-1979).

2.5. Calcite of the cement raw materials.

A typical sedimentary minerals form by chemical precipitation through the evaporation of solutions rich in Calcium bicarbonate or by the extraction through the action of marine and fresh water organism (Arnoldo, 1997). Remains stable under metamorphic conditions up to the highest grades. Simply re-crystallizing and increasing in grain size as long as the pressure of the carbon dioxide remains high. If the pressure is reduced it dissociate, resulting in complex Calcium silicates. Primary calcite of igneous origin is rare, though calcite is certainly present in magma since late volcanic solutions may deposit it in vacuoles in lava. Also found in low-temperature hydrothermal veins associated with sulfides. Calcareous rocks constitute 4 present, by weight, of the earth crust and 40 present of its surface. Most of calcite occurs in Limestone rocks.

2.6. Quartz in the cement raw materials.

Quartz is a one of the commonest minerals in the earth's crust (12 present by volume). It crystallizes directly from igneous magma, from the pegmatite pneumatolytic to the low-temperature hydrothermal stage. Quartz occurs in plutonic and volcanic rocks. Stable in sedimentary conditions either as a detrital mineral (Alluvial, Marine and desert sands) or as a cement in consolidated rocks (sandstone). It also crystallizes from hot solutions and cold solutions and occurs as a digenetic minerals derived from the skeletons of and high-grade metamorphic conditions, although in some cases easily mobilized. It is one of the first components to refuse in the process of anatexis and is also one of the first to re-crystallize. Cristobalite forms in cavities of lava rocks were rapid cooling has occurred, as an in volcanic glass and through the action of high temperature metamorphisms of quartz rich rocks (Arnoldo, 1997).

As quartz is so common it is impossible to list all the places where it is found, so a few localities for the most characteristic veracities are given. a). Milky Quartz

b). Smoky Quartz
c). Blue Quartz
d). Rose Quartz
e). Rutilated Quartz
f). Rock crystal
g). Aventurine Quartz
h). Amethyst
i). Citrine

Milky Quartz

The commonest variety found in pegmatites and hydrothermal veins. Numerous bubbles of gas and liquid in the crystal generally cause the colour.

Smoky Quartz

The colour is Light or dark brown to black. Probably caused by exposure to natural radioactivity. When heated turns yellow then white. The Quartz crystals has been found from high-temperature hydrothermal veins.

Blue Quartz

This blue colour comes from tiny rutile, tourmaline or zoizite inclusions and this type common in metamorphic rocks

Rose Quartz

The colour appears to be caused by traces of manganese or titanium. It occurs in massive from in many pegmatites, but well formed crystals are very rare. Loses its colour when heated and turns black if exposed to radiation.

Rutilated Quartz

Contains acicular yellow and red rutile crystals

Rock crystal

It occurs mainly in pegmatites, Alpine fissures and geode in varies rocks.

Aventurine Quartz

Contains scales of mica or goethite that give a spangled green or brownish-yellow look.

Amethyst

Violet colour caused by trace amounts of ferric iron. Turn white when heated to 300oC,then yellow at 500oC,but become violet again if expose to x-rays or bombarded with alpha particles.

Citrine

Yellow or brown because of inclusions of colloidal iron hydrates. Turns white if heated, and dark brown if exposed to X-rays.

Chapter 03
3.Methodology

3.1 Collection of information about burning issue.

Even though there was a burning issue (burning difficulties of cement raw materials) in August, September, and October year of 2004, the reason was not directly identified. They have suggested that issue comes from accumulation of quartz into limestone. Because of this suggestion unconfident, the causes of this issue have to be discovered of this period. The data was collected of kiln production and quartz content of incoming materials of 2004, to find out the relationship between reductions of kiln production rate with accumulation of quartz into limestone,

The average daily kiln production data and average daily quartz content in kiln feeding materials of 2004 were analyzed to conclude the variation of daily input quartz content with reduction of kiln production. If there is a direct relation ship between decreases of kiln production with quartz content in raw materials, it is very useful to accept that their suggestion was correct.

3.2. Analysis of root causes about burning issue.

After analyzed relationships between reduction of kiln production rate and quartz content of limestone, the project have to be conducted in two ways they are;

1). Analyze the quartz variation of the cement raw materials.
2). Find out all other minerals, which were affected to this issue.

3.2.1. Analyze Quartz variation of the cement raw materials

There were a lot of crushed core drill rods, which is taken from QSO (an area of the quarry, where operated according to Quarry Scheduling, and Operation expert software) area of quarry. These core drill rods (40 m height) have been cut into small pieces (2 feet height) and the sample was prepared after crush and powdered by disc mill to analyze Quartz.

The 200 g of crushed core drill sample were taken after composite of Corner and quartering methods and it's powdered by disc mill. 5 g of powdered sample was added into beaker with 50 ml of water, 10 ml of HCl. This mixture stirs well and heated until react Limestone with HCl. this reacted mixture was washout 45um sieve and it is keep inside the oven at temperature 105° C. After 20 minutes can be get insoluble residue in HCl by weighting.

Approximately the higher amount of quarts and miner amounts of other mineral can be seen in this insoluble residue. More than 250 samples were analyzed to find quartz in QSO area according to that procedure.

After analysis of quarts content in this QSO area, it can be graphically presented in 3 dimensionally using some software.

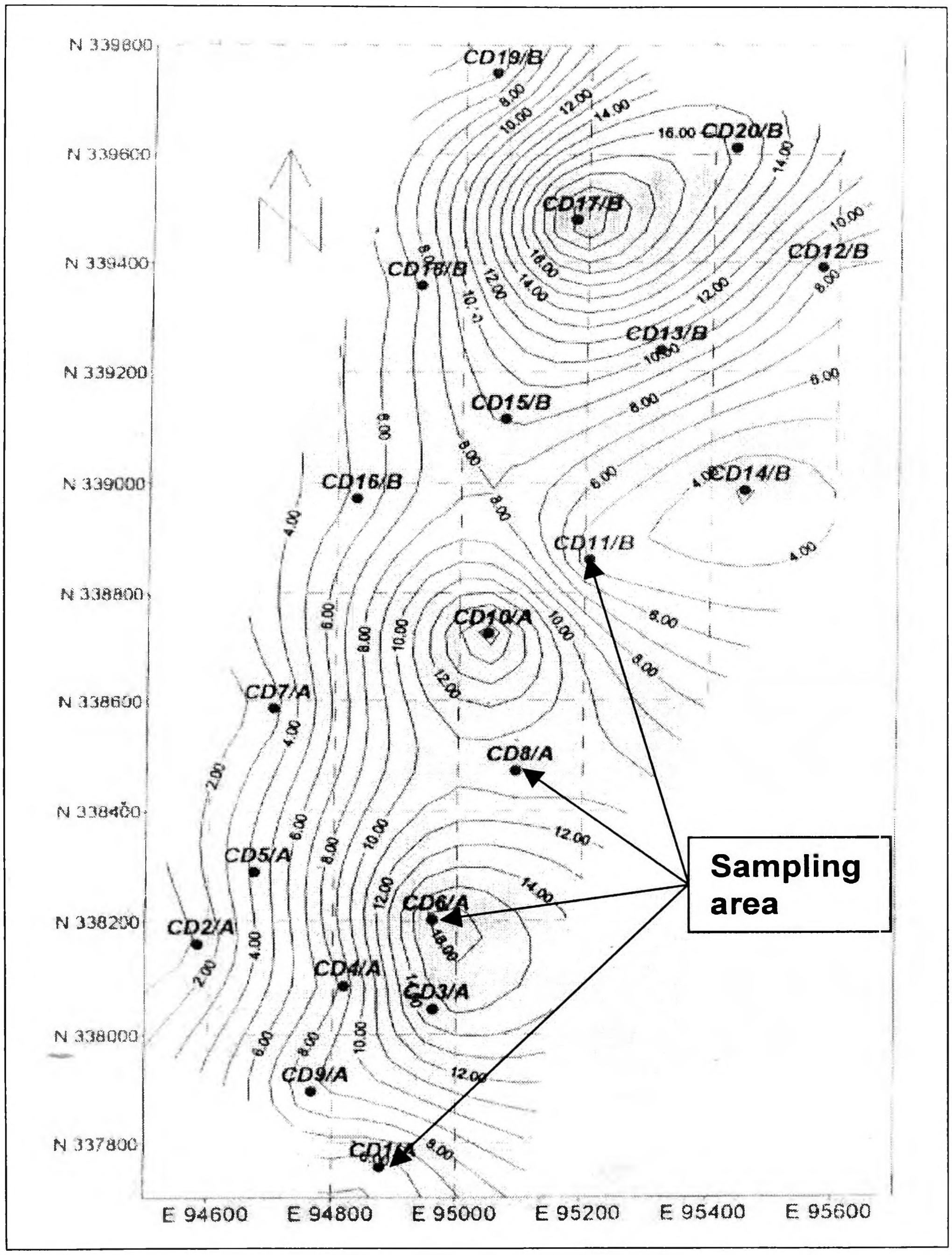


Figure 3.2. A photograph of the sampling area, quarry site, Aruwakkalu. Showing elevation of the sampling location (CD1, CD2, CD3...CD20).

3.3. Collection of Samples from the Aruwakkalu quarry site.

The several composite drill-hole samples were collected from following areas of the Aruwakkalu quarry site to analyze minerals.

1). CD6-High-grade limestone bed
2). CD6-Low-grade limestone bed
3). CD6- limestone with shell bed
4). CD6-Hard limestone layer
5). CD6-Base limestone layer
6). Old-Karative quarry area
7). Red earth above the quarry

By analyzing of minerals in above samples it will represent all the minerals in Aruwakkalu quarry because of above composite sample represent the all area of the quarry. Therefore it can be easier to take final decision of minerals that is affected to burning process.

3.4. Sample analyzes for the minerals

Several analyzes were carried out for testing the minerals of above samples they are,

1). XRD (X-Ray defractometer) & XRF (X-Ray Fluorescence defractometer) analysis.
2). Thin section preparations
3). Magnetic separations
4). Optical identifications

3.4.1. XRD & XRF analysis for minerals and elements

Several (8) samples were sent to XRD analyze which is crushed and powdered until 90 % pass the 63 um sieves. The peaks of the graph show the minerals of each sample that is useful to identify minerals of every sample.

3.4.2. Magnetic separations for the minerals.

The several (7 sample) samples were collected from different places of Quarry to analyze minerals using magnetic separator. About 20 kg of each sample were collected and each were crushed and reduced in to a powder. 50 g of each sample were dissolved in conc. HCl and the residues were obtained. The residues were separated into different groups using magnetic separator due to different angle and different current of the magnetic separator. Separated minerals were identified using petrologic microscope. Below samples were used for magnetic separator.

1). Upper layer of low quality limestone bed at CD4.
2). Lover layer of low quality limestone bed at CD4.
3). Shell bed of CD4.
4). Pebble layer of quartz at CD4.
5). Clay layer at CD4.
6). Low quality limestone at TML site.
7). Low quality limestone at Old Karative site.

3.4.3. Thin-section preparations

The several thin sections of rock samples were analyzed for minerals by using Optical microscope under PPL (Plain polarized light) and CPL (Cross polarized light) methods.

01). Upper layer of low quality limestone bed at CD4
02). Intermediate limestone layer of low quality bed at CD4
03). Lover limestone layer of low quality bed at CD4
04). Low quality limestone at TML site
05). Old Karative Site
06). High quality of CD4 bed

3.4.4. Optical identifications of minerals in quarry faces.

Optical identification methods of minerals were used for identified minerals at quarry faces and blasted materials.

3.5. Find out of minerals in cement raw materials.

By using representative composite samples to mineral identification methods, some minerals were identified which is useful to analyze properties that can be affect of burning issue.

3.6. Collection of properties of minerals

Using some Books, Article, Project papers and some Official web sites, could be collected the properties of minerals that can be effected to burning of process of raw materials (Asesoria, 1991).

3.7. Compare properties of minerals

Identification of properties of all minerals in the Limestone, it is very useful to identify methods to remove burning issuing minerals from raw materials. The properties between calcite and other minerals, which are very useful to remove, unwanted materials or impurities of limestone.

Chapter 04

4. Results and discussion

4.1. Results

4.1.1. Magnetic separation

Samples from different sites of the quarry were analyzed for minerals in Limestone by using magnetic separator. The information of the places from which the samples were collected is as follow.

Table 4.1. A table of sample numbers and its location, which was taken to Magnetic separation for, find the minerals in the raw materials.

Sample Number	Sample Location
Sample No-01	Upper layer of Low Quality bed at CD4 site
Sample No-02	Lower layer of Low Quality bed at CD4 site
Sample No-03	Shell bed at CD4 site
Sample No-04	Pebble layer at CD4 site
Sample No-05	Low quality limestone layer at TML site
Sample No-06	Clay layer at CD4 site
Sample No-07	Low quality limestone at Old Karative site

Table 4.2. A table of the results of magnetic separation of the cement raw materials (as weight percentages).

Mineral Group	Samples by weight of (g)%						
	Sample No-01	Sample No-02	Sample No-03	Sample No-04	Sample No-05	Sample No-06	Sample No-07
Ilmenite & Garnets	0.044	0.093	0.029	0.005	0.152	0.025	0.065
Clay, Limonite, Garnet	0.024	0.068	1.291	0	0.102	0.045	0.039
Clay, Limonite	0.016	0.017	0.275	0	0.662	0.068	0.047
Clay, Quartz, Limonite	0.049	0.061	0.023	0	0.632	1.308	0.12
Quartz	3.448	4.605	0.065	5.295	5.937	0.557	7.933

4.1.2. Thin section analysis for minerals in raw materials

Samples from different areas of the quarry were analyzed for minerals of rock thin-section by using petrologic microscope. Analyzed sample photographs are as follows.

Table 4.3. A table of sample numbers and its location, which was taken to thin section preparation for, find the minerals in the raw materials.

Samples number	Sample location
Sample No:01	Upper layer of low quality limestone bed
Sample No:02	Intermediate layer of low quality limestone bed
Sample No:03	Lower layer of low quality limestone bed
Sample No:04	Low quality limestone bed at TML site
Sample No:05	Limestone layer at Old Karative site
Sample No:06	High quality limestone bed at CD4

The Calcite and Quartz were found as major minerals of these thin sections. The photographs of thin sections have been attached of appendixes.

4.1.3. Optical identification of minerals in quarry site of Aruwakkalu.

Calcite, Quartz, Ilmanite, and some Clay minerals can be seen in this quarry and there are high amount quartz of some places of the quarry is shown as photograph which is attached to appendixes.

4.1.4. XRD and XRF results

XRD analyze

Samples from different places of the quarry were sent to XRD analyzer and obtained following results. The results have been attached to appendixes and **quartz, calcite, plagioclase, kaolinite and ilmenite** can be seen as major minerals of cement raw materials.

Table 4.4. A table of sample numbers and its location, which was taken to XRD analyzer for, find the minerals in the raw materials.

Sample Number	Location
Sample N0:01	CD4 High-grade limestone
Sample N0:02	TML Low-grade limestone
Sample N0:03	Old Karative Low-grade limestone
Sample N0:04	CD4 Hard rocks limestone

XRF analyze

Several samples of limestone were analyzed for elements, which were found **Silicon, Aluminum, Iron, Calcium, Chlorine, magnesium, sodium and potassium** as major elements in Limestone by using XRF analyzer.

4.1.5. Quartz variation of the quarry

Analyzed quartz content (by weight percentage) of the quarry (QSO area) has shown on the Appendixes 2, where as analyzed along the depth of every core drill of QSO area.

4.2. Discussion

4.2.1. Root causes for the burning issue of the cement plant.

Due to results of analyzed burning issued data that is describing the burning issue were mainly come from Quartz. The production rates have been reduced of that month of 2004 with relation of increased of quartz content of raw materials. Due to this graphs it will be described very easily. Therefore, the quartz is a main cause to burning issue as a major impurity of Cement raw materials.

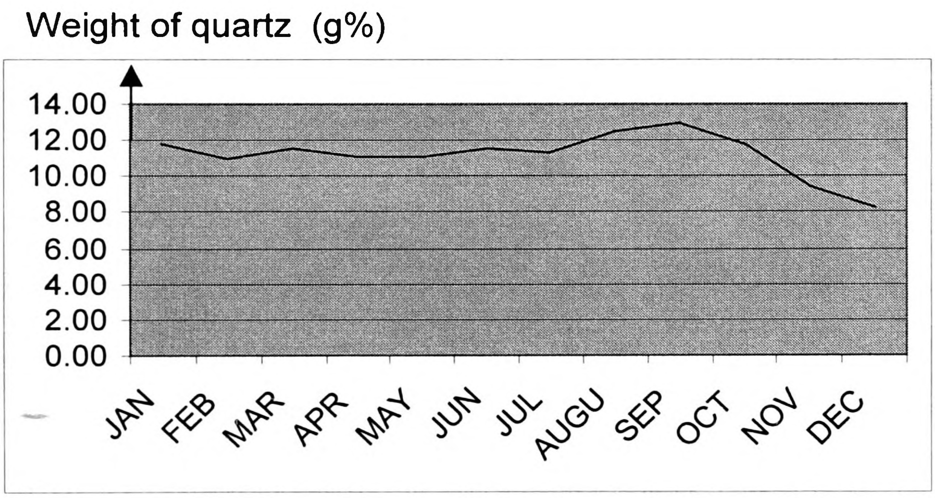


Figure 4.1. A graph of the variation of quartz percentage of cement raw materials in year Of 2004, cement plant, Puttalam. Showing the

highest quartz percentage of September, October and November in year of 2004.

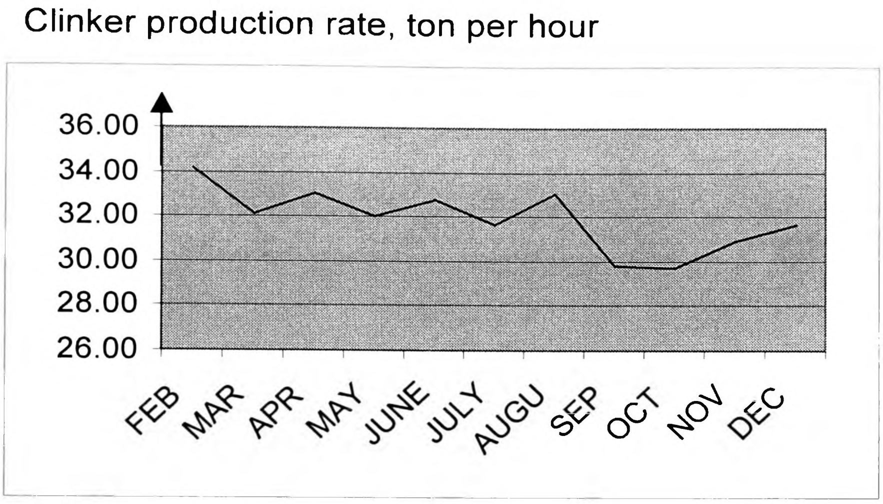


Figure 4.2. A graph of the variation of clinker production rate of cement kiln in year 0f 2004, cement plant, Puttalam. Showing the lower clinker production of September, October and November in year of 2004.

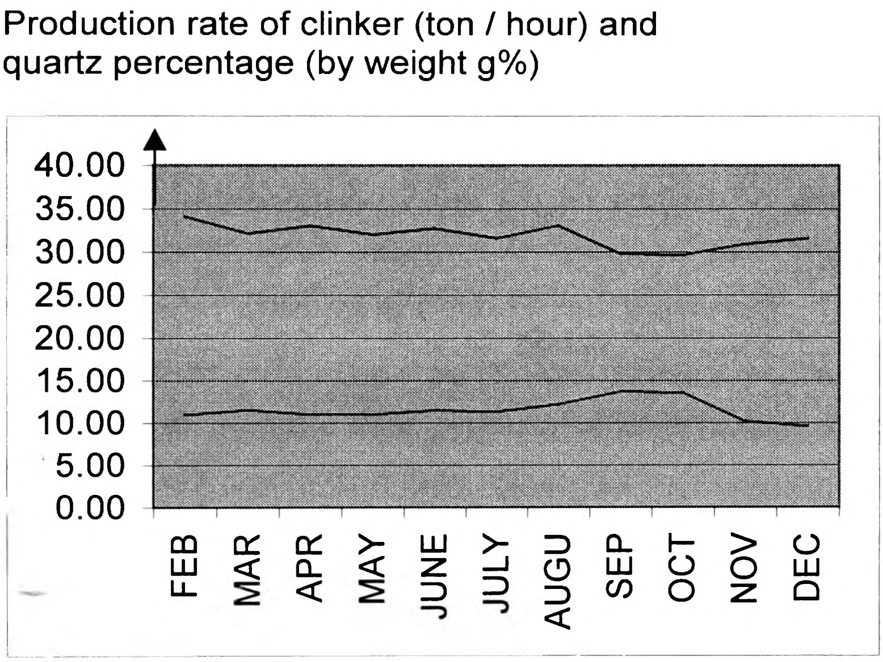


Figure 4.3. A graph of the variation of clinker production rate of cement kiln and variation of quartz percentage in year 0f 2004, cement plant, Puttalam. Showing the clinker production has been reduced with

relatively increasing of quartz percentage of September, October and November in year of 2004.

4.2.2. Results of the magnetic seperation of cement raw materials

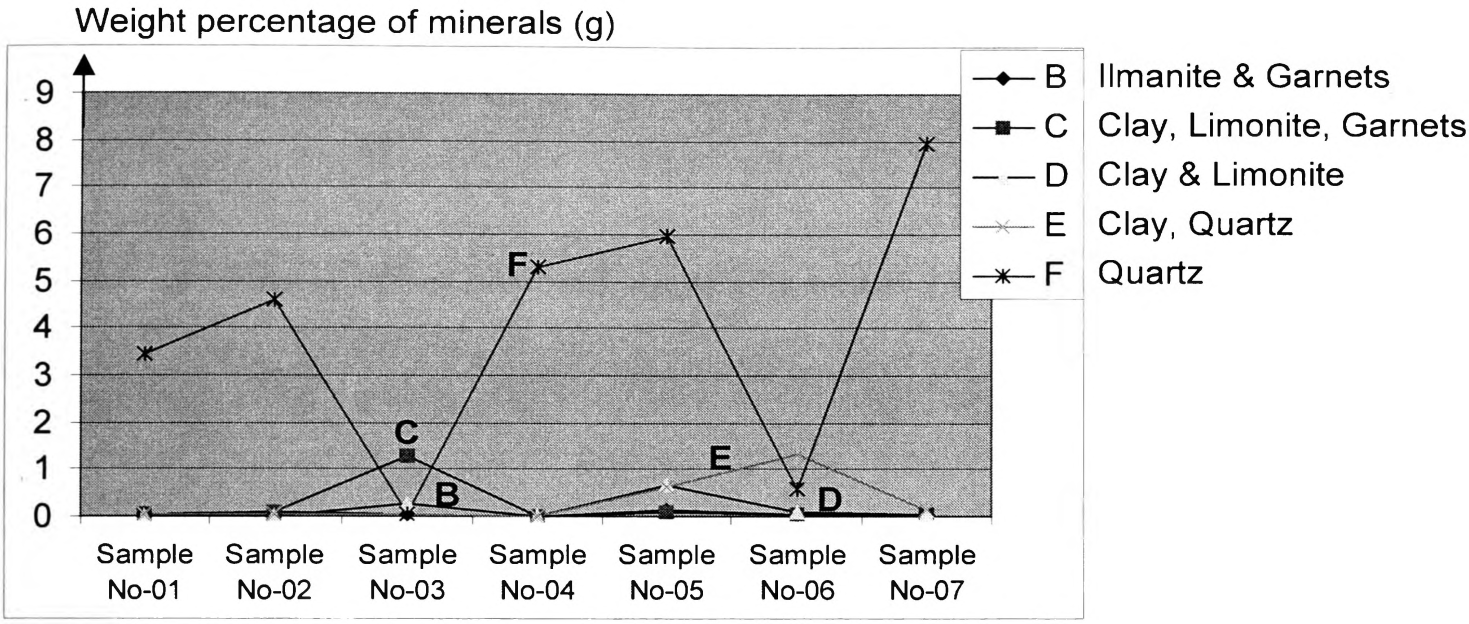


Figure 4.4. A graph of the "minerals" found by magnetic separation of cement raw material residue. Showing the Quartz is the major mineral (F, E) and Clay, Limonite, Ilmanite (B, C, D) are minor minerals. Note the Quartz is the main mineral in cement raw material residue and second major mineral in cement raw materials.

Most of samples contain high amount of quartz and low amount of other minerals (like Ilmanite, Limonite and clay minerals) as above graph. There is higher amount of quartz in each part of the quarry because of those all samples are represent every part of the quarry,

Approximately 9 % and 7 % of quartz contain in low and high-grade limestone rocks according to the quartz content in residue of limestone above 95 %. This higher amount of quartz can be created some burning issues as a major impurity of limestone.

4.2.3. The results of the thin sections analysis

Calcite and Quartz can be identified as major minerals of these thin sections by using PPL (Plain Polarized Light) and CPL (Cross Polarized Light lights) of Petrologic microscope. But in some areas the large size grains of quartz can be identified which are directly affected to burning process of cement. As an example there were large quartz grain in Old Karative areas than other areas. (All thin section figures have attached in appendixes)

a). Thin sections of upper layer of Low quality bed at CD4 site

Fine grained particles bound by very fine-grained matrix. Particles are mainly calcareous non-crystalline coated grains (about 80 %) and Quartz (5 %). Matrix/ cementing material is non-crystalline calcareous matter where some parts are crystallized into fine calcite grains. Rock is less compacted and porosity is about 10%. Quartz grains are about 0.33mm in size.

b). Thin sections of intermediate layer of Low quality bed at CD4 site

Almost same as SE-1, but the amount of quartz is less than SE-1. More compacted and the porosity is about 3-5 %

c). Thin sections of lower layer of Low quality bed at CD4 site

Fine-grained particles are bound by Ultra fine matrix. Particles are calcareous and the amount of quartz is almost nil. Fine size voids are present and crystallized fine size calcite grains occur along the rim of the voids. It is a less compacted rock with a porosity of about 20 %.

d). Thin sections of hard layer of high quality bed at CD4 site

Fine size bio-clasts (parts of organisms) cemented together by matrix. The matrix is partly crystallized into fine-grained calcite. The rock is highly compacted and the porosity is 1-2 %. No quartz grains observed in this thin section.

e). Thin sections of Low quality bed at TML site

The rock is composed of very fine-grained calcite and quartz grains. Size of the grains is about 0.2-0.3 mm. Calcite grains are well crystallized and make about 90 % of the rock. Amount of quartz is about 1-2 %. Highly compacted and the porosity is about 5 %.

f). Thin sections of Old Karative upper layer

Medium sized particles (0.7-1 mm) bounded by fine-grained matrix. The particles are calcite and quartz, which compose about 65 % of the rock. The matrix is made up of microcrystalline calcareous matter. The rock is moderately compacted and the porosity is about 10-15 %.

g). Thin sections of Old Karative lower layer

The whole rock is composed of calcareous mater. It contains voids about 0.5 mm in size. The rim of the voids are lined by crystallized calcite while the other parts are non crystalline. The rock is less compacted and the porosity is about 10 %.

4.2.4. Optical identifications of Quartz in the quarry faces

Quartz can be seen in many places of the quarry shown as Appendixes, which can be removed easily by optical identification. This is the easy and very low cost methods of remove quarts from the quarry.

4.2.5. XRD and XRF analysis

From graph, the highest peaks are showing major minerals of the samples. Therefore, Calcite and Quartz was shown as major minerals by analyzing peaks and its values of the graph. Very small amount of Dolomite was presented in some limestone samples, which is taken from hard layer of CD-4 area. Approximately, there should be minimum 3 peaks to a single mineral in a graph but there can be shown more than three peaks due to intensity of minerals.

The silicon, calcium, iron, aluminum, magnesium, sodium, and potassium were found as major element in limestone by XRF analyzer. Therefore the silicon, calcium and magnesium are present as Quartz, Calcite and dolomite. However, other minerals were not presented as minerals due to its low intensity.

4.2.6. Analyze the Quartz variation of the quarry

Due to the result of quartz variation of QSO area of the quarry, the quartz content can be describe very easily for the QSO area of the quarry. Before planning of quarry for new quarry faces, it will more useful to mine low quartz area.

4.2.5. XRD and XRF analysis

From graph, the highest peaks are showing major minerals of the samples. Therefore, Calcite and Quartz was shown as major minerals by analyzing peaks and its values of the graph. Very small amount of Dolomite was presented in some limestone samples, which is taken from hard layer of CD-4 area. Approximately, there should be minimum 3 peaks to a single mineral in a graph but there can be shown more than three peaks due to intensity of minerals.

The silicon, calcium, iron, aluminum, magnesium, sodium, and potassium were found as major element in limestone by XRF analyzer. Therefore the silicon, calcium and magnesium are present as Quartz, Calcite and dolomite. However, other minerals were not presented as minerals due to its low intensity.

4.2.6. Analyze the Quartz variation of the quarry

Due to the result of quartz variation of QSO area of the quarry, the quartz content can be describe very easily for the QSO area of the quarry. Before planning of quarry for new quarry faces, it will more useful to mine low quartz area.

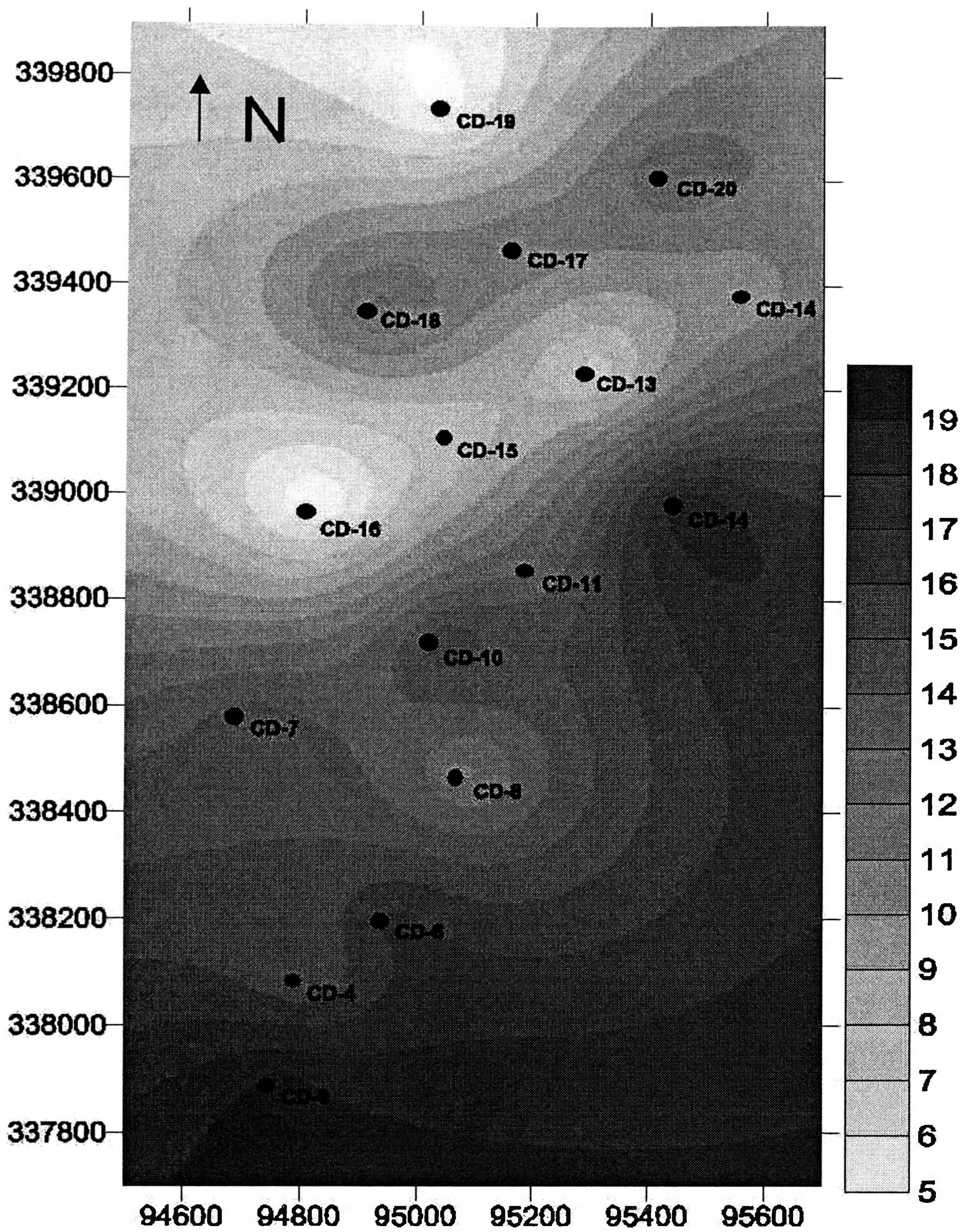


Figure 4.5. A graph of the quartz variation of the QSO area of the quarry, quarry site, Aruwakkalu. Showing the sample-collected areas (CD-1 to CD-20 of the quarry site. Note the high quartz content of south area than other area of the quarry site.

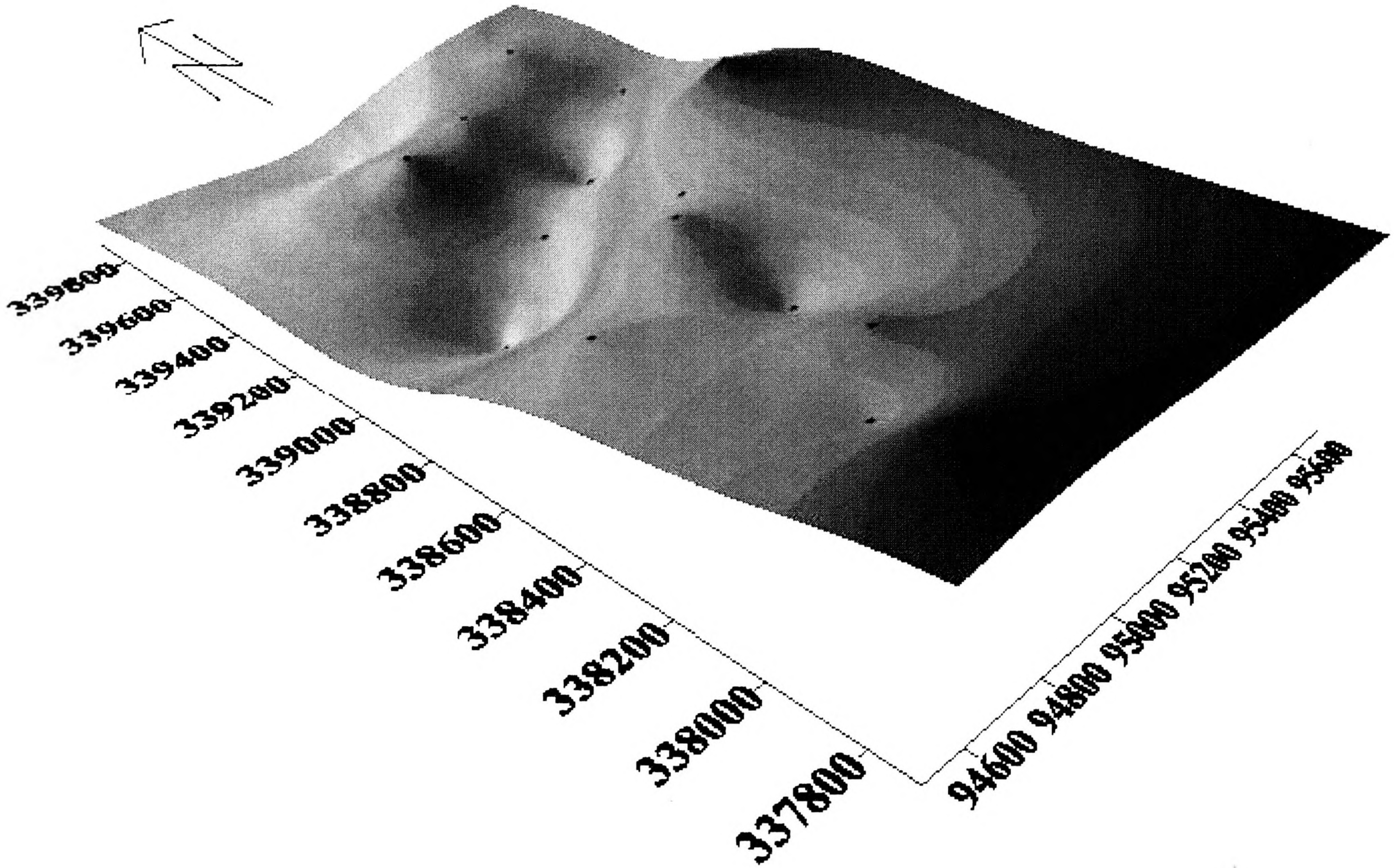


Figure 4.6. A "3-D" model. Showing quartz variation of the limestone quarry site (QSO area), Aruwakkalu. Note there is low quartz content (light color area) in north side than south side of the quarry.

Chapter 05
5. Conclusions and Recommendations

5.1. Conclusion

Due to this graphs were taken from period of the burning issue of 2004,show the direct relationship between reduced of production rate of Kilns with increased of quartz content of Cement raw materials like Laterite and Limestone.

The Quartz is the major impurities of Limestone and Literate as shown as above methodologies. Therefore, the burning issue could be created due to this High amount of quartz. By compare of properties of quartz with other minerals of raw materials, quartz has very uncommon properties like chemical inertness, High melting point, and temperature resistance, to melt quarts it has been heated above at 1600° C. Due to quartz has some high energetic bond and specific structure which can not be breaking easily. The burning issue could be created that above periods by reason only quartz.

Quartz can be removed easily from this quarry by applying above methodologies especially Optical identification of quartz. That is the best method to reduce cost and get good quality clinker without lost of production cost.

Not only quartz remove from this raw materials but also reduction of the quartz content from raw materials also very important to reduction production cost which can be done by mixing well of different material.

It is because of quartz content have been analyzed in QSO area of the quarry, very useful to plan future mining where as area of low quartz content.

Better bed cleaning before the mining, remove of quartz layers with optical identification and successful quarry planning is very easy and useful method to remove quartz from raw materials.

When quarts removed from these raw materials, useful raw materials also can be removed that is a material wastage. Therefore, the quartz remove from cement process is very applicable method.

Calcite and Quartz have very different properties, those are: hardness of calcite is 3 and quartz is 7, there are low melting point to calcite and high melting point of quartz, calcite is very low density mineral and quartz has very high density, therefore Quartz and calcite can be easily identified to removed by some physical removal method.

After raw mill the raw materials become powdered, therefore that is a good place to introduction of physical removal method. Due to high-density differences of Quartz and calcite, the centrifugal system can be introduced to remove Quartz from cement raw materials. It is a best method to remove quartz from raw materials without wastage of materials.

5.2. Recommendations

- Analysis of the quartz content of core-drill samples must be required before the mining of the quarry.
- Before the materials feed the kiln, XRD analyzer should identify the quartz content of the raw materials.
- To minimize of raw material wastage and cost, quartz-removing method should be introduced to cement process.
- Before the quarry planning, quartz content must be included to QSO to optimize materials with quartz.
- The quarry raw material mixing method is not systematic therefore; the systematic and practicable methods want to be introduced, to better mixing of raw materials.
- All workers should be knowledgeable about quartz and quartz addition methods to raw materials

6. References

Arnoldo.M, 1997. Rocks and Minerals, 2 : 1 - 607.

Asesoria.S.A, 1991. Evaluation of Limestone Reserves of the Aruwakkalu Raw material deposits, 1 – 650.

Cooray. P.G, 1994. The Geology of Sri Lanka, 2 : 1 – 340.

Cooray. P.G, 1995. Geology of the country around Battulu Oya and Puttalam, 1 - 41.

Dahanayake, 1982. Chemical composition of the Laterite, 1 - 55.

Dissanayake. C.B. 1979. Laterite deposits of Sri Lanka. 1 – 23.

Dissanayake. C.B. and Perera. L.R.K, 1994. Journal of the Geological Society of Sri Lanka 5, 135 –139.

Drissel. H, 2003. Analysis of Limestone for quartz, 1 – 552.

Department of Geology, University of Peradeniya, 1992. Mineralogy and chemical composition of the Laterite of Sri Lanka.

Fedrick.M.L, 1999. The chemistry of cement and concrete 3 : 1 - 727.

Gokhale.N.W, 2001. Theory of Structural Geology, 1 – 221.

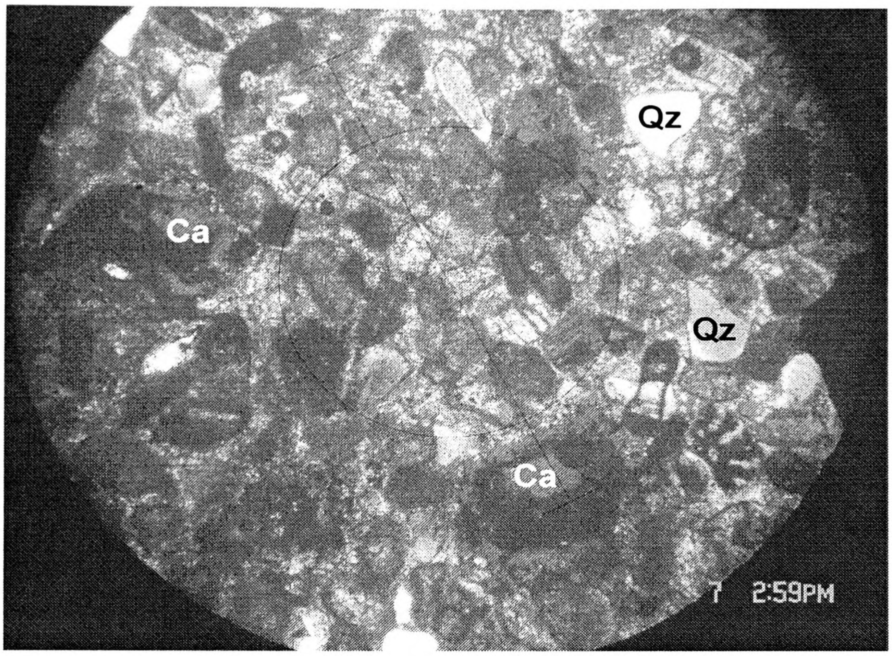
Hewawasam.A.L.T, 2001. Geology of Sri Lanka.

Lahee.F.H, 1997. Field Geology, 6 : 1 – 926.

Lanka Ceramic Limited, 1990. Sri Lanka minerals.

Mathur.S.M, 2001. Guide to Field Geology, 1 – 203.

06. Appendixes



4 mm

Figure 01. A photograph of a thin-section of rock sample, upper layer Low quality limestone CD-4 bed at quarry site, Aruwakkalu. Showing the mineral grains of calcite (Ca) and quartz (Qz). Note the grains are mainly calcareous non-crystalline coated grains (about 80 %) and Quartz (5 %). Rock is less compacted and porosity is about 10%. Quartz grains are about 0.33mm in size.

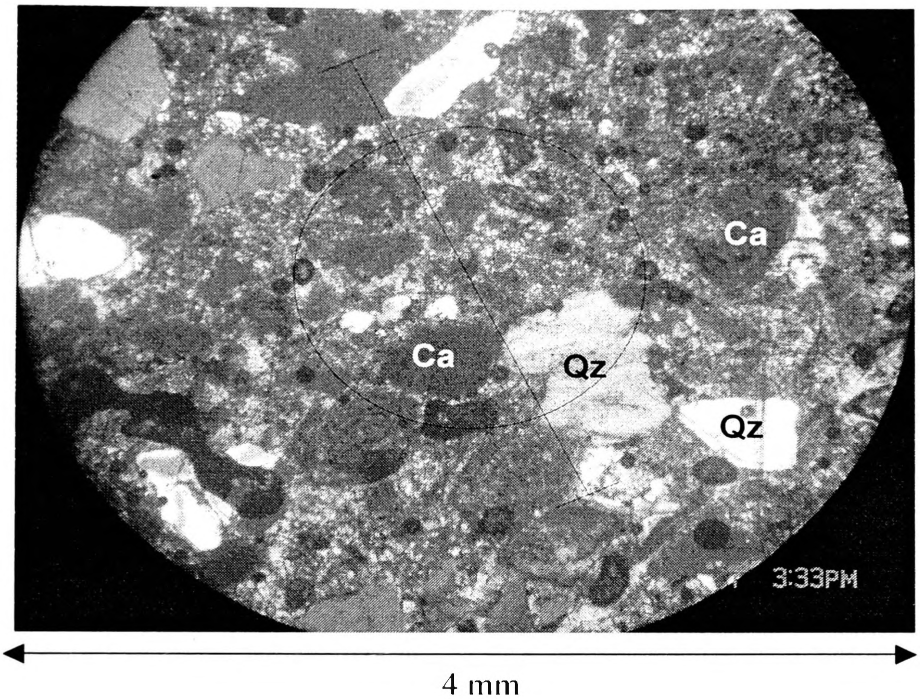
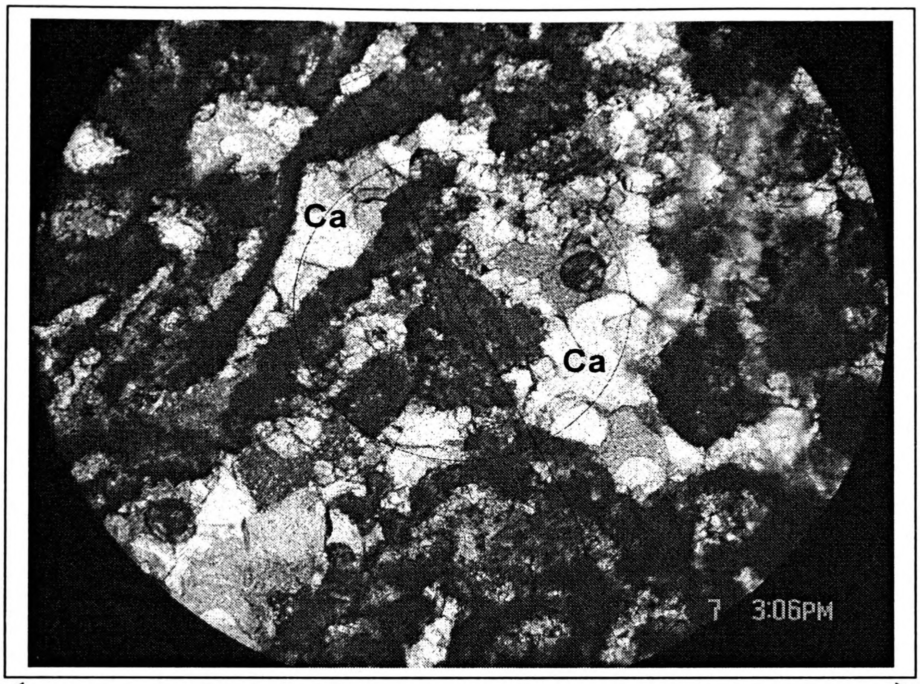


Figure 02. A photograph of a thin-section of rock sample, upper layer Low quality limestone old Karative bed at quarry site, Aruwakkalu. Showing the mineral grains of calcite (Ca) and quartz (Qz). Note the particles are calcite and quartz, which compose about 65 % of the rock. The matrix is made up of microcrystalline calcareous matter. The rock is moderately compacted and the porosity is about 10-15 %.



4 mm

Figure 03. A photograph of a thin-section of a rock sample, hard layer high quality limestone CD-4 bed at quarry site, Aruwakkalu. Showing the mineral grains of calcite (Ca). Note the matrix is partly crystallized into large-grained calcite. The rock is highly compacted and the porosity is 1-2 %. No quartz grains observed in this thin section.

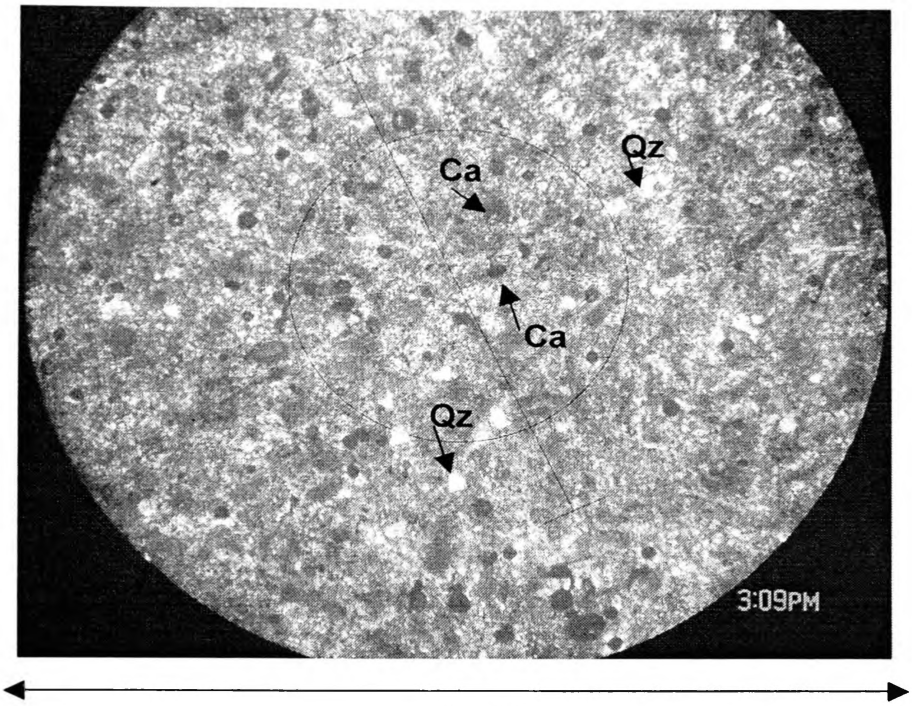


Figure 03. **A photograph of a thin-section of a rock sample, high quality limestone TML bed at quarry site, Aruwakkalu. Showing the mineral grains of calcite (Ca) and calcite (Qz). Note the rock is composed of very fine-grained calcite and quartz grains. Size of the grains is about 0.2 - 0.3 mm. Calcite grains are well crystallized and make about 90 % of the rock. Amount of quartz is about 1 - 2 %. Highly compacted and the porosity is about 5 %.**

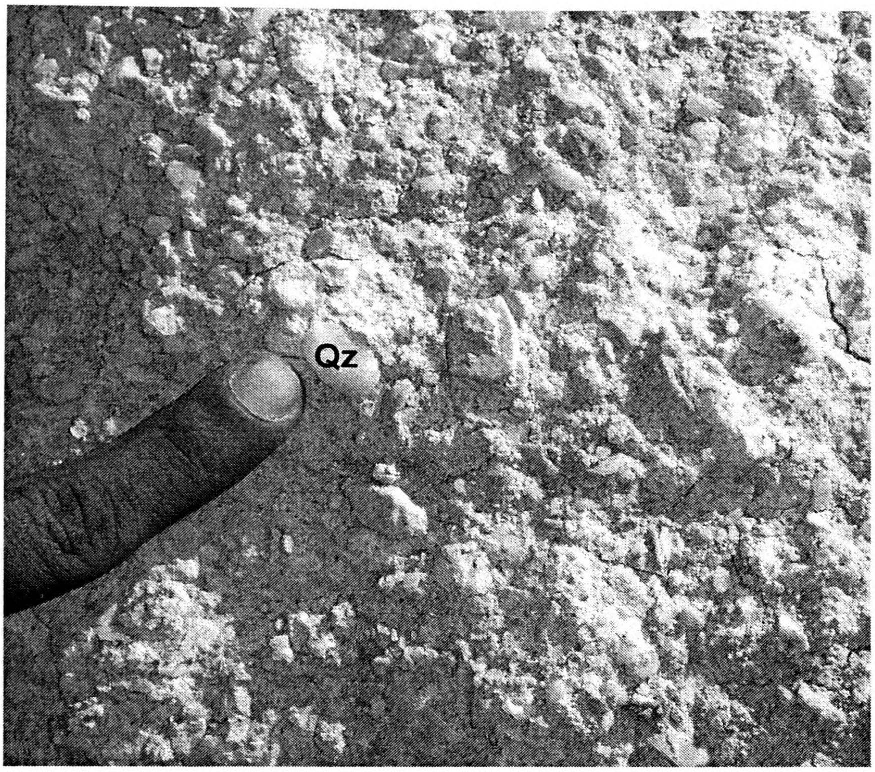


Figure 05. A photograph of the quartz grains in a limestone rock sample, at quarry site, Aruwakkalu. Showing the quartz (Qz) grains as one of major mineral of the raw materials. Note the quartz grains are commonly included both of low quality and high quality limestone beds.

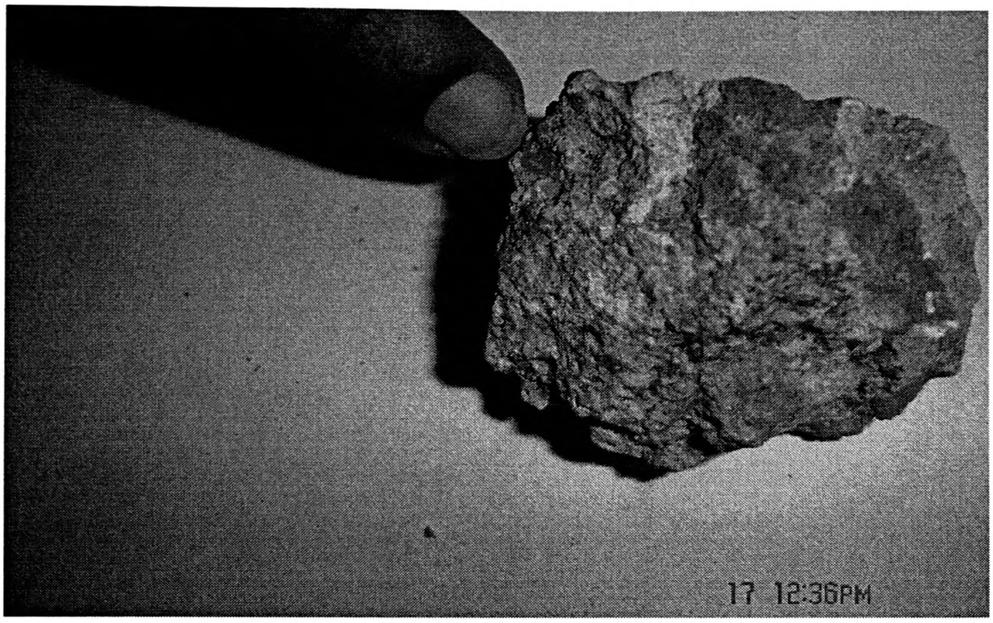


Figure 05. A photograph of the quartz grains in a high quality limestone rock sample, at quarry site, Aruwakkalu. Showing the quartz (Qz) grains as one of major mineral of the raw materials. Note the quartz grains are commonly included both of low quality and high quality limestone beds.

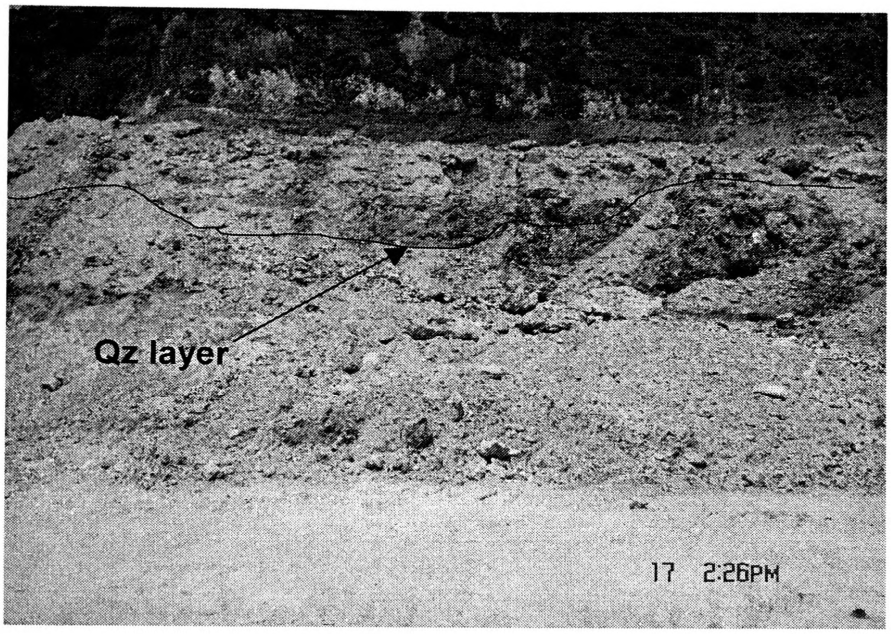


Figure 05. A photograph of the quartz layer at quarry site, Aruwakkalu. Note the long felt quartz layer with thickness of 0 ~ 1 feet commonly included limestone beds at core drilled area.

Table 01. A table of quartz content at fourth core drill (CD 4), quarry site, Aruwakkalu. Showing analyzed quartz content according to depth of the core drill.

CD 4				
Sample No	Thickness		Composite	Quartz (g) %
	From (m)	To (m)		
1	15.10	16.90		92.86
2	16.90	18.15		10.00
3	18.15	19.00		10.90
4	19.00	19.25		
5	19.25	20.80		15.68
6	20.80	22.15		13.80
	22.15	23.05	WOOD	
7	23.05	23.65		1.5
8	23.65	24.00		1.80
9	24.00	25.75		
10	25.75	27.00		4.80
11	27.00	28.50		29.54
12	28.50	29.00		33.17
13	29.00	30.00		
14	30.00	32.75		19.24
15	32.75	34.00		22.68
16	34.00	34.70		
17	34.70	37.50		46.54
18	37.50	40.00		67.36

Table 01. A table of quartz content at fourth core drill (CD 6), quarry site, Aruwakkalu. Showing analyzed quartz content according to depth of the core drill.

CD 6				
Sample No	Thickness		Composite	Quartz (g) %
	From (m)	To (m)		
1	6.90	8.45		19.2
2	8.45	10.00		25.2
3	10.00	10.60		
4	10.60	12.15		20.4
5	12.15	13.65		11.2
6	13.65	15.15		
7	15.15	16.81		19.8
8	16.81	18.70		74.2
9	18.70	19.65		32
10	19.65	21.90		41
11	21.90	23.40		18.8
12	23.40	23.65		2.2
13	23.65	25.75		3.6
14	25.75	26.70		53.4
15	26.70	27.30		
16	27.30	29.00		69.4
17	29.00	30.00		64.4
18	30.00	36.00		74
19	36.00	42.00		79.2

Table 01. A table of quartz content at fourth core drill (CD 7), quarry site, Aruwakkalu. Showing analyzed quartz content according to depth of the core drill.

CD 7				
Sample No	Thickness		Composite	Quartz (g) %
	From (m)	To (m)		
1	21.60	23.80	1	11.32
2	23.80	24.62	2	11.48
3	24.92	25.82		0.88
4	26.17	26.73	3	5.66
5	26.73	27.57		0.64
6	27.57	28.32		0.62
7	28.32	28.87	4	0.96
8	28.87	30.07		0.52
9	30.07	31.27	5	1.64
10	31.27	32.05		0.24
11	32.05	32.47	6	0.36
12	32.77	33.47		1.58
13	33.47	34.97	7	0.48
14	35.58	36.83		26.78
15	36.83	37.33	8	42.9
16	37.33	37.53	9	12.36
17	37.53	37.63		9.76
18	37.63	38.78		29.98
19	38.78	39.53	10	52.98
20	39.53	41.48	11	13.4
21	41.48	42.08	12	17.94
22	42.08	42.68		
23	42.68	43.18	13	15.7
24	43.18	43.58	14	12.34
25	43.58	44.98		21.92
26	44.98	45.43	15	45.9
27	45.43	46.13		18.5
28	46.13	46.56		
29	46.56	47.04	16	10.14
30	47.04	47.42		7.36
31	47.42	48.04		4.24
32	48.04	48.60		
33	48.60	49.22		16.3
34	49.22	49.78		8.94
35	49.78	50.20		9.72

Table 01. A table of quartz content at fourth core drill (CD 8), quarry site, Aruwakkalu. Showing analyzed quartz content according to depth of the core drill.

CD 8				
Sample No	Thickness		Composite	Quartz (g) %
	From (m)	To (m)		
1	10.55	11.9		20.82
2	11.9	13.9		16.02
	13.9	14.25	WOOD	
3	14.25	16.2		31.82
4	16.2	16.9		43.56
5	16.9	17.2	WOOD	
6	17.2	18.7		
	17.8	18.85		
7	18.85	19.3		12.96
8	19.3	20.55		
9	20.55	22.3		1.92
10	22.3	24.05		3.94
11	24.05	25.55		1
12	24.55	27.9		3.8
13	27.9	28.9		
14	28.9	29.6		22.2
15	29.6	32.1		24
16	32.1	33.8		10.58
17	33.8	34		56.42
18	34	35		61.12
19	35	40.5		56.68
20	40.5	46		34.54

Table 01. A table of quartz content at fourth core drill (CD 9), quarry site, Aruwakkalu. Showing analyzed quartz content according to depth of the core drill.

CD 9				
Sample No	Thickness (m)		Composite	Quartz (g) %
	From (m)	To (m)		
1	8.20	10.78		17.82
2	10.78	12.75		21.1
3	12.75	13.46		
4	13.46	15.18		10.32
5	15.18	15.54		25.48
6	15.54	16.18		11.7
7	16.18	17.08		20.66
8	17.08	17.43		
9	17.43	18.80		9.94
10	18.80	20.60		4.7
11	20.60	22.10		7.7
12	22.10	23.25		10.84
13	23.25	24.55		0.48
14	24.55	26.90		3.32
15	26.90	28.02		55.24
16	28.02	29.00		61.24
17	29.00	30.40		57.32
18	30.40	31.04		41.14
19	31.04	32.12		41.08
20	32.12	32.76		76.8
21	32.76	34.07		31.62
22	34.07	36.57		26.74
23	36.57	39.00		62.36

Table 01. A table of quartz content at fourth core drill (CD 10), quarry site, Aruwakkalu. Showing analyzed quartz content according to depth of the core drill.

CD 10				
Sample No	Thickness		Composite	Quartz (g) %
	From (m)	To (m)		
1	9.00	10.00		6.6
2	10.00	10.30		32.3
3	10.30	13.00		13.32
4	13.00	15.00		6.12
5	15.00	17.00		10.84
6	17.00	18.20		16.42
7	18.20	18.90		22.12
8	18.90	19.20		10.14
9	19.20	21.82		28.18
10	21.82	22.80		16.88
11	22.80	23.22		17.6
12	23.22	23.60		34.88
13	23.60	23.92		14.68
14	23.92	24.92		11.56
15	24.90	26.87		1.18
16	26.87	28.03		0.6
17	28.03	28.80		1.28
18	28.80	31.10		6.08
19	30.10	31.60		3.5
20	31.60	32.82		68.4
21	32.82	33.10		28.2
22	33.10	34.66		35.34
23	34.66	35.01		52.24
24	35.01	40.00		51.26

Table 01. A table of quartz content at fourth core drill (CD 11), quarry site, Aruwakkalu. Showing analyzed quartz content according to depth of the core drill.

Sample No	CD 11			
	Thickness (m)		Composite	Quartz (g) %
	From (m)	To (m)		
1	15.25	15.50		15.2
2	15.50	19.30		46.12
3	19.30	20.35		5.44
4	20.53	20.65		3.7
5	20.65	22.15		3.3
6	22.15	24.85		1.76
7	24.85	25.45		2.26
8	25.45	25.90		5.6
	25.90	26.40	WOOD	
9	26.40	28.40		0.7
10	28.40	29.75		5.52
11	29.75	30.55		61.24
12	30.55	31.70		55.46
13	31.70	36.00		49.52
14	36.00	40.00		67.34

Table 01. A table of quartz content at fourth core drill (CD 12), quarry site, Aruwakkalu. Showing analyzed quartz content according to depth of the core drill.

CD 12					
Sample No	Thickness (m)		Composite		Quartz (g) %
	From (m)	To (m)			
1	17.40	18.60			15.62
2	18.60	20.55			16.5
3	20.55	22.95			16.1
4	22.95	23.20			12.1
5	23.20	25.42			20.7
6	25.42	27.35			1.82
7	27.35	28.25			9.42
8	28.25	28.85			13.24
9	28.85	29.18			24.58
10	29.18	30.98			
11	30.98	32.86			
12	32.86	34.25			
13	34.25	35.40			52.36
14	35.40	40.00			49.36

Table 01. A table of quartz content at fourth core drill (CD 12), quarry site, Aruwakkalu. Showing analyzed quartz content according to depth of the core drill.

CD 12				
Sample No	Thickness (m)		Composite	Quartz (g) %
	From (m)	To (m)		
1	17.40	18.60		15.62
2	18.60	20.55		16.5
3	20.55	22.95		16.1
4	22.95	23.20		12.1
5	23.20	25.42		20.7
6	25.42	27.35		1.82
7	27.35	28.25		9.42
8	28.25	28.85		13.24
9	28.85	29.18		24.58
10	29.18	30.98		
11	30.98	32.86		
12	32.86	34.25		
13	34.25	35.40		52.36
14	35.40	40.00		49.36

Table 01. A table of quartz content at fourth core drill (CD 13), quarry site, Aruwakkalu. Showing analyzed quartz content according to depth of the core drill.

CD 13				
Sample No	Thickness (m)		Composite	Quartz (g) %
	From (m)	To (m)		
1	15.50	17.05		9.12
2	17.05	18.95		5.8
3	18.95	19.80		6.98
	19.80	21.65	WOOD	
4	21.65	23.35		13.7
5	23.55	25.65		14.22
6	25.65	27.85		5.2
	27.85	28.45	WOOD	
7	28.45	30.75		1.88
	30.75	31.00	WOOD	
8	31.00	33.00		0.48
	33.00	33.25	WOOD	
9	33.25	33.50		3.12
	33.50	34.00	WOOD	
10	34.00	34.80		2
11	34.80	36.10		2.26
12	36.10	38.10		0.86
13	38.10	39.95		9.88
14	39.95	41.45		65.28
15	41.45	43.00		64.3

Table 01. A table of quartz content at fourth core drill (CD 14), quarry site, Aruwakkalu. Showing analyzed quartz content according to depth of the core drill.

CD 14				
Sample No	Thickness (m)		Composite	Quartz (g) %
	From (m)	To (m)		
1	16.82	19.63		9.46
2	19.63	21.96		3.18
3	21.96	24.68		4.04
4	24.68	26.71		14.4
5	26.71	27.00		49.42
6	27.00	28.06		61.72
7	28.06	28.95		29.02
8	28.95	29.40		51.74
9	29.40	31.65		49.2
10	31.65	33.67		19.7
11	33.67	34.37		29.54
12	34.37	36.47		31.38
13	36.47	37.03		58.34
14	37.03	40.00		23.7

Table 01. A table of quartz content at fourth core drill (CD 15), quarry site, Aruwakkalu. Showing analyzed quartz content according to depth of the core drill.

CD 15				
Sample No	Thickness (m)		Composite	Quartz (g) %
	From (m)	To (m)		
1	17.75	20.40		19.78
	20.40	21.30	WOOD	
2	21.30	21.80		37.86
3	21.80	23.00		18.9
4	23.00	24.75		22.6
5	24.75	26.00		25.74
	26.00	27.00	WOOD	
6	27.00	29.00		9
7	29.00	31.00		2.34
8	31.00	32.50		0.86
9	32.50	34.20		0.84
	34.20	34.50	WOOD	
10	34.50	36.20		0.5
	36.20	37.30	WOOD	
11	37.30	39.50		4.28
12	39.50	42.50		62.74

Table 01. A table of quartz content at fourth core drill (CD 17), quarry site, Aruwakkalu. Showing analyzed quartz content according to depth of the core drill.

CD 17				
Sample No	Thickness (m)		Composite	Quartz (g) %
	From (m)	To (m)		
1	22.4	24.5		21.46
2	24.5	27.1		21.46
3	27.1	27.3		30.08
	27.3	27.8	CAVITY	
4	27.8	28.6		30.8
	28.6	29	CAVITY	
5	29	30.9		30.86
	30.9	31.9	CAVITY	
6	31.9	32.2		23.52
7	32.2	33.5		26.46
8	33.5	33.95		21.8
9	33.95	35.18		33.94
	35.18	35.85	WOOD	
10	35.85	37.20		12.7
11	37.20	37.70		12.64
12	37.70	38.70		
13	38.70	39.20		19.8
14	39.20	40.00		5.88
	40.00	41.65	CAVITY	
15	41.65	42.65		8.28
	42.65	43.20	CAVITY	
16	43.20	44.20		25.6
17	44.20	44.85		3.2
18	44.85	45.75		
19	45.75	47.00		0.77
20	47.00	49.00		0.58
21	49.00	50.20		0.74

Table 01. A table of quartz content at fourth core drill (CD 18), quarry site, Aruwakkalu. Showing analyzed quartz content according to depth of the core drill.

CD 18				
Sample No	Thickness (m)		Composite	Quartz (g) %
	From (m)	To (m)		
1	23.15	23.30		29.6
	23.30	27.80	Sudden Drop	
2	27.80	28.70		33.2
3	28.70	29.50		77.2
4	29.50	30.00		20.8
5	30.00	31.25		16.8
6	31.25	31.80		14.6
	31.80	32.75	Wood	
7	32.75	34.90		1.2
8	34.90	36.60		0.06
9	36.60	38.75		1.4
10	38.75	41.05		1.4
11	41.05	42.15		6.2
12	42.15	42.50		56.6

Table 01. A table of quartz content at fourth core drill (CD 19), quarry site, Aruwakkalu. Showing analyzed quartz content according to depth of the core drill.

CD 19				
Sample No	**Thickness (m)**		**Composite**	**Quartz (g) %**
	From (m)	**To (m)**		
1	25.20	27.16		13
2	27.16	30.60		19.46
3	30.60	31.50		3.4
4	31.50	32.75		7.68
5	32.75	34.00		3.4
6	34.00	35.20		0.2
7	35.20	37.80		0.16
8	37.80	39.72		0.24
9	39.72	41.40		0.2
10	41.40	43.70		1
11	43.70	44.40		1.6
12	44.40	45.30		64.2
13	45.30	45.80		

Table 01. A table of quartz content at fourth core drill (CD 20), quarry site, Aruwakkalu. Showing analyzed quartz content according to depth of the core drill.

CD 20				
Sample No	Thickness (m)		Composite	Quartz (g) %
	From (m)	To (m)		
1	19.83	22.31		54.5
2	22.31	24.20		24.06
3	24.20	24.61		30.74
4	24.61	27.51		26.5
5	27.51	29.91		19
6	29.91	31.41		28.86
7	31.41	32.91		72.41
8	32.91	34.00		10.98
9	34.00	35.11		19.86
10	35.11	36.01		9.34
11	36.01	38.00		3.36
12	38.00	40.66		0.96
13	40.66	43.00		2.06
14	43.00	45.00		1.36
15	45.00	46.54		13.2
16	46.54	47.00		2.7
17	47.00	48.80		17.68

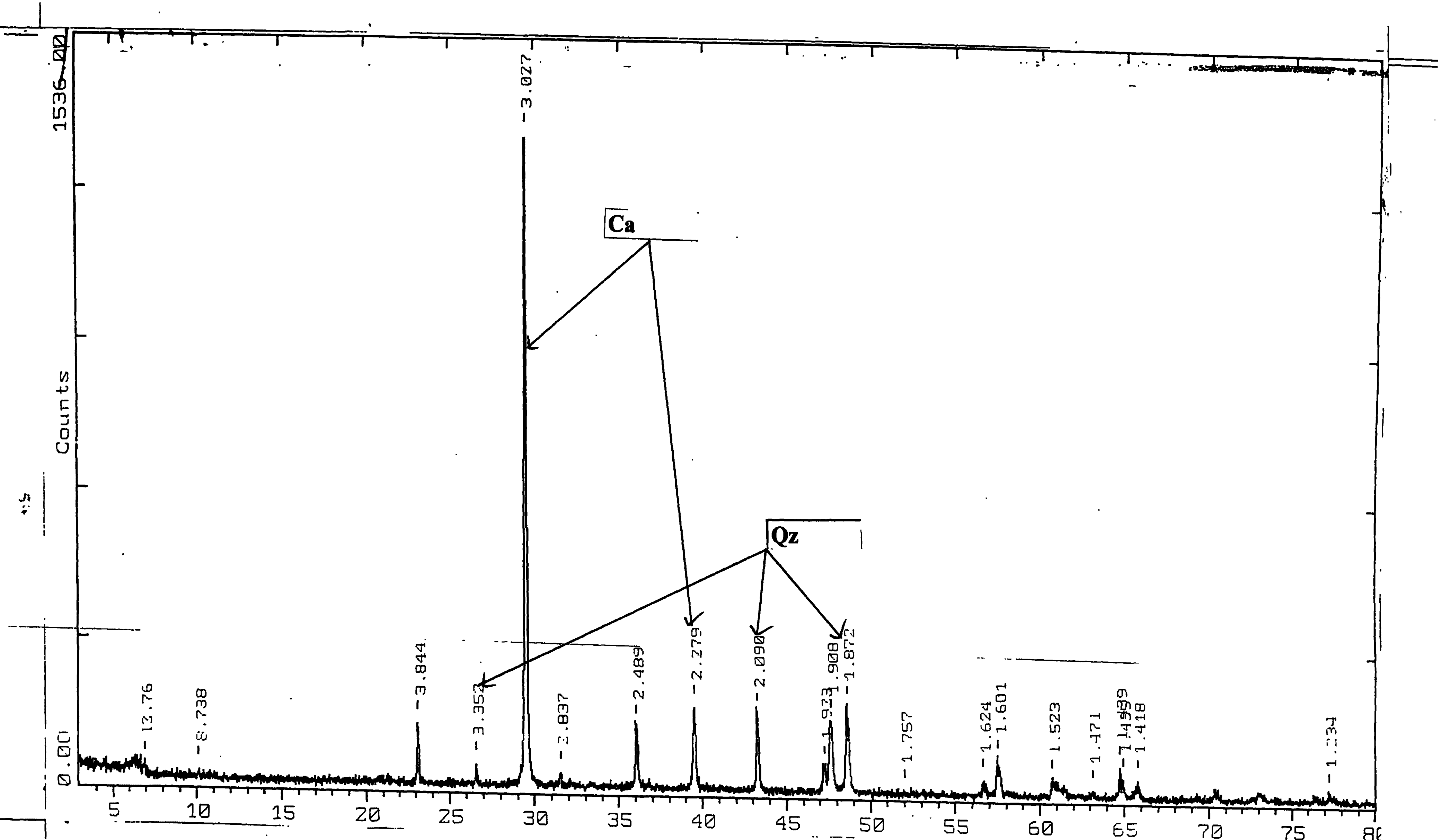


Figure 01. A graph of XRD (X-Ray Defractometer) analysis of the rock sample from CD –6, High-grade limestone layer, quarry site, Aruwakkalu. Showing different height of peaks, which is related to different types of minerals. Note the calcite (Ca) and quartz (Qz) as major minerals of high-grade limestone.

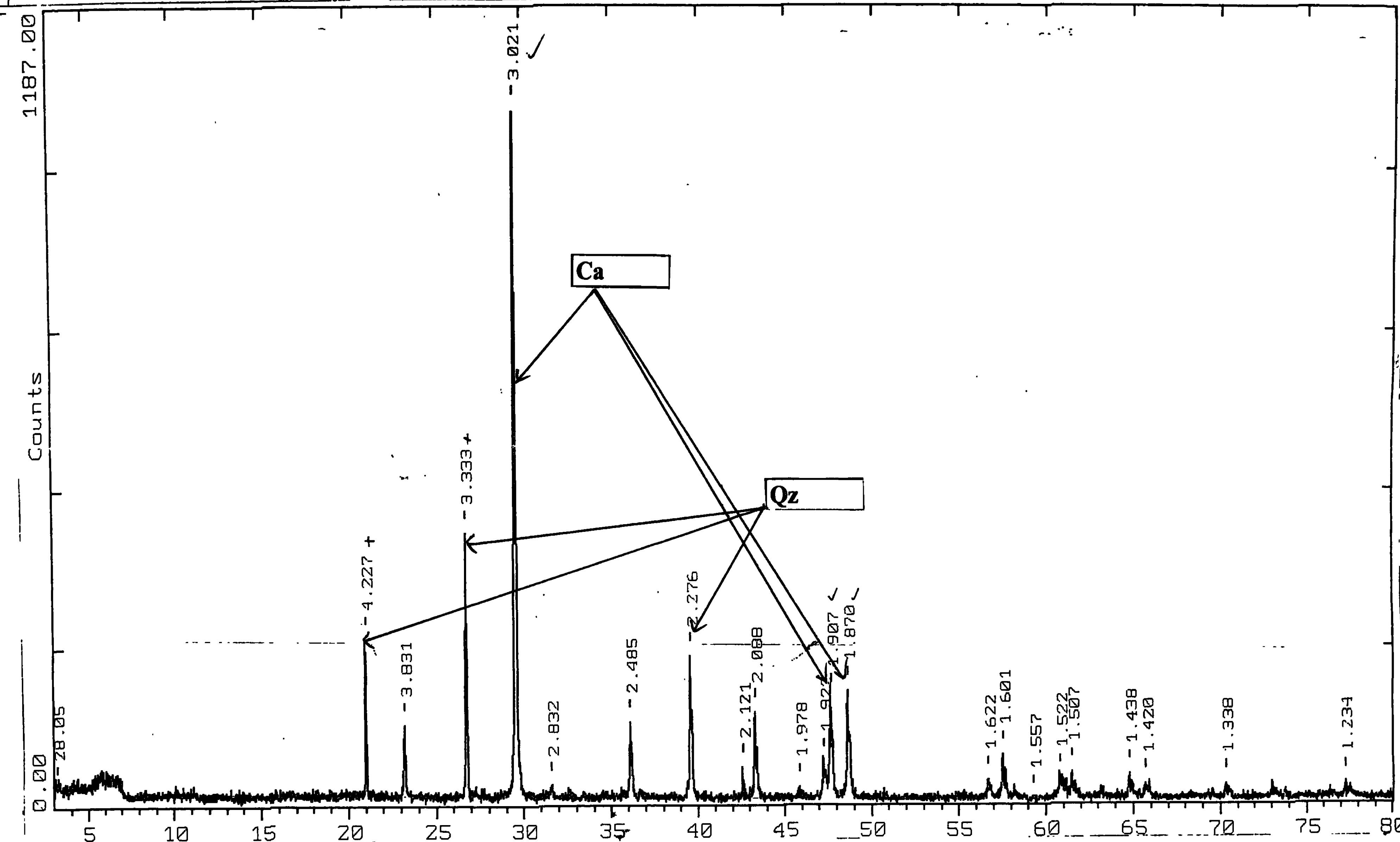


Figure 01. A graph of XRD (X-Ray Defractometer) analysis of the rock sample from Old Karative, Low-grade limestone layer, quarry site, Aruwakkalu. Showing different height of peaks, which is related to different types of minerals. Note the calcite (Ca) and quartz (Qz) as major minerals of high-grade limestone.

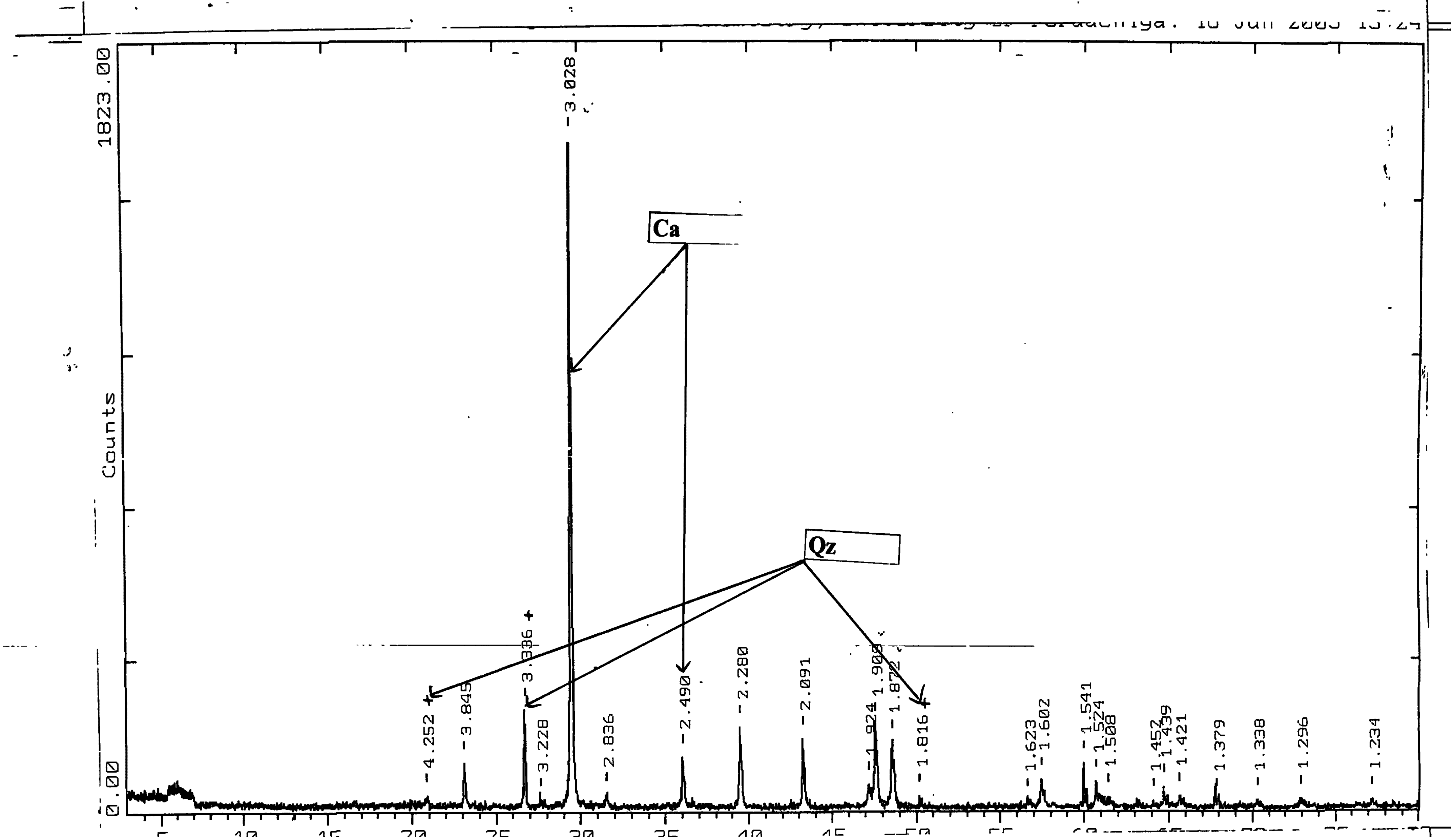


Figure 01. A graph of XRD (X-Ray Defractometer) analysis of the rock sample from TML-Site, Low-grade limestone layer, quarry site, Aruwakkalu. Showing different height of peaks, which is related to different types of minerals. Note the calcite (Ca) and quartz (Qz) as major minerals of high-grade limestone.

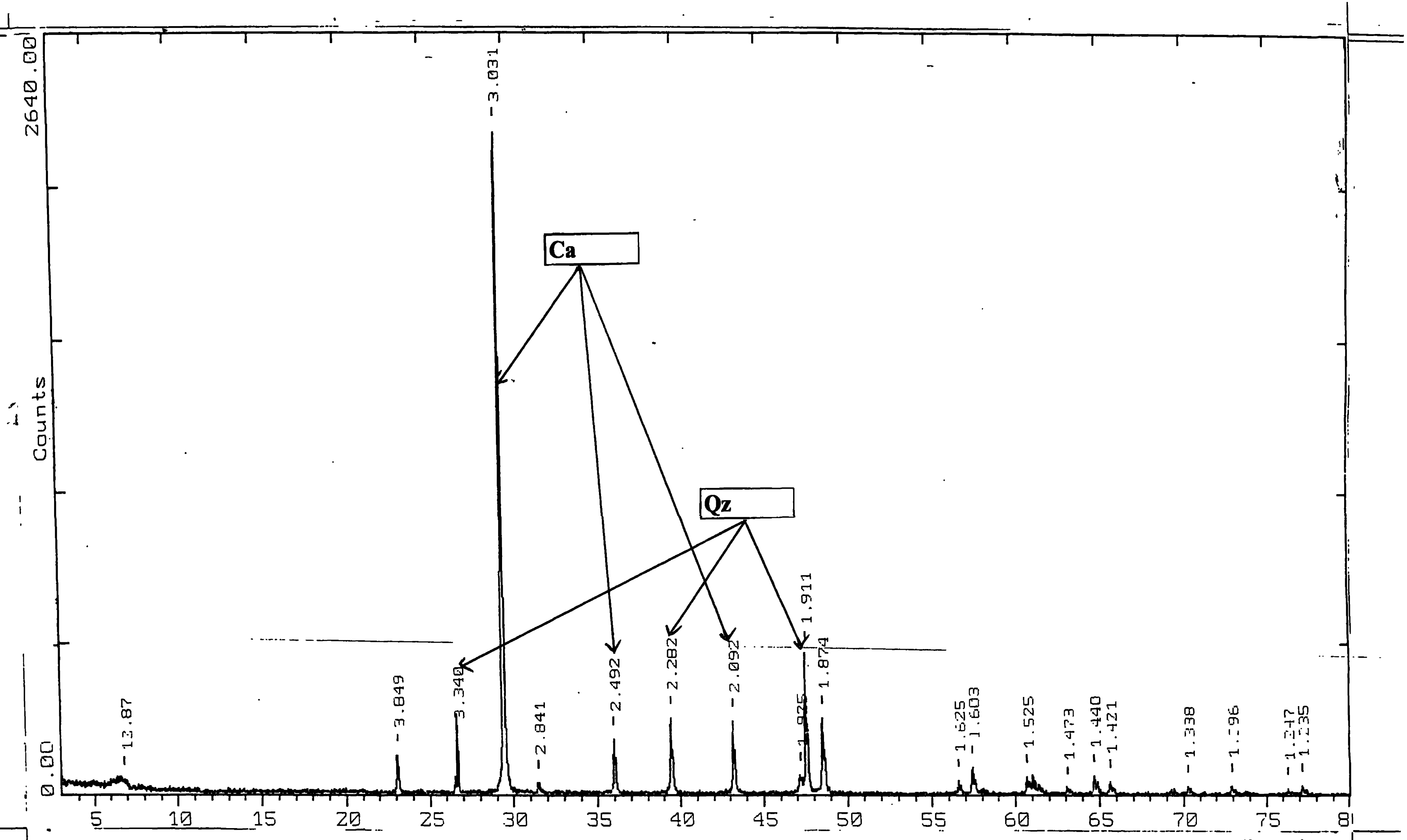


Figure 01. A graph of XRD (X-Ray Defractometer) analysis of the rock sample from CD-6, High-grade (hard) limestone layer, quarry site, Aruwakkalu. Showing different height of peaks, which is related to different types of minerals. Note the calcite (Ca) and quartz (Qz) as major minerals of high-grade limestone.

National Digitization Project

National Science Foundation

Institute : Sabaragamuwa University of Sri Lanka

1. Place of Scanning : Sabaragamuwa University of Sri Lanka, Belihuloya
2. Date Scanned : ...2017-09-26...
3. Name of Digitizing Company : Sanje (Private) Ltd, No 435/16, Kottawa Rd, Hokandara North, Arangala, Hokandara
4. Scanning Officer

Name : ...G.A.C. Gadaruwan...

Signature : ....

Certification of Scanning

I hereby certify that the scanning of this document was carried out under my supervision, according to the norms and standards of digital scanning accurately, also keeping with the originality of the original document to be accepted in a court of law.

Certifying Officer

Designation : LIBRARIAN...

Name : T.N. NEIGHSOOREI...

Signature : ....

Date : ...2017-09-26.........

"This document/publication was digitized under National Digitization Project of the National Science Foundation, Sri Lanka"