Chapter One

INTRODUCTION

1.1 Background

Mineral resources are the backbone for the development of world. They make country stronger socially and economically. There is not a single industry which can develop without minerals or their products. Minerals form a part and parcel of our daily life.

Limestone is one of the versatile rock in industries. It is a basic raw material for many industries such as the manufacturer of cement, cynamide, carbide, glass etc. It is used as flux in the ferrous and non-ferrous metal industries, as a soil-stabilizing agent in the manufacture of caustic soda and sulphate pulp. In fact, it is an indispensable material for various chemical industries. Certain varieties of limestone also serve as a building stone; they are widely used for flooring, exterior and interior facings and monuments.

Nepal has been prospecting and exploring for limestone since late sixties. A large number of limestone deposits of various grades were discovered, explored and several industries were established on their basis. A total of about 1250 million tons of cement grade limestone is estimated to exist in country, of this, about 224 million tons have been proved by drilling. Due to the infra-structural constraints, at present only the areas accessible by roads are prospective for cement plants and they lie in the southern parts of the country along the Mahabharat Range (Sah, et.al. 2003)

Limestone of different age from Precambrian to Tertiary are known in Nepal Lesser Himalaya. Limestone has also been found in Sub-Himalayan Zone in Udayapur. The late Precambrian and Cambro-ordovician limestones are the main sources of limestone for cement plant in Nepal (UNDP, 1993). Different formation and units are important in Nepal which includes Chandragiri Limestone, Bhainsedobhan Marble and Jhiku bed within Benighat slate.

Bhainsedobhan Marble is the geological formation containing calcareous rocks with potential for cement grade limestone. Deposits in exploitation stage like Sindali, Udayapur; Bhainse and Okhare, Makawanpur; Kakaru Khola, Sindhuli belongs to this formation. This dissertation mainly concerned mainly with the geology, mining and processing of Okhare Limestone Deposit of Hetauda Cement Industries Limited.

1.2 Location and Accessibility

The study area lies in the Makawanpur District of the Narayani Zone. Geographically, it extends between longitudes $85^{0}01'48''$ to $85^{0}07'30''$ east and $27^{0}26'46''$ to $27^{0}30'33''$ north latitudes(Fig 1.1). It is accessible by the Tribhuvan Rajmarg.

Okhare Limestone deposit lies at latitude $27^{0}28'36''$N and longitude $85^{0}07'$E. this area is at the boundary of Nibuwatar V.D.C. and Ambhanjyan V.D.C.

The deposit is located in Chhatre Bhanjyang mountain range south of Okhare village. Deposit is accessible by about 16km road connecting it to Baghjhora khola at Tribhuvan Rajmarg (Fig. 1.2).

1.3 Climate

The region falls in sub-equatorial zone and bears subtropical climate. It is hot and humid in summer. Average seasonal temperature of summer and winter is 28^{0}c and 13^{0}c respectively. The difference between day and night temperature show a difference ranging from $\pm 10^{0}$c in August to $\pm 20^{0}$c in March and April. The humidity touches its highest in August about 81% and is least in April at about 7%.
The area experiences an annual rainfall of around 3000mm which is strongly concentrated in the monsoon season(from June to September).

The higher hills have congenial climate even during summer. During winter there is occasional snowfall at altitudes above 2000m but it does not lasts long.

1.4 Topography and Drainage

The study area belongs to the Lesser Himalaya of Central Nepal. It shows the great variation in elevation ranging from 2080m near Chhatre Bhanjyang to 500m at Samari khola. The topography of the study area is rugged.
The study area consists of a part of watershed of Samari Khola and Rapti Khola and exhibits dendritic drainage pattern(Fig. 1.2). The trunk river of the area is the Rapti Khola. Poldamki Khola and Samari Khola are its big tributaries. Tributaries of Samari Khola are Budal Khola, Sukaura Khola, Jyamire Khola, Bhalu Khola and their tributaries form gorges.

Fig.1.1: Location map of the study area

Fig. 1.2: Drainage and accessibility map of the study area

1.5 Objectives

The objectives of the study are:

- To clarify the regional geology of the study area.
- To evaluate the quality and reserve of Okhare Limestone Deposit.
- To have a general understanding on mining and processing of limestone by Hetauda Cement Industries Limited.

1.6 Methodology

The following works were conducted in the present study:

1.6.1 Preliminary work

Preliminary work includes review of literatures, study of different maps and documents to prepare for detail plan for future. The purpose of literature review was to collect relevant maximum information regarding the study area. Various papers, journals, texts and maps giving information about study area were collected and compiled, which gave the general idea of the study area.

1.6.2 Field work

Because of the lack of regional geological map of the deposit area and to know the feature of the deposit and for collection of samples for study of minerals in thin section, fieldwork was carried out. Fieldwork was carried out by taking geological traverses across the geological trends. In the field, attitudes of beds were taken during field traverse using a Brunton compass. Photographs of the significant features were taken in the necessary places. Columnar sections were prepared in different places by measuring the vertical thickness of the beds. The boundaries between different formations were marked on a 1:25,000 scale topographic map during geological traverses.

1.6.3 Desk and laboratory work

After the completion of field work, desk and laboratories work were performed. These tasks were following:

_ Determination of chemical constituents of limestones

_Study of limestone in thin section

_ Interpretation of the laboratory data

_ Reserve estimation of deposit

_ Preparation of geological map, cross-sections and columnar sections by using computer softwares.

1.6.4 Report prepation

This thesis was compiled using both the primary as well as secondary data. The final report was prepared by the detail study of the primary data, secondary data, laboratory analysis as well as considering the comments and suggestions from the supervisor.

1.7 Limitation of the study

As the scope of the study is limited to the fulfillment of the dissertation, data collection, analysis and interpretation are also limited to that extent. The reserve estimation has been done with the help of few cross sections, borehole data, and existing topo–graphic map. The accurate estimation of the reserve requires the preparation of detail large-scale topographic maps of the area. Three dimensional modeling of the deposit with computer, using the borehole data and topography of the area can provide the distribution view of cement grade limestone within the deposit.

Chapter Two

PREVIOUS WORKS ON CEMENT GRADE LIMESTONE DEPOSIT

2.1 Background

Nepal has several large and small scale deposits of cement grade limestone. Different researchers are participating in exploration of limestone since late sixities.

Khattri(1977) has summarized the available data on mineral resources of Nepal including cement grade limestone deposits of Nepal. Mentioning the different uses of limestone, he stressed that the limestone zone is developed up to Karnali in the west and up to Koshi on the east.

2.2 Bhainsedobhan Marble

Of the different limestone bearing formations, Bhainsedobhan Marble is one of the most important Formation. The occurrence of limestone or marble at Bhainsedobhan and other areas around was recorded as early as 1875 by Mr. H. B. Medlicott of geological survey of India in his note on the geology of Nepal(Medlicott, H.B., 1875).

A very useful account of the Bhainsedobhan Marble and other area around is given by Mr. V. P. Sondali of the Geological Survey of India who examined the area in 1947 in order to ascertain the suitability of this area for manufacturing cement(Baskota, 2007).

In 1949, Dr. J. B. Auden of geological Survey of India visited the Bhainsedobhan area, and samples collected by him showed slightly higher percent of silica, magnesia and alkali than to be permissible in the cement industry. So, Auden suggested the use of Bhinsedobhan Limestone after beneficiation as done for similar type of limestone at Valley Forge, Catasauqua, Pennsylvania, U.S.A (Auden, 1963). In 1952-53, Mr. S. P. Nautiyal and P. C. Sogani of geological Survey of India investigated the Limestone at Bhainsedobhan and the area around. Certain bands of cement grade quality were found at Bhainsedobhan, separated from one another by dolomitic and siliceous bands (Nath and Sogani 1955).

Kohres and Ruolf (1965) reported three cement grade limestone deposits, namely Bhainsedobhan, Okhare and Hathisund deposits. The CaO and MgO content of the surface samples from Bhaisedobhan deposit is given in Table 2.1.

Table 2.1 Chemical compositions of the Bhainsedobhan Deposit (After Kohres and Ruolf 1965)

Site of sampling	Chemical composition	Percentage
Rapti River	CaO	34.11% – 47.3%
	MgO	2.49% – 4.01%
Kitni Khola	CaO	36.9% – 46%
	MgO	2.08% – 5.05%

2.2.1 Bhainse Deposit

Nath and Sogani (1955) did the detailed work under the Geological Survey of India with sectional sampling over that and reported 25 MT of the cement grade limestone.

The exploration work of NBM took place at the eastern side of the resource in the Rapti riverbed in 1968. The average value resulting from the chemical analysis of their samples is presented in the Table 2.2.

Table 2.2 Chemical Constituent of the Bhainsedobhan Limestone Deposit (NBM, 1968)

Chemical Constituents	**Weight Percentage**
Insoluble	9.27
CaO	47.26
MgO	1.92
R_2O_2	1.66

The detailed exploration work on the Bhainse limestone deposit was again started by NBM in the year 1972/73.

Shah and Kansakar(1973) worked out with seven boreholes of 1,431.12m total depth and seven trenches of 1,400m aggregate length in the area and estimated the total reserve of cement grade limestone to be 3.37 MT without blending and 5.14MT with blending. Average composition of the limestone without blending and with blending was calculated as CaO: 45.67%; MgO: 1.36% and CaO: 44.16%; MgO: 1.95%, the limestone to waste material ratio was calculated as 1:1.3 and 1:0.69 respectively for these two conditions.

Khattri and Kansakar(1973) reported the total reserve of 8MT of cement grade limestone. The strike length of the deposit was taken 715m and average depth was taken 86 m. The average composition of the deposit was found to be 44.3% of CaO and 2.75% of MgO. They drilled three boreholes totaling 515.4m in length and dug ten trenches aggregating 787m in length. The average dip of the limestone was put as 60^o N/20^o E. Limestone to waste material ratio was estimated to 1:0.84. On these findings they had suggested for the establishment of 750tpd cement plant running for 22years.

Detailed work for the establishment of the cement plant using limestone deposit of Bhainse Deposit was done by Holtec Engineers(1975). The quantity of total reserve calculated by this company was about 10.8 MT with tonnage factor of 2.6 and voidage of 20%. The limestone to waste material ratio was kept about 1:0.70. The shape of the body was described about 654m long and 130m wide in average. They have also suggested for the availability of 6.5 –7 MT of cement grade limestone in the west of the selected area and additional 8.6 MT of the
Okhare Deposit could be used for the same plant.

2.2.2 Okhare Deposit

Okhare Limestone deposit has been investigated many times for a long period. These data are as follows:

Investigation Year	Content
1955	The investigation was done on Bhainse Dobhan, Okhare and Hathisund Limestone for the manufacture of Portland cement by Mukti Nath and P.C. Sogani.
1964	China team investigated Cement raw material in Hetauda area
1975	Nepal Bureau of Mines investigated in detail Okhare Limestone deposit for Cement raw material by Borings and Trenches. 8 Borings the total sum 978.76m. Trenches (5 recent trenches, some former trenches). Surface samples 465.
1987	COSMO INTERNATIONAL CO. LTD in association with UBE industries LTD. Japan investigated the

deposit with the help of the data of NBM and studied in detail its quality, reserves, mining techonology, infrastructure development and economic factor associated with deposit.

The result of NBM(1975) shows that the Okhare limestone deposit has a total proved reserve of 10million tones of cement grade limestone (taking 85% recovery factor) within a strike length of 640m and 140m average depth along dip slope. The limestone has almost east-west strike dipping 34^0-56^0 northerly (average being 45^0). The average composition of proved limestone is as follows:

Cao- 46.31%, Mgo- 1.30%, Insoluble- 11.9%.

The result of UBE, Japan shows that the limestone layer is to be about 100m thick, and this deposit consists largely of limestone, but includes some phyllite lenses of maxium 25m thick. This deposit is lenticular and thins down from east to west. In order to indicate the detailed quality of this deposit they divided it into 12,000 blocks each of which are 10m long, 10m wide and 5m high, regarding the deposit as a model. Cao content quantity are as follows:

Cao%	**Quantity(ton)**
0-30	1,684,540
30-40	3,384,680
40-45	3,573,440
45-50	5,853,640
50-53	507,520
	15,003,820

2.3 Other cement grade Limestone Deposit

A research team of UNDP, 1993 has enlisted the cement grade limestone deposits of Nepal with their reserve category, quality i.e. percentage of CaO and MgO and reserve in their Atlas of Mineral Resources.

Shrestha (2001) has described about the limestone deposits and prospects of Nepal giving details of their development stage. Distributions of these deposits and prospects are accompanied by the geological formations containing calcareous rocks with high potential for cement grade limestone (Fig. 2.1). The updates of these deposits have been summarized as below.

2.3.1 Deposits in Exploitation

- Chobhar, Kathmandu District-Its proved reserve is 14.5 MT with CaO-47.93% and MgO- 1.29% and was exploited by Himal Cement Factory.
- Okhare, Makawanpur District- This deposit is near to Bhainse Deposit and is used by the Hetauda Cement Factory. Total proved reserve is 10 MT with CaO 46.31% and MgO 1.3%.
- Sindali, Udaypur District- Huge reserve of 72 MT is proved with good grade of CaO-52% and MgO- less than 1.5%. A 800 TPD cement plant, Udayapur Cement Factory, has already established
- Kakaru Khola, Sindhuli District- Total reserve of 1 MT is licensed to a private party. Based on this, a mini cement plant, Maruti Cement Industry, is established.
- Jogimara, Dhading District- The deposit lies at 90 km, from Kathmandu on Kathmandu-Phokara Highway. This deposit has high quality limestone with Cao- 53.2% and MgO- less than 0.7%. Total estimated reserve is 3.6 MT. It was used by Agricultural Lime Corporation.
- Beldanda, Dhading District- It is located at 93 km from Kathmandu on the Kathmandu – Pokhara road. Annapurna Quarry, based on this deposit has been established as a private sector. The total reserve is 1.72 MT of high quality limestone has been proven. The average CaO is 54.4% and MgO is 0.28%.
- Bhainse, Makawanpur District- Hetauda Cement Industry with 750 TPD is established. CaO - 45% and MgO - 2.5% with total reserve of 8 MT.

2.3. 2 Cement Grade Limestone Deposits offered to industry

- Chaukune, Surkhet District- The deposit is located at the Guttu Village, Badichaur near Surkhet valley. A reserve of about 31 MT is probable. Where CaO- 47.86%, and MgO less than 1.3%. This deposit is offered to private sector for the establishment of 1,000-tpd cement factory.
- Narapani, Arghakhanchi District- The deposit is situated near the Narapani Pass. A probable reserve is of about 17.44 MT with CaO- 47.32% and MgO- 2.58%. The deposit is licensed to Dynesty Cement Industries for the establishment of 800-tpd cement factory.
- Nigale, Dhankutta District- At present 12 km long foot trail connects the deposit with the nearest motorable point Sindhuwa on the Dhankutta–Basantapur road. Out of 12.63 MT proved reserve of cement grade limestone the mineable reserve is estimated to be about 6.34 MT proven and 12.63 MT probable, where CaO- 51.2% and MgO – 1.02%.
- Sharada, Dang and Sallyan Districts- To Total probable reserve is 524.71 MT with CaO: 48.78% and MgO: 2.14%. This is licensed to Dang Cement Pvt. Ltd.

- Kajeri, Sallyan District- The deposit is located at 61 km, point of the Tulsipur–Musikot road. The proven reserve is 29.63 MT and possible reserve is 74.11 with CaO- 51.9% and MgO- 1.86%.

2.3.3 Limestone Deposits in various stages of exploration

- Gandhari, Dang District- 14 MT of reseve. Grade is CaO-42.11% and MgO-4.94%.
- Lakharpata, Surkhet District- About 30 MT of limestone with CaO-47.73% and MgO- 2.19%.
- Supa, Arghakhanchi District- 8.2 MT of cement grade limestone with Cao-47.32% and MgO-2.58%.
- Balthali, Karvre District- The reserve of 0.45 MT is licensed to private sector.
- Nandu, Karvre District- The reserve of 4.67 MT is licensed to private sector.
- Galtar, Udayapur District- Total probable reserve of 18.29 MT is licensed to a private party. It has CaO-52.29% and MgO-1.23%. The reserve has been licensed to Golchha Organization.
- Bhatte danda, Lalitpur District- Total reserve of 5.68 MT is licensed to a private party. It has CaO-50.11% and MgO-2.97%.
- Mane, Karvre District- The reserve of 0.9 MT is licensed to private sector.
- Nigure, Karvre District- The reserve of 0.45 MT is licensed to private sector.
- Lamatar, Lalitpur District- Total reserve of 21.54 MT is licensed to a private party.
- Halesi, Khotang District- It is located near the under construction Katari- Okhaldhunga Road. It has 8 MT of cement grade limestone with CaO-50.66% and Mgo-2.2%.

2.3.4. Limestone prospects identified but not explored

- Kurichour, Sallyan District- Only reconnaissance survey was done. It has CaO- >50% and MgO- <1%.
- Badhare Khola, Arghakhanchi District- Only reconnaissance survey was done . It has CaO- 47% and MgO- 2%.
- Kerabari, Palpa District- An extension of more than 10 km limestone belt with CaO- 50-54% and MgO- 2-5% was traced in vicinity of Tansen-Butwal Road.
- Diyarigad, Baitadi District- DMG has carried out preliminary exploration works. A reserve of about 175 to 200 MT of limestone with CaO-49.10% and MgO-2.0% is estimated. Nearby lying prospects Bhumiswar and Chaurha prospect have 40-50 and 3-4 MT respectively.

Fig. 2.1 Limestone distribution map of Nepal

Chapter Three

GEOLOGY OF THE STUDY AREA

3.1 Background

The Nepal Himalaya is located in the central part of the Himalayan arc and covers about one-third (i.e. 800km) of its total length extending from east to west between the Mechi and Mahakali Rivers, respectively. Geographically, it is bounded by latitudes $26^{0}2$'N and $30^{0}27$'N and longitudes $80^{0}11$'E and $88^{0}27$'E.

The study area lies in the central part of the Nepal Himalaya, which is most studied by foreign and native geologists than other parts(eastern and western part).

Auden (1935) is one of the earliest workers who has given a fairly detail geology of central Nepal and noticed the superposition of high-grade metamorphic rocks on low-grade metamorphic rocks in the Mahabharat Range.

Hagen (1969) developed the concept of nappe structure in the Nepal Himalaya. He first delineated the Kathmandu Nappe with its root zone to the Langtang Himalaya through the Gosainkunda Tectonic Bridge(Fig. 3.1).

Stocklin and Bhattari(1977) described the 'Lesser Himalayan Crystalline' in Eastern and Central Nepal, found as isolated Klippe and thrust sheets which overlie the low grade metasediments of Nawakot Complex.

Stocklin(1980) mentioned that the crystalline complex of Kathmandu consists primarily of right-way-up sequence of regionally metamorphosed sediments displaying a metamorphic zonation roughly concordant with stratigraphy and a regular decrease in metamorphic grade from highly garnetiferous schist at the base to barely metamorphosed, fossiliferous Palaeozoic sediments on top. The contact of the Kathmandu Crystalline Zone with the underlying metasediments is marked by intense shearing and by a stratigraphic, metamorphic and structural discontinuity indicating a thrust plane. The Kathmandu Crystalline Zone is interpeted as the remnant of a nappe, rooted in the Central Crystalline Zone.

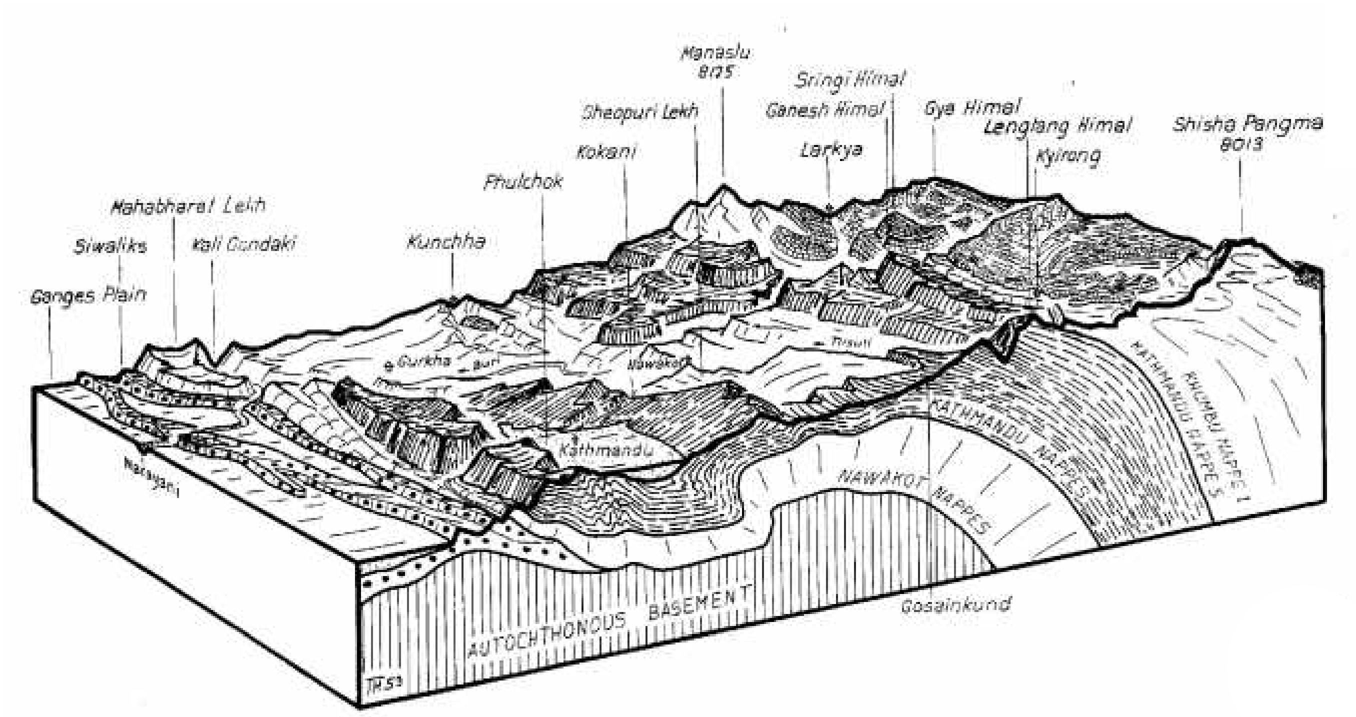


Fig. 3.1 Block diagram showing major geological structures of central Nepal (Hagen,1969)

Stocklin and Bhattarai had also visited the study area for conforming data obtained by photogeology. They noticed the area consists of the southern flank of the Mahabharat Synclinorium in its western central part. They made a geological map of the area(Fig.3.2).

Stratigraphic subdivision of the central Nepal, Lesser Himalaya given by Stocklin (1980) is suitable for study area.(Table 3.1).

Literature helping for study also found in literature of Sah, et.al. (1999) in SAN vol.1, who studied the rocks of Himalaya in terms of age and divided the rocks of Lesser Himalaya into two different geological settings: allochthons and autochthons.

Rocks of allochthons of Prcambrian age are comparable with the Bhimphedi Group of Stocklin(1980), which comprises medium to high-grade metamorphic rocks.

Fig. 3.2: Gelogical map of the study area after Stocklin and Bhattarai(1977)

Table 3.1 Stratigraphic subdivision of Central Nepal Lesser Himalaya after Stöcklin (1980)

Unit	Formation	Main lithology	Apparent Thicknes(m)	Age
Bhimphedi Group	Markhu Formation	Marble, schist	1000	LatePrecambrian
	Kulikhani Formation	Quartzite, schist	2000	Precambrian
	Chisapani Quartzite	White quartzite	400	Precambrian
	Kalitar Formation	Quartz, schist	2000	Precambrian
	Bhainsedobhan Marble	Marble	800	Precambrian
	Raduwa Formation	Garnetiferous schist	1,000	Precambrian
------------------------------------Mahabharat Thrust------------------------------------				
Midland Group	Robang Formation	Phyllite, quartzite	200-1000	Precambrian
	Malekhu Limestone	Limestone, dolomite	800	Precambrian
	Benighat Slate	Slate, argillaceous dolomite	500-3000	Precambrian

Rocks of autochthons of Precambrian age are comparable with the Nawakot Complex of Stocklin(1980) which has been divided into two Groups: Lower Nawakot and Upper Nawakot.

Because of the problem of Nawakot and Nuwakot, different ranking units: Nawakot Complex, Lower Nawakot Group, Upper Nawakot Group, Sah(1999) suggested to adopt another stratigraphic term " MIDLAND" to name the entire Precambrian autochthons succession of Lesser Himalaya as proposed by Arita et.al., (1973).

Rocks of study area falls in Midland and Bhimphedi Group. Two Formations of Bhimphedi Group and three Formations of Bhimphedi Group are present. The two groups are separated by Mahabharat Thrust.

In the study area, the rocks of Siwalik Group are exoposed in the southern part.

Fig. 3.3(1/3) Geological map of the study area

Fig. 3.3(2/3) Geological cross- section of the study area along B(S) – B'(N)

Fig. 3.3(3/3) : Geological cross-section of the study area along A(SW) – A'(NE)

Fig. 3.4: Columnar-Section of the geological formations of the study area along the road section.

3.2 Lithostratigraphy

The rocks of the Lesser Himalaya starts from south with Benighat Slate, Robang Formation, Raduwa Formation, Bhainsedobhan Marble and Kalitar Schists in north(Fig. 3.3). The thickness of these Formations and their lithology along the road section is shown in Table 3.2 and Fig. 3.4.

Table3.2 The Stratigraphic sequence of the Lesser Himalaya of the study area

Groups	**Formation**	Main Lithology	Approx. thickness (m)
Bhimphedi Group	Kalitar Formation (Pandrang Quartzite)	Dark green-gray Schists Light gray Quartzite	+250
	Bhainsedobhan Marble,	White, light to dark gray medium to coarse-grained marble	1650
	Raduwa Formation	Garnetiferous schist	475
Mahabharat Thrust			
Midland Group	Robang Formation	Phyllite, Quartzite, Amphibolite,	1675
	Benighat Slate	Slate, Phyllite, Dolomite, Limestone	1475

3.2.1 Midland Group

Two formations of Midland Group are exposed towards north of MBT.

3.2.1.1 Benighat Slate

The name is derived from the village of Benighat at the confluence of Burhi Gandaki and Trisuliganga. This formation consists of dark, soft-weathering slates and phyllites, mainly argillaceous, sub-ordinately siliceous or finely quarzitic. In places, some zones of calcareous rocks are found which have been distinguished as “Jhiku Calcareous Beds”.

In study area, Benighat slate is well exposed around Tribhuvan Highway, Budal Khola, Khaireni Khola, Majuwa Khola and Bhalu Khola. It covers the largest portion of the study area.

In Highway, it is represented by dark grey slates with intercalated dolomite of light grey in colour and medium bedded. Some small scale folds found in the beds of dolomite. Drag folds found in dolomite band near Sanutar village(Fig 3.5).

Fig. 3.5 Drag fold found near Sanutar Gaon.

Some quartzite and phyllite also found in the way.

Attitude of foliation plane: 312^0/46N

Columnar section

In Budal Khola, it consist of soft weathering calcarious slate, dark grey dolomites. Some quartz veins (not continuous) are also found in calcareous slate. Beds of calc. conglomerate and small band of light grey limestones also found. Non – calc. slate found somewhere.

In Khaireni Khola, dolomite is ash colour looking slaty type with thin layers of calc.slate with quartz vein near MBT. Thicker zone of non calc. black slate with thin parting and veins of quartz with beds of light grey and white platy dolomite found around upstream toward Robang Formation.

In Majuwa Khola, it consists of light to dark grey, non-calc., highly compact phyllite giving metallic sound, which also contains dark grey thin layers of metasandstone.

Attitude of foliation plane: 100^0/65^{0}N

In Majuwa mine, thick bands of dark grey limestone of total thickness of 9m are exposed with overburden and lower part consisting of phyllite(Fig. 3.6).

Attitude of Limestone: 100^0/55^{0}N

Majuwa mine lies around upstream of Majuwa Khola, just below MT at the meeting point of MT and a local fault resulting landslides in the mining area. Limestone bands are folded.

Fig. 3.6 Photo of Limestone band at Majuwa mine

Photo of thin section (Fig. 3.7) shows the dominancy of calcite and development of crystallinity. The percentage of minerals are: Calcite-79%, quartz-6%, Mica-5%, others-10%. The general size of Calcite is 30 micron in length, 20-25 micron in width. 7 micron in length and 5 micron in width are of Quartz and 15 micron in length and 2 micron in width of Mica are of general sizes.

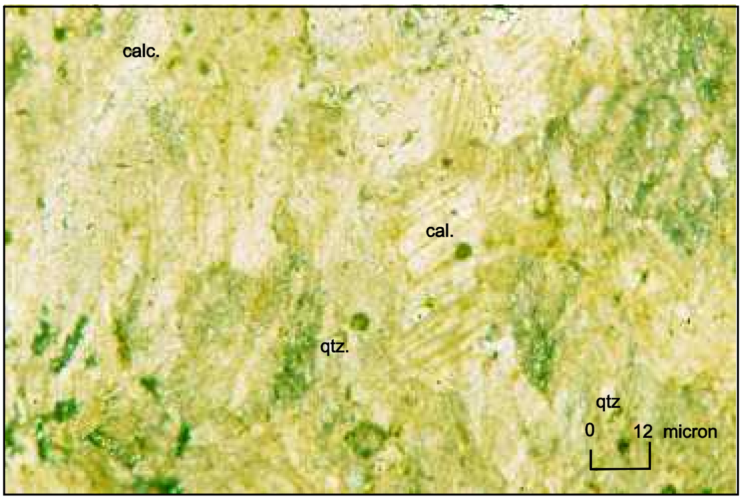


Fig.3.7 Microphotograph of Majuwa Limestone

The chemical composition of Majuwa Limestone as provided by HCIL is: Cao-45.11%, Mgo-1.22%, Fe_2o_3-0.56%, AL_2O_3-2.36%, Sio_2-9.80%, LOI-38.71%. which shows cement grade quality of the Limeston

Columnar section of Limestone is presented in (Fig. 3.8).

Rocks of Benighat Slate are stronger towards MT.

Fig. 3.8 Columnar Section of Majuwa Limestone (at mine).

3.2.1.2. Robng Formation

The name Robang was adopted from the village 'Robang' in the source area of the Hugti Khola Central Nepal.

The Robang phyllites and associated quartzites are found everywhere in strongly tectonized condition immediately below the MT. This has made it impossible to work out anything like a "normal" section of the formation. Green- grey phyllites of sericitic-chloritic type is its characteristic constituents.

In Tribhuvan Highway, it starts with quartzite bed, light grey phyllite with schistocity plane and amphibolites. This formation consists of greenish grey phyllites, amphibolites and milky white quartzites. Thick zone of monotonous bands of white quartzite found toward the upper part. Amphibolite found in lower, middle and upper part of the formation along the road. The maximum thickness of the Amphibolite is 60m and attitude of $90^0/59^0$N.

Attitude of quartzite:290^0 /65^0 N

In Khaireni Khola, white quartzite with green-grey phyllite as partings found. Which in upper side contains green-gray phyllite looking quartzite because of strength and continues by being intercalated quartzite and phyllite.

Attitude of phyllite: 120^0 /40^0N

Robang Formation was not seen in Majuwa Khola, so it must be cutten by MT in between Khaireni and Majuwa Khola.

3.2.2 Bhimphedi Group

The name was borrowed from the Indian geologists, who introduced it in the form of "Bhimphedi Formation" to the relatively high-grade metasediments that are widely developed around the town of Bhimphedi, and it is primarily to these rocks and their lateral extensions that the name "Bhimphedi Group" refers.

3.2.2.1 Raduwa Formation

The name "Raduwa" was taken from a village in the lower Gorandi Valley.

The main rock type is mica-schist of coarse crystalline aspect. Dark green-grey colour, due to biotite as predominant mineral, is most common, but lighter varieties with sericite or muscovite and chlorite also occur. Red garnet is particularly characteristic and may occur in great abundance, sometimes in crystals upto 1cm in diameter.

Around the Rapti river in Taubas area, it consists of brownish gray quartzite and schist with garnet and without garnet. The schist is light grey to dark grey, highly foliated and medium to thick bedded with lots of quartz vein and boudinage structures. A fault is present in the quartzite band near MT, opposite of Taubas village(Fig. 3.9).

Attitude of foliation plane: 284^0 /55^0N

Fig: 3.9 Fault near MT, opposite of Taubas village.

In upper side of Majuwa, garnets are large that was used in gun in past and was recognized as Girkha Khani.

3.2.2.2 Bhainsedobhan Marble:

Named by the Indian geologists (S.P. Nautiyal?) after the Bhainsedobhan village on the Tribhuvan Highway.

This formation at the type locality consists of white-blue marble(Fig.3.10 marble at Bhainse mine) of medium to coarse crystallinity (calcite crystals of several millimeters size). Some layers of siliceous and dolomitic marble are also present. The rocks has a massive appearance but at close view shows always distinct bedding and often a fine layering or foliation (Fig.3.11).

Fig. 3.10 White-blue marble exposed at Bhainse mine.

Along the Tribhuvan Highway, the contact of this formation with underlying Raduwa Formation and overlying Kalitar Formation is sharp. Lower and upper part of the formation is more siliceous and micaceous. The contact of Bhainsedobhan Marble and Kalitar Schists upstream of Poldamki Khola is indicated by a thin zone(around 5-10m) of sheared materil of loose sand releasing rocks of platy nature.

The marble itself can be categorized into three different varieties on the basis of colour and grain size:

- medium- grained yellowish to pinkish variety
- medium-grained white to light blue or grey variety
- coarse-grained light to dark grey variety

The notable characteristic of this marble is the presence of pyrite. These pyrite are not equally distributed all over the formation but limited to some particular marble layers. The upper part of the Bhainsedobhan Marble contain white marble with pyrite crystal around Okhardada Village. The weathering of the rock mass is higher where it consists of phyllitic material. Numerous joint sets are also present within the rock mass.

Around Okhare deposit, light to dark grey, medium to coarse-grained marble with dark-grey phyllitic spots and coatings. Phyllitic coatings is present parallel to bedding plane looking phyllite bed. Thin bed has more phyllitic material than thick

Fig.3.11: Columnar section for the Bhainsedobhan marble at right bank(downstream) of Rapti Khola about 1km down from Bhainse.

bed (Fig. 4.2). Phyllitic portion is lower around Chattre Bhanjyang where marble is dark grey coarse-grained.

Attitude of marble: 100^0 /40^0 N

Big blocks formed by clasts of calcite cemented together by calcitic material are found around Poldamki Khola. This block contain white calcite grain with yellow colour in weathering. Villages are rest upon these blocks.

3.2.2.3 Kalitar Formation:

The name kalitar was taken from a village on the Tribhuvan Highway.
The main rock type of this formation is mica-schist. Strongly micaceous quartzites occur as regular intercalation but on the whole are subordinate to the schist. The general colour is dark green-grey with brownish weathering colour. Lower schist(Ls), Bhimsen Dolomite(Bm), Pandrang Quartzite(Pa) and Jurikhet Conglomerate(Ju) members are within Kalitar Formation.

In the study area, only lower schist member and Pandrang Quartzite are exposed. Lower schist member is well exposed in the Tribhuvan Highway. Which consists of garnetiferous schist and contrasts as a very dark, soft-weathering zone with the cliff-forming marble.

Attitude of foliation: 282^0/79^0N

In the study area, most of the area of Kalitar Formation is covered by Pandrang Quartzite. It is well-exposed in Bhainse-Bhimphedi road, Guhe Khola, Poldamki Khola. In Guhe Khola, it consists of light grey quartzite with some bands looking folded and some bands containing schists partings.

Attitude of foliation plane: 110^0 /75^0 N

In Poldamki Khola, smoky quartzite and dark-gray quartzite found. Beds are platy, medium bedded. In downstream, near Rapti Khola, some quartzite beds containing schist partings found. Around Okhardada village, quartzite is dark-gray with low strength, releasing sand grains on hammering.

3.2.3 Siwalik Group

The name ‘Siwalik’ was introduced for the fluvial sediments of the Sub-Himalayan rocks by Medlicott(1864), after the Siwalik hill in Deharadun, India. It is commonly used for the molasses-type sediments deposited on foreland basins in front of emerging mountain range.
In field, Siwalik group of rocks are well exposed in the southern part of the study area. It is found along Tribhuvan Highway, Samari Khola, Jyamire Khola, Bhalu Khola. It is represented by sandstone, mudstone and conglomerate.

In Tribhuvan Highway, Siwalik is represented by alternated bands of yellowish gray to pinkish gray mudstone and light gray, fine grained sandstone. Toward MBT, about 3m thick light brown conglomerate bed seen.

Attitude of bed:$92^0/45^0$N

In Samari Khola and its tributaries, Siwalik is represented by, alternated beds of sandstone and mudstone of light to dark grey colour. Sandstone is mostly fine to medium grained with some beds containing pebbles; bioturbated mudstone also found. In between them some beds of conglomerate are found formed by pebbles of quartzite, sandstone and mudstone.

Attitude of bed: $120^0/50^0$N

Columnar – Section of Siwalik near MBT in Sukaura Khola is given in (Fig. 3.12).

3.3 Geological Structure

Several geological structure both regional and local are found in the study area as described below:

3.3.1 Major structure

3.3.1.1 Main Boundary Thrust(MBT):

This is one of the major thrusts of the Himalaya region which separates the Siwalik rocks with the Lesser Himalayan rocks. It is well exposed in Budal Khola, Sukaura Khola(Fig. 3.7) and Bhalu Khola. In Budal Khola it is thick zone of 50m. Presence of crushed material of Lesser Himalaya, highly disturbed bed of Siwalik, change of topography and change of vegetation are some points of evidence of MBT.

Fig. 3.12: Columnar – Section prepared for Siwalik near MBT in Sukaura Khola

Fig. 3.13 MBT at Sukaura Khola.

3.3.1.2 Mahabharat Thrust(MT)

Mahabharat Thrust is exposed at upstream part of Baghjhora Khola. The hanging wall of MT comprises high-grade metamorphic rocks of Bhimphedi Group, whereas footwall comprises low-grade metamorphic rocks of Midland Group. The upper part of the Robang Formations is highly crushed Phyllite with frequent quartz veins, whereas Raduwa Formation contains garnetiferous schist. This shows metamorphic break i.e. from greenschist facies to epidote-amphibolite facies indicating a tectonic break.

3.3.2 Minor Structure

Several small scale structures as foliation, lineation, folding of lineation plane, drag fold, joints and folds were observed in the study area.

Folding of lineation plane: folding of lineation plane was well observed in phyllite of Benighat Slate in river area of upstream of Budal Khola.

Folds: At the right bank and about 150m upstream from the bridge over Rapti Khola near Sanutar, successive syncline and anticline are found.
Along the uphill side of the Tribhuvan Highway and about 500m towards Bhainse from the suspension bridge over Rapti River near the village Sanutar, small scale plunging folds in dolomite bed is observed whose hinge lines has trend/plunge: 305^0 /32^0; 316^0 /29^0; 338^0 /45^0.
Fold also seen in Majuwa mine forming anticline and syncline.

Drag Fold:

Drag folds are the micro folds developed in the incompetent beds between two competent beds. It is observed near Sanutar gaon in the dolomite beds where the folds are observed(Fig. 3.5).

Fault: Faults are found in Majuwa Mine, near MT opposite of Taubas village, and also shown in survey map of Okhare Limestone Deposit. Crushed material showing the possibility of fault is present as boundary of Bhainsedobhan and Kalitar around Poldamki Khola near Chilaune Village.

By the presence of major and numerous minor structures and numerous landslides, it can be said that the area is the area of intense tectonic activity.

Chapter Four

GRADING AND RESERVE ESTIMATION

4.1 Grading

Okhare Limestone(Marble) is of crystalline variety having vitreous luster. This is sedimentary-metamorphic type of deposit overlying chlorite-quartz mica schist intercalated with quartzite bands of different thicknesses.

The notable characteristic of Okhare Limestone is phyllitic limestone. Here, phyllite is present as lenses and discontinuous laminations within the limestone bed with parallel orientation with the bedding plane(Fig. 4.1). Phyllite is also present as coating on the bedding plane of the limestone looking phyllitic thin bed whose thickness is 1.5mm to 8mm. Bedding plane also contain leaching of calcite.

Fig. 4.1 distribution of Phyllite laminations within the Limestone Layer.

Here, beds are thin to thick bedded. Thin beds are 20-30cm and thick beds are 5-6m. Thin beds are more phyllitic, looking phyllitic bed but at close view, calcite crystals are present within the phyllitic material. Calcite crystals are seemed to be weathered around phyllitic materials. So thin beds are weaker than thick beds; thick beds are slided over thin beds in the mining area(Fig. 4.2).

Fig. 4.2 Sliding of thick bed over thin beds.

Generally, thick beds have phyllitic coating on bedding plane of thin thickness. But some beds contain phylllitic layering disturbed by calcite all over the bed in certain section(Fig. 4.1). Phyllitic material is unevenly distributed in limestone bed and this material is comparatively lower in Chhatre Bhanjyang(eastern part of the deposit).

Limestone is light grey to dark grey and coarse grained. Darkness of colour and grain size increases towards Chhatre Bhanjyang.

To estimate the quality of the limestone or for grading, different methods can be used. Which are chemical analysis, petrographic study and X-ray analysis. These analysis give us an idea about chemical composition, mineral composition and grain size which should be within certain limit to make the limestone usable for the cement production (Table 4.1 and 4.2).

Table 4.1 Chemical composition specification of cement grade limestone (IBM, 2005)

Chemical identities	Weight percentage
SiO_2	14-15
Al_2O_3	2-8
Fe_2O_3	2.5-3
CaO	>44
MgO	<3
SO_3	<1.5
Alkalis	0.5-1.5

Table 4.2 Limiting Particle Size of Raw Mix for better Burnability and Grindability (Ghosh, 1978)

Mineral/Rock Fragments	Composition	Limiting Size, Microns
Quartz, Cherts	SiO_2	44
Calcite	$CaCO_3$	100-150
Dolomite	$CaMg(CO_3)_2$	125-250
Feldspar	Ca, Na, K $Al_{1-2}Si_{3-2}O_8$	63
Shale or Marl	Clay+Limestone Mixture	50

4.1.1 Chemical Analysis

For chemical analysis, the data of work of NBM and UBE, Japan is available.

In field, route map with sample collection by chipping rock for 10metres for one sample was done from primary crusher to present mining area which is at the western side of Okhare deposit. Some samples from present mine area and Okhare deposit were tested in the lab of HCIL.

NBM work

In order to evaluate Okhare limestone deposit, detailed exploration work was done by NBM in the fiscal years 1973-74 and 1974-75. In which 43 Hectare area was mapped and explored in detail.

Five new trenches and few old-trenches(by Chinese) aggregating 573.40m length were excavated collecting 465 samples therefrom for chemical analysis.

Eight bore holes totaling 978.76m depth were core drilled from which 404 core samples were collected for chemical analysis. Average core recovery for 8 holes was 91.34% (Annexes I-IV).

Of the 8 bore holes, greater number of samples obtained in number 1 and least in number 4. Bore hole 7 shows the good quality and bore hole 4 shows the least quality for cement manufacturing. Data of bore hole 3, 4, 5 are poor for cement grade. Bore hole result shows the presence of non-cement grade limestone with the cement grade limestone and western side of the deposit is better than eastern side for cement manufacture (Fig 4.3, Table 4.3).

Fig. 4.3: Columnar- Section of Bore Holes of Okhare Limestone Deposit (after NBM 1975)

Table 4.3 Result of bore hole

Bore hole no.	Total sample collected	% of cao				
		≤ 30%	30 - 40%	40 – 44%	44 – 50%	≥ 50%
1	65	18%	21%	9%	13%	2%
2	61	22%	19%	6%	12%	2%
3	49	15%	22%	4%	8%	
4	34	13%	13%	6%	1%	
5	40	15%	11%	6%	7%	1%
6	39	8%	10%	3%	14%	4%
7	62	10%	13%	6%	26%	6%
8	54	12%	9%	9%	12%	5%

In 10 trenches, greater number of samples obtained in trench number D and and lowest in number C. Samples of trenches show good data for cement grade limestone than samples of bore holes(Table 4.4). Data of bore hole and trenches show cement grade limestone is near surface and the cement band thins from weast to east. Which is underlain by non-cement grade limestone.

Table no. 4. 4 Result of trenches

Trench no.	Total sample no.	% of cao				
		≤ 30%	30 – 40%	40 - 44%	44 – 50%	≥ 50%
A	21	2%	4%	3%	10%	4%
B	72		9%	12%	28%	20%
C	11			1%	7%	3%
D	88	2%	10%	14%	48%	13%
E	54			1%	32%	23%
F	39	1%	4%	9%	20%	3%
G	66	1%	4%	6%	41%	13%
H	48		2%	4%	28%	13%
I	21		1%	2%	16%	2%
J	20	1%	1%	5%	8%	5%

From the work of NBM, the average Cao% is 46.31 and Mgo% is 1.305 in the deposit.

UBE, Japan has also collected 102 samples of which B(1-5) were collected from B trench by chipping, and B(6 – 12) were collected along the path which is parallel with and 5m under B trench. In D trench, 28 pieces of chipped sample were collected which shows best data except D(14-16) indicating phyllite rich limestone. 5 pieces of chipped sample were collected from E trench which shows good quality for cement.

In F trench, 39 pieces of chipped sample were collected from the outcrops on the F trench and several points on the line running through F trench north and south. Here four phyllitic rich places were found, the Cao content of these are under 30%. The Cao content of the samples except them are as good as 42.5-51.9%.

For the purpose of confirming the existence of deposit and its quality, 10 pieces of chipped sample were collected along 1900m contour line at 40m interval.

Except 19-2, all the samples show the existence of good quality limestone in 1900m contour line.

In the work of UBE, the Cao content of 42% of data are in ≥ 50% , 37% are in 44-50%, 10% in 40-44%, 5 in 30-40% and 7% in ≤30%. Which indicated good quality of limestone for the manufacturing of cement.

Of samples collected in field, 39 samples of route map was tested in the lab of HCIL for rapid analysis (4.5). The route map was made from the Chhagothe to present mining area. Chhagothe is the area of the primary crusher and it is about 12km from Trivhuwan Highway. It lies toward west of Okhare deposit. The attitude of the beds were $260^o/43^o$NE and $253^o/42^o$NW. The length of the route map is about 4.3km. In the route mapping Marble with Phyllite coating found. The result of chemical analysis suggests the presence of cement-grade limestone in between Chhagothe and present mining.

Table 4.5: Rapid Test Result of Samples of mine road from Chhagothe to mining area of Okhare Deposit Area

Date	Sample No.	% Cao	% Mgo
2064/03/30	1.	38.69	1.01
	2.	40.94	0.81
	3.	28.32	1.61
	4	41.78	0.81
	5.	34.77	0.60
	6.	44.58	1.01
	7.	22.71	2.62
	8.	43.18	1.81
	9.	35.05	2.82
	10.	50.75	0.81
	11.	41.50	0.81
	12.	18.79	1.21
	13.	49.63	0.41
	14.	17.38	4.03
	15.	37.85	1.41
	16.	39.54	0.40
	17.	40.10	0.80
	18.	47.95	1.21
	19.	48.79	1.00
	20.	43.15	0.60
	21.	35.61	1.21
	22.	44.86	0.81
	23.	32.25	1.61
	24.	40.10	1.61
	25.	23.83	1.21
	26.	38.41	0.81
	27.	46.82	0.40
	28.	46.82	0.81
	29.	34.49	0.40
	30.	20.18	0.60
	31.	51.87	0.60
	32.	27.76	1.21
	33.	40.66	0.40
	34.	46.55	1.10
	35.	46.27	0.81
	36.	42.90	1.21
	37.	32.25	1.61

Six samples collected irregularly in the the field were tested, four for total analysis and two for rapid analysis. Of six samples, one sample(A_2) is collected near Okhardada Village near the contact of Bhainsedobhan and Kalitar Formation, two samples(36 and 37) from present mining area and three(A1, D1, D2) from Okhare deposit (Table no. 4.6 and 4.7).

Table no. 4.6 Result of rapid analysis of limestone of Okhare area

S. No.	**Sample no.**	**Cao %**	**Mgo %**
1	A_2	43.74 %	0.40%
2	A_1	51.59 %	0.20 %

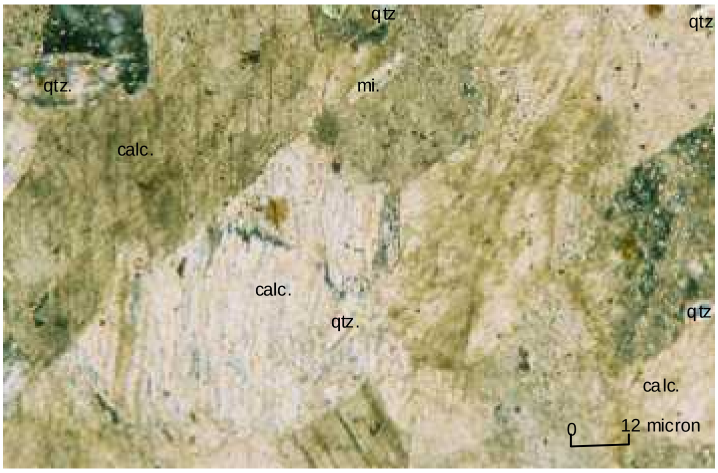
Table no. 4.7 Result of total analysis of limestone of Okhare area

S.N.	**Sample no.**	**Cao %**	**Mgo %**	**Al_2o_3%**	**Fe_2o_3**	**LOI**	**Sio_2 and IR**	**Total**
1	36	28.6%	0.1%	0.44%	1.25%	21.88%	47.29%	99.56%
2	37	44.44%	0.71%	0.47%	1.12%	35.35%	17.45%	99.54%
3	D_1	47.38%	0.4%	0.6%	0.82%	38.72%	11.3%	99.22%
4	D_2	52.59%	0.69%	0.46%	0.73%	41.49%	3.76%	99.72%

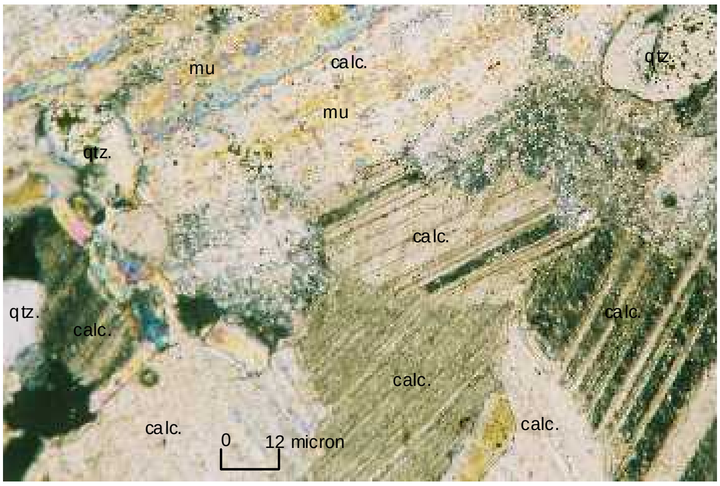
Data shows samples are of cement grade limestone except sample no 36 which was rich in phyllitic material .

4.1.2 Petrographic study

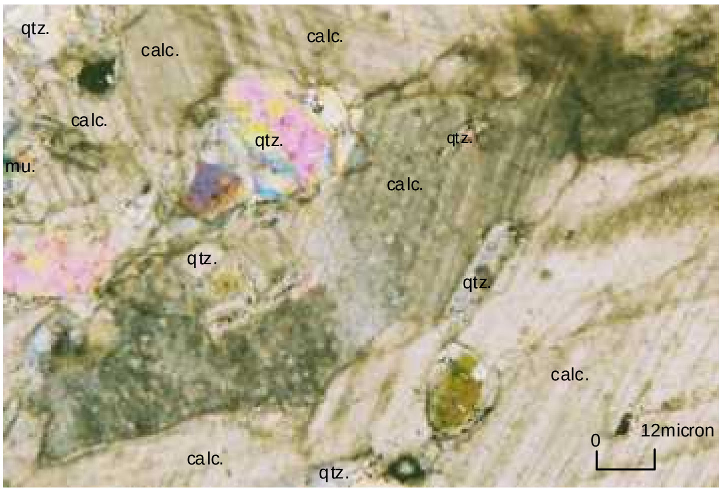
For petrographic study, five samples were worked in the lab of the central department of Geology,T.U for thin – section(three of which are shown in Fig. 4.4). Which shows dominancy of calcite over other minerals. Quartz is second mineral found and mica and other follows.



Sample III



Sample I



Sample no. II

Fig. 4.4 Photomicrograph of Okhare limestone

The percentage of minerals found in thin section are as follows:

(I) Calcite-60%, Quartz-15%, Mica-20%, and others-5%.

(II) Calcite-65%, Quartz-20%, Mica-10% and others-5%.

(III) Calcite-65%, Quartz-15%, Mica-10% and others-5%.

(IV) Calcite-70%, Quatz-15%, Mica-8% and others-7%.

(V) Calcite-78%, Quartz-10%, Mica-8% and others-4%.

The average grain sizes of minerals are as follows:

Calcite average grain size is 75 to 100 micron in length and 35 to 70 micron in width as 100 and 70 micron, 90 and 60 micron, 90 and 35 micron, 60 and 60 micron etc. Calcite in the range of 20 micron in length and width are also found at some places. Generally, calcite grains are around and above 80 micron in length. Quartz grains are in the range of 8 to 15 micron in length and 3 to 10 micron in width. Mica grains are in the range of 12 to 25 micron in the length and 3 to 5 micron in width.

Sizes of minerals obtained are correlated with the limiting particle size of raw mix for better Burnability and Grindability(Ghosh,1978)

Table 4.8 Table of correlation of grain sizes

Minerals	Limiting Size (micron)	Size obtained (micron)	Remarks
Quartz	44	15	Acceptable
Calcite	100-150	100	Acceptable

Quartz grain are found as groups of itself and with mica and also as isolated grain in between calcite grain at some places. Generally, grains of Calcite and Mica are subhedral. Quartz grains are anhedral.

From above data, specific bands of Okhare limestone deposit show good for cement manufacturing both from chemical composition and grain size.

4.2 Reserve Estimation

Reserve estimating is a geological, rather than a mathematical problem and is essentially reduced to interpretation and extrapolation of the outlines as accurately as possible, with due regard for all the geological factors.

The choice of method is controlled by the geological features of the deposit and the methods used to explore it.

Cross-Section method was used to calculate the reserve of Okhare Limestone Deposit because of the inclined nature of the deposit. For this survey map in the scale 1:2,777 as provided by HCIL was used. Here, eight Cross-Sections were made with reference to eight Bore-Holes (Fig. 4.5). Where distribution of cement-grade and non cement-grade limestone were plotted from the data of trenches and Bore-Holes. Area of the deposit and overburden and waste was determined with the help of graph paper. Area obtained was multiplied by the strike length of each Cross-Sections which was taken as the half-distance of each adjacent section. Volume obtained by this method was multiplied by the specific gravity of Limestone(2.6) which is also considered as tonnage factor, the value obtained is the reserve of the deposit(Table 4.9 and 4.10).

Result :

Total volume of cement grade limestone = 58,97,934

Total volume of waste = 18,98,452

The ratio of the volume of ore to waste = 1:0.32

Reserve of the deposit = 153,34,629

Reserve at 85% recovery = 130,34,434

Capacity of HCIL = 750 ton/day

Required quantity of limestone = 750 t-clinker/day x 1.6 tons/t-clinker x 335 days/year x 0.9

= 360,000tons/year

Life of mine = 130,34,434/ 360,000

= 36 year.

Table(4.9) Estimation of reserve

Section	Area (m^2)	Strike length(m)	Volume (m^3)	Tonnage Factor	Tonnage (Tonnes)
1-1’	8103	120	972378	2.6	2528182
2-2’	7872	65	511656	2.6	1330305
3-3’	8566	79	676729	2.6	1759494
4-4’	6328	100	632818	2.6	1645325
5-5’	3318	125	414804	2.6	1078490
6-6’	13891	75	1041833	2.6	2708767
7-7’	14663	69	1011736	2.6	2630513
8-8’	9492	67	635981	2.6	1653551
Total	**153,34,629**		**58,97,934**		

Table (4.10) Estimation of volume of overburden and waste

Section	Area (m^2)	Strike length (m)	Volume (m^3)
1-1’	1543	120	185215
2-2’	3087	65	200650
3-3’	2315	79	182899
4-4’	5402	100	540210
5-5’	1543	125	192932
6-6’	3087	75	231518
7-7’	1543	69	106498
8-8’	3858	67	258529
Total			**18,98,452**

Chapter Five

MINING PROCEDURE

5.1 Background

Work done to extract mineral, or to prepare for its extraction, is called mining. Mining creates voids called mine workings in the mineral or waste rocks. Mine workings can be exceedingly varied in shape, dimensions, location and function.

Okhare limestone deposit lies at latitude $27^0$28’36” and longitude $85^0$07’E.

Okahare deposit lies at the top of the hill of 2080m with hill slope of 50-75^0. Southern slope of the hill is steeper than the northern slope, which bear dense mixed forest whereas southern slope bear scattered bushes. Outcrops are prominent on southern slope.

Around Okhare deposit, there are steep mountains and many deep valleys, scarcely flat area. Above all, 80- 90^0 slope such as cliff can be seen toward western side in southern slope. Overburden to be removed seemed to be thin.

Okhare deposit has not yet been worked but it will be worked in near future. There is a problem of landslide at the western edge of the deposit. Mining is at present at the road near the western edge of the deposit.

Opencast mining will be used for Okhare deposit because of thin overburden and presence of the deposit at the top of the hill.

The word opencast implies all the excavations, waste heaps and equipment needed for extracting mineral in the open and thus forming an independent mining unit. In opencast the work is safer and the men’s output is higher than in underground mining.

Geologically, this deposit contains not only cement grade limestone but also very low grade limestone to be rejected. For getting high grade limestone efficiently, some residual walls should be remained in various directions.

Mining area in Okhare is approximately 190,000sq.m. Mining area includes the area above 1900m above sea level because of estimated average 100m thickness of the limestone band.

Okhare deposit will be worked with present drilling and blasting technology used in near mining site. For developing Okhare deposit, two process: quarrying and stripping methods should be selected.

Quarrying Method

Of the choices of bench cut, slope cut and glory hole, bench cut method is the most suitable for Okhare quarry. The reasons why bench cut method is adopted are as follows:

a. Easy for quality control.

b. Able to use heavy machines.

c. Topographic and geological condition of the deposit.

d. Influence of climate on mining operation is little.

e. Safety for workers and equipment

Stripping

Stripping procedure is suggested as follows:

1. As the first step, trees and bushes grown around the mountain top with altitude of 2080m should be cut. The area more above 2045m would be mined at first year.

2. After cutting trees or bushes, over burden covering the deposit should be stripped by bulldozer or shovel.

3. Stripped over burden should be thrown away in the northern slope of the mountain, where barrier will constructed.

4. Even after quarrying operation starts at quarry face, stripping should be continued according to the developing speed of quarry face.

Mining procedure for Okhare deposit is suggested with the help of knowledge gained in present mining, report of the COSMO Internationl Co. Ltd(1987), Japan and text books of mining, which is as follows:

5.2 Development of Quarry face

5.2.1 Bench specification:

The specification of the quarry face bench should be determined considering the heavy equipment to be used, the production scale, and the necessity of quality control on the bench, so that higher productivity and efficiency could be obtained.

The main items for the bench specification to be recommended are as follows.

a. Bench height

The bench height of 15m to 20m is effective to obtain high productivity and efficiency. But 5m is suitable for Okhare, because strict quality controlled mining is required at quarry face.

b. Bench width

The bench width of more than 20m is required for the stable operation on the bench floor even if the width depends on the heavy equipment to be used.

Namely, in the normal blasting, blasted limestone are spread on the floor as long as the bench height. The width to be needed for truck haulage operation is the same as the minimum turning radius of trucks. In addition, loaders need some width for loading operation.

Therefore, the minimum width to be required amounts to 20m to 25m.

c. Bench lenth

Overall length of the effective bench for stable quarrying should be determined on the basis of the following equations(COSMO INTERNATIONAL, 1987):

$$L= f \times n \times T/ H \times B \times g$$

Wher, L: overall length of the bench(m)

T: daily production (700 t/ d is considered because of present mining has given this amount to HCIL which is sufficient for factory)

H: height of the bench (5m)

B: burden of the bench (5m)

G: specific gravity of limestone (2.6 kg/ cu.m)

f: safety factor

n: number of major works in one cycle

Normally, “3” is adaptable to “n”.

Drilling, blasting and loading are major works in one cycle on the bench.

“f’’ is the factor for accidental works which are as follows.

(a) The failure of basting

(b) Leveling of bench floor

(c) Removal of unuseful stone

(d) Mixing of low grade stones with high grade stones for quality control

(e) Large lumps handling in blasted stone

Considering the condition of Okhare quarry, “2.5” is adoptable to “f”

$$L = 2.5 \times 3 \times 700 / 5 \times 5 \times 2.6 = 80m$$

It will be difficult to make a bench of 80m length in Okhare quarry. Therefore, it is desirable to keep at least two benches in the quarry face for the efficient quarry operation.

5.2.2 Developing Quarry Face

In Okhare quarry, quarry face should be developed considerng the following points on the basis of the geological condition.

1. The quarry face should go ahead from west to east so that hualing is easy.

2. Some residual walls should be prepared in order to decrease quantity of waste to be removed.

3. The route of road sometimes should be changed for not to haul blasted stone upward.

4. It is desirable that the number of quarry face should be two at least to make quality control easy.

5.3 Quality Control

In Okhare quarry in order to obtain cement- grade limestone, unuseful material generating on the quarry face should be completely distinguished and rejected.

Therefore, mining should be carried out on the basis of the mining plan considering limestone grade on the quarry face.

The procedure to make the plan is suggested as follows:

1. Quarry faces should be divided into small unit mining blocks (Ex. 10m x 10m x 5m)

2. In advance of drilling and blasting, the limestone sample indicating the representative material grade of each block should be predetermined.

3. Cao% content of the samples should be analyzed.

4. The unit block should be classified into cement grade and non-cement grade .

5. Mining plan should be made on the basis of the results of “4”.

5.4 Drilling and blasting

Drilling pattern

Drilling provides the hole in which explosives are charged. An adequate tonnage and the suitable sizes of blasted limestone are obtained by adjusting explosive quantity.

Blasting pattern should be designed based on the following factors:

_ Geological condition

_ Physical property of rocks to be blasted

_ The desired sizes of blasted rocks fed into crusher

Drilling pattern used in present mining, the same unit would be used in future mining in Okhare deposit, is as follows:

a. Bore hole diameter

Diameter of 70mm is used from the view point of bench specification, production scale, and the size fed into the crusher that is maximum 9 inch.

b. Burden

It is the shortest distance of the effect of explosive from the centre of the charge to the free face. Usually the length of burden is 35 to 45 times of the bore hole diameter, that is, approx. 2.5m is adoptable.

c. Spacing

Usually the length of spacing is 0.8 to 1.4 times of the burden, 2 to 3.0m is in use.

d. Drilling angle

Usually the drilling of 45^0 to 90^0 to the horizontal plane is adopted.

The smaller the angle is, the better the blasting effect is. To prevent the toe from remaining, small angle is useful. But if it is too small, the drilling work will be troublesome.

The angle of 70^0 is suitable.

e. Explosive

Charge weight of explosive is theoretically given by the equation below(COSMO INTERNATIONAL, 1987):

$$L = C \times D \times B \times H \text{ (kg/ hole)}$$

Where, L: Charge weight of explosive (kg/ bore hole)

C: Factor concerning to the following

_ property of rock blasted

_ kind of explosive

_ condition of tamping

D: Spacing

B: Burden

H: Bench height

In the other hand, big lumps from the primary blasting must be broken down to the size of 0.9m by secondary blasting or from the other way such as breaker.

5.5 Dumping waste material

Waste can be utilized for building retaining walls around mining area and along the mine road. Waste can be temporary stored in spoil heap which can be made in between Chhagothe and Canteen near Kailash which can be best utilized as making roads around Hetauda Cement Industry as social work of HCIL.

Chapter Six

SAFETY IN MINING

6.1 Introduction

No engineering problem today can be isolated from the questions of safety. Every engineer and research worker engaged in mining must, to some degree, involve himself in the recommendation and development of methods aimed at providing not only more production, but the utmost safety in the conditions of operation.

In the mining industry, the principal means for attaining safe working conditions in the pits and underground is wide-scale mechanization of all possible operations of the mining process.

6.2 Hazardous Factors:

Generally there are different factors creating hazard in mining which are as follows:

- Noises, vibration and shaking
- Explosives
- Slides and falls
- Machines and transport system
- Electric current and electric field

a) Noises, vibration and shaking:

- As a rule, industrial noise, shocks and vibration are not direct causes of accidents, but they contribute considerably to discomfort and weakens the attentiveness of the operators and increases the danger of accidents because the signals may be drowned by the noise of the operating equipment.

- Noises can be reduced by using silencers for machines and personal hearing protectors for workers.

- Noisy machines should be replaced by noiseless or less noisy units as possible and should be maintained regularly.

b) Explosives:

Hazards arise from the fact that explosive instantaneously frees a very large amount of energy at the point of ignition. At the point where the explosion occurs, it produces noxious gases and a considerable concentration of rock dust. Hazards from explosive can be reduced by following methods:

- Person working in mine should have self-control and a resourceful mind.

- Whenever explosives are handled, they should not be subjected to jolts or impacts. Boxes or canisters containing explosive materials must never be pushed, dropped, dragged, rolled over or hit. No smoking or any form of naked flame should be allowed within 100m of the explosives.

- The safe distance can be found from the strength of the air shock wave, the range of flight of the fragments, the propagation of the detonation, and the seismic effects. It can be found by following formula:

The value of the impulse acting per sqm of surface normal to the direction of shock wave propagation can be expressed by the equation(Melnikov and Chesnokov, 1963):

$$I_1 = QV/(9.8)(12.6r^2)$$

Where, Q = weight of the charge,kg

V = flight velocity of expelled fragments, taken approximately equal to 1500m/sec

9.8= acceleration of gravity, m/sec

$12.6r^2$ = area of a sphere of radius r, where r is the distance to the centre of the charge, m

If we denote the maximum permissible impulse by I_{max} , the distance to the centre of the charge, i.e. the safe distance as regards the shock wave, can be found from the equation,

$$r = \sqrt{24Q/I_{max}}$$

By substituting k_w for $\sqrt{24/I_{max}}$, we obtain the expression

$$r_w = k_w\sqrt{Q}$$

Where, r_w = safe distance as regards shock wave, m

Q= weight of charge, kg

k_w = coefficient depending on the position of the charge and the ability of the protected object to withstand the impulse

The maximum permissible weight of a charge that can be exploded at a given distance from a building or structure without any danger of damaging it can be found by equation,

$$Q_{max} = (r_a/ k_w)^2$$

Where, Q_{max} = max. permissible weight of the charge, kg

r_a = actual distance to protected structure, m.

- It is better to work breaker with blasting, material loosened by blasting can be worked by breaker. This reduces the use of explosive.
- Danger from flying fragment can be reduced by covering free surface with metal netting, bags, sheathing.
- Safety rules prohibit redrilling of the remainder of a borehole, whether it is free of explosives or not.

c) Slide and fall:

Slided and falled material or rocks cause serious damage to mining equipment and transport facilities and resulted in injury to the personnel. This can be reduced by following methods:

- It is very essential that the face should be correctly positioned with respect to the layout of the strata, the fissures in the beds, the faults etc.
- The face should be cut so that the strata are inclined away from the pit The height of the face should not exceed the maximum digging height or depth of the excavator.

d) Machines and transport system:

Danger can occurs from drilling equipment, loader, breaker, crusher and transport system.

- All machines should be equipped with visible and audible signaling devices, brakes, guards for covering the moving and rotating parts and also work platforms, fire fighting appliances and also electric lighting.
- The drilling operator should inform his relief operator of the operating conditions of the rig mechanisms and there should be a strict traffic rules and regulation in mining area.
- Excavator should be provided with a strong road bed that has been made smooth and has a slight slope which will ensure full stability in any position at the face.

e) Electric current and electric fields:

Electicity is used in mine for blasting and crusher.

The most important point for controlling accident in mine is to trained all person for work in mine before they are put. Well-expected “reminder” circuit diagrams and placards as well as warning signs, should also be posted where they will attract attention.

6.3 Prevention measures:

There are different action which should be established for the prevention of accidents in which are as follows:

a) The establishment of danger zones:

In blasting operations, a danger zone must be established in such a way that there will be no risk of any pieces of material flying beyond it and no hazard from the shock and air waves and also seismic vibrations that go beyond it. It can be establidhed by calculating safe distance.

b) Signals:

Signals are a fundamental measure in the prevention of accident and signals can only foster safer conditions of work when their meaning is well known to all persons within the zone in which the signal operates.

c) Safety clearances:

It defines the dimensions of a danger zone for one specific object, say, an excavator, in regard to some object.

d) Personal protective appliances and devices:

It can be considered as one of the duplicated safety measure forms because they should be used, as a rule, as a supplementary aid to the basic safety precautions to prevent accidents, injuries and occupational diseases. For example: safety goggles, helmets (hard hats), special types of footwear and overall respirators, hearing protectors, electrician's gloves, gauntlets and footwear.

e) Preventive- maintenance tests and inspections of all the machines and equipment that are in service comprise an integral part of accident prevention.

Besides there are some other points important for the accident prevention:

- Before any qualified engineer or technicians are to be put on the job, he must undergo a medical examination and receive a certificate to the effect that his health and age permits him to perform the particular job.

- The preliminary accident prevention training and instruction of a worker must be completed before he is put on the job and is assigned to a regular shift.

- During everyday operation, each work area must be checked for safe working conditions at the beginning of every shift. This is done either by the mine inspector or the shift leader during the course of the shift they must also watch that the conditions of work still remain safe.

Chapter Seven

CEMENT PRODUCTION SYSTEM

7.1 Background

Generally cement production system consists of mixing of the different raw materials in specified ratio and processing it into mills and silos before it comes to the packing units.

The major raw materials used are limestone, clay, silica sand, iron ore, gypsum and coal as fuel.

The main source of limestone for the industry is the Bhainsedobhan Marble of Bhimphedi Group. Limestone for the industry is mined from four different areas- Bhainse, Okhare, Majuwa and Jogimara. Among these four, the high- grade limestone for cement production is from Jogimara area(Jhiku Bed). Here in HCIL, for cement, limestone is mixed in 82-85%. The silica content of Bhainse and Okhare limestone is high, so the silica sand does not mix during the cement production.

Hematite is used as iron ore, which is imported from Orissa, India and mixed with other raw materials in 1-1.5%..

Clay for aluminium in cement is mined from Lamasure, near HCIL factory. This is mixed in 10-15%.

Gypsum and coal are imported from Iindia.

The proporation of these raw materials are kept in fixed range according to their composition and intensive quality checking process is carried out in the laboratory to maintain the quality of the cement production process.

Although, the machineries and the system of cement production of HCIL are built up considering the 100% production of the company capacity(750ton/day), due to many disturbances, the production of cement has never crossed 50% of its capacity.

7.2 Production System

The whole cement production system can be simply described with the series of these units: Mixing hopper, raw grinding mill, Blending silo, Rotary Kiln, Coal Mill, Clinker Silo, Cement Mill, Cement Silo and Packing Unit. Limestone rock from mine goes to mining Hopper via. Primary Crusher and Secondary Crusher.

7.2.1 Mixing Hopper

The limestone crushed by secondary crusher is kept on the limestone yard and clay silica sand and iron ore are also kept in different yards in the form of pile. Different belt conveyers bring these raw materials to the mixing hopper where they go into different weighing feeders. The weighing feeders are systemized in a such a way that the raw materials keep the percentage of CaO and MgO almost same. Sending them in one conveyer by different feeders mixes the raw materials. The ratio of raw material in the mixture is kept according to the composition of limestone.

7.2.2 Raw Grinding Mill

Mixed material is transferred to the Raw-Grinding Mill through conveyer, which main function is to grind and mix the material uniformly. The mill consists of three rollers and one rotating plate. The grinded material is moved up by the centrifugal force and airflow. This mill has high efficiency and low electricity consumption about 2300KW. The grinding capacity of the mill is 70ton per hour.

7.2.3 Blending Silo

The Blending Silo is used to get homogenous mixture for the consistent quality of the material. Blowing the materials by air carries out the blending.

7.2.4 Rotary Kiln

After processed in the Blending Silo the materials come into Rotary Kiln via weighing feeder and suspension pre heater. Pre-heating is done by oil firing. The rotary kiln is inclined in 5^0 to make the movement of materials easier. Rotary Kiln is provided with high aluminium containing refractory bricks. The pre-heated material is feed into kiln from one end and the coal is feeded from another end. So at the entry point the temperature is about 800^0C, which increases to 1000^0C in the middle part and 1200^0C -1400^0C in the exit point, which may sometimes reach about 1600^0C. The reaction in the kiln is started with the evaporation of H_20 and dissociation of $MgCO_3$ and $CaCO_3$. Then the formation of Wallastonite, Belite, Aluminate, Ferrite and Alite take place respectively ending with the formation of interstitial material . In some factory, Vertical Kiln is used instead of Rotary Kiln. In Rotary Kiln the movement of materials is get by the rotation and inclination of the kiln. The end product of the Rotary Kiln is cement clinker. As the system produce large amount of heat energy, air cooler(<100^0C) and water cooler(>$100\ ^0$C) are used to separate dust particles from the unburnt clinker. Before coming into Rotary Kiln the coal goes into the Coal Mill with the capacity of 12T/hr and Bag filter, Weigher and Ejector also acts upon it.

Problem in burning Okhare Limestone in Kiln is felt by HCIL pointing to the presence of Quartz.

7.2.5 Clinker Silo

The Clinker Silo is provided with hammer crusher for crushing the clinker. From this silo the clinker moves into the vibrator feeder and weigh feeder. Then the materials go into the cement mill.

7.2.6 Cement Mill

Gypsum from the weigh feeder also comes into the Cement Mill besides the clinker from the Clinker Silo. The main purpose of adding gypsum is to increase setting time of the cement mixture. In the Cement Mill differently sized iron balls are used

over the mixture of crushed clinker and gypsum and by grinding them together the cement is formed. This mill is also called Ball Mill as the main work is done by the collision of the balls. This mill has high power consumption but low efficiency in comparison to the Raw Grinding Mill. Water Spray and Bag Filters are used here for the reduction of dust production.

7.2.7 Cement Silo

10000 metric ton of cement can be stored here before sending it to the dispatching unit. Vibrating Screen sizes out the coarse materials and the fine passing through it is passed to the Packer.

7.2.8 Packing and Dispatching

Automatic cement packing is done without sewing the bags of 50kg capacity. The bag's mouth is attached to the packer, it automatically stop in filling when it reaches 50kg and the bag is loaded down where it is kept into the truck. One truck carry about 100ton of cement and it takes 15minutes to fill the truck. With this speed 100 trucks can be filled in 8hrs.

7.2.9 Central Control Room

As the production system is partially automatic main parts of the system are observed and controlled by the central control room. The Centrol Control Room, controls all the processes of cement formation from material presenting in the Mixing Hopper. Some of which can be noted as, the mixing of raw materials in Mixing Hopper, rotating speed of plate in the Raw Mill, amount of pressure, temperature and water used in the whole system, supply of gypsum etc.

Chapter eight

CONCLUSION AND RECOMMENDATION

Conclusion

- The studied area consists of sedimentary rocks of Siwalik Group, low-grade metamorphic rocks of Midland Group and medium to high-grade metamorphic rocks of Bhimphedi Group, which are separated from eachother by two major thrust MBT and MT.

- Two formations of Midland Group: Benighat Slate and Robang Formation and three formation of Bhimphedi Group: Raduwa Formation, Bhainsedobhan Marble and Kalitar Schists are exposed in the studied area.

- Siwalik Group consists of mudstone, sandstone and conglomerate; Midland Group consists of slate, phyllite, dolomite, limestone and white quartzite; and garnetiferous schists, marble and dark- grey quartzite are of Bhimphedei Group.

- All rocks of the area have NW-SE strike with north dipping and dip amount being 40^0-75^0.

- Okhare and Bhainse Limestone Deposit belongs to Bhainsedobhan Marble, Majuwa Limestone Deposit belongs to Jhiku Bed of Benighat Slate.

- White-blue, medium-grained marble of Bhainse deposit; light to dark-grey, medium to coarse graine marble of Okhare deposit; dark-grey fine-grained limestone of Majuwa deposit are limestone sources for HCIL.

- Phyllitic limestone is the notable characteristic of Okhare Limestone Deposit.

- Okhare deposit lies at the top of the hill as outlier, with average dip amount being 45^0; strike NWW – SEE. Average cao is 46.31% and mgo is 1.30%. Limestone band vary in the percentage of cao and sio_2 because of the presence of phyllitic marerial which points to the selective mining. Minerallogically, the limestone is calcite rich and sizes of minerals permit the production of cement. Quartz is the second most abundant mineral.

- Cross-Section of Okhare deposit show limestone bands are thinner toward inside of the hill which indicate there may be some structural problem.

- The reserve of the Okhare deposit is 15.33 million ton with 13 million ton at 85% recovery factor and the life of mine is at least 36 years for HCIL.

- Opencast mining is the method of mining with the bench-cut method in the deposit; drilling and blasting are major work of mining .

- Limestone from mining goes to cement packing unit through Primary Crusher, Secondary Crusher, Mixing Hopper, Grinding Mill, Blending Silo, Rotary Kiln, Clinker Mill Silo and Packing Unit.

Recommendation

- Because of the steepness of the slope of hill around the deposit, it is best to reduce the hill slope which may be by forming benches of retaining wall, which reduces the danger of accidents and wastages of limestone.

- Detailed geological study should be done for confirming structural problem of the Okhare deposit.

- 5m height and 20-25m width benches should be developed.

- At least two quarry face should be made for quality control.

- The face should be cut so that the strata are inclined away from the pit.

- For prolonging the mining of limestone, eastern and western side of the deposit and the area around Okhardanda Village, toward north of the Okhare deposit are the area of further exporation of limestone.

- Rules of Safety should be considered for mining by HCIL.

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ANNEX I

Table: Amount of Exploration Done of NBM(1975)

S. No.	Exploration activity	Unit	Amount of work done	Remarks
1.	Area explored and mapped	Hectare	43	Meterage (length) includes, excavation made in old trenches also
2.	Trenches excavated	Numbers	5	
		Meters	573.40	
3.	Bore holes	Numbers	8	
		Meters	978.76	
4.	Samples (for chemical analysis)			
4.1	Trenches	Numbers	465	Including 18 chip sample
4.2	Bore holes	Numbers	404	
			869	

Table: Findings of Exploration of NBM(1975)

S.No.	Object	Unit	Finding	Remarks
1.	Reserve	Million tones	11.93	
2.	Average assay	Cao %	46.31	
		Mgo %	1.30	
		$(Fe_2o_3+Al_2o_3)\%$		
		Insoluble	11.99	
3.	Average thickness	Meters	50.5	
4.	Total strike length	Meters	640	
5.	Average depth along dip	Meters	140	Maxium average depth from surface is 85m
6.	Limestone to waste material ratio		1:0.378	

ANNEXE II

Table: Brief description of Bore holes

Bore Hole No.	Collar Height (m)	Direction	Angle	Depth Penetrated	Topsoil or weathered rock	Core recovery (%)
1.	1964.12	N - S	49^0S	159.55	3.05	94.19
2.	1973.22	N - S	35^0S	151.65	3.05	94.30
3.	1948.83	N - S	20^0S	119.30	3.05	87.98

4.	1978.32	N - S	40^0S	83.75	3.05	89.87
5.	2001.21	N - S	45^0S	92.90	3.05	90.79
6.	2038.01	N - S	45^0S	113.65	3.05	82.30
7.	2013.42	N - S	35^0S	137.26	3.05	92.03
8.	2007.30	N - S	48.5^0S	120.70	3.60	95.99
				978.76		91.34

AVERAGE CORE RECOVERY = 91.34%

ANNEX- III

ANALYTICAL RESULT OF BOREHOLE NO. 1

Sam. No.	From (m)	To (m)	Core thickness(m)	Cao (%)	Mgo (%)	Fe_2o_3 $+Al_2o_3$ (%)	Insoluble (%)

Sam. No.	From (m)	To (m)	Core thickness (m)	Cao (%)	Mgo (%)	Fe_2o_3 + Al_2o_3	Insoluble (%)
OD/1/1	3.05	5.85	2.50	50.19	0.40	1.80	7.92
OD/1/2	5.85	8.95	3.05	45.98	1.20	1.60	14.24
OD/1/3	8.95	9.30	0.20				
OD/1/4	9.30	10.20	0.85	33.36	0.60	2.04	36.46
OD/1/5	10.20	12.10	1.80	48.78	1.41	1.40	8.88
OD/1/6	12.10	14.50	2.30	37.57	0.80	1.90	28.62
OD/1/7	14.50	16.50	2.00	42.34	1.00	1.62	19.60
OD/1/8	16.50	17.00	0.40	41.77	1.61	1.54	20.22
OD/1/9	17.00	20.85	3.70	41.49	6.04	1.34	11.56
OD/1/10	20.85	25.15	3.90	43.18	0.60	1.64	20.28
OD/1/11	25.15	27.50	1.80	24.11	1.00	2.94	50.78
OD/1/12	27.50	30.50	2.42	45.14	1.81	1.68	12.98
OD/1/13	30.50	32.70	2.10	45.14	1.41	1.56	14.54
OD/1/14	32.70	35.40	2.70	50.47	0.60	1.38	7.24
OD/1/15	35.40	39.20	3.80	48.22	1.20	1.44	9.16
OD/1/16	39.20	42.00	2.62	43.18	0.40	1.80	19.04
OD/1/17	42.00	44.65	2.55	48.22	0.80	1.40	10.40
OD/1/18	44.65	47.00	2.35	33.64	1.81	1.88	33.56
OD/1/19	47.00	51.55	4.23	20.18	0.20	2.70	59.92
OD/1/20	51.55	53.50	1.90	30.28	1.20	3.52	38.94
OD/1/21	53.50	54.55	0.90	35.33		2.68	33.23
OD/1/22	54.55	57.95	3.40	40.09	1.41	2.32	22.30
OD/1/23	57.95	62.00	3.90	44.58	1.61	1.86	14.92
OD/1/24	62.00	65.75	3.40	35.61	0.80	1.86	31.62
OD/1/25	65.75	70.30	4.55	48.50	0.80	1.34	9.96
OD/1/26	70.30	73.55	1.85	24.67	0.40	2.88	52.38
OD/1/27	73.55	73.85	0.30	17.10		2.14	67.30
OD/1/28	73.85	74.45	0.60	16.54	2.01	2.84	62.34
OD/1/29	74.45	75.00	0.55	25.79	1.00	3.18	47.22
OD/1/30	75.00	77.85	2.75	49.35	0.80	1.36	8.62
OD/1/31	77.85	80.25	2.30	49.07	2.01	1.26	5.92
OD/1/32	80.25	82.65	2.40	49.07	2.21	1.26	5.24
OD/1/33	82.65	85.70	3.05	47.10	2.21	1.14	9.72
OD/1/34	85.70	90.00	4.30	46.54	0.40	1.20	13.96
OD/1/35	90.00	92.80	2.02	37.57	0.40	1.88	29.42
OD/1/36	92.80	94.30	1.00	42.62	0.80	1.84	19.00
OD/1/37	94.30	96.40	2.05	33.64	1.00	1.52	35.10
OD/1/38	96.40	97.90	1.50	29.72	0.80	1.74	43.00

OD/1/39	97.90	99.55	1.60	20.18	0.40	2.16	60.36
OD/1/40	99.55	101.35	1.80	28.04	0.60	1.92	46.08
OD/1/41	101.35	104.90	3.55	32.24	1.61	2.22	35.78
OD/1/42	104.90	107.95	3.05	41.77	1.81	1.86	18.80
OD/1/43	107.95	111.00	3.05	39.25	0.80	1.64	25.66
OD/1/44	111.00	113.35	2.35	35.33	1.20	1.50	32.08
OD/1/45	113.35	116.35	2.75	36.45	1.61	2.08	29.20
OD/1/46	116.10	117.75	1.65	30.00	1.00	2.48	41.44
OD/1/47	117.75	121.47	3.00	28.88	0.60	2.24	43.84
OD/1/48	121.47	125.10	2.93	32.52	1.41	2.86	35.22
OD/1/49	125.10	126.95	1.80	39.25	0.60	1.78	27.42
OD/1/50	126.95	130.15	3.20	24.11	1.41	2.12	50.88
OD/1/51	130.15	132.55	2.40	31.40	1.20	2.50	38.50
OD/1/52	132.55	133.70	1.15	23.55	2.01	3.78	49.86
OD/1/53	133.70	137.25	3.34	37.01	1.81	2.28	28.10
OD/1/54	137.25	141.30	3.95	38.69	2.41	2.62	23.52
OD/1/55	141.30	141.50	0.20	29.44	0.40	2.68	43.48
OD/1/56	141.50	143.65	2.15	38.97	3.02	2.06	21.12
OD.1/57	143.65	145.65	2.00	27.47	1.00	3.26	44.68
OD/1/58	145.65	148.95	3.15	43.46	0.60	1.74	18.75
OD/1/59	148.95	149.50	0.50	23.55	0.60	2.28	53.58
OD/1/60	149.50	151.35	1.68	30.28	0.40	1.42	42.24
OD/1/61	151.35	153.60	2.22	19.90	0.40	2.28	59.88
OD/1/62	153.60	154.85	1.25	31.68	1.20	2.70	36.88
OD/1/63	154.85	158.30	3.45	21.87	0.80	2.30	55.68
OD/1/64	158.30	159.05	0.75	31.96	2.62	2.74	33.58
OD/1/65	159.05	159.55	0.50	21.87	2.21	2.78	52.32

Bore hole no. 2			Bore hole no. 3			Bore hole no. 4		
Depth (m)	Cao (%)	Mgo (%)	Depth (m)	Cao (%)	Mgo (%)	Depth (m)	Cao (%)	Mgo (%)
5.85	46.26	0.40	7.30	15.98	2.02	6.10	40.65	1.61
8.55	47.38	1.41	8.75	12.89	2.82	9.15	42.90	
9.65	29.15	1.20	11.50	43.18	1.00	2.01		
12.20	51.59	0.40	12.80	45.14	1.81	12.60	38.13	2.01
15.20	40.00	0.40	15.45	36.45	1.20	14.55	37.85	0.80
19.60	49.91	0.60	21.27	44.30	0.80	15.85	31.12	0.80
20.45	49.63	1.20	26.90	34.48	1.00	19.50	34.48	0.40
25.50	50.47	0.20	28.90	49.07	1.87	20.55	28.32	2.21
28.40	39.81	1.00	29.53	49.91	1.20	21.45	39.25	0.40
33.05	44.30	1.41	30.80	29.72	1.00	24.05	34.20	1.41
36.30	21.87	1.41	32.65	44.30	2.01	27.65	42.34	1.00
40.00	21.31	1.00	35.90	44.30	0.60	31.00	36.73	1.20
42.40	27.19	1.00	39.20	31.90	0.20	33.60	29.16	0.60
44.10	26.07	1.00	40.05	47.94	1.20	36.33	22.19	2.01
45.05	47.38	1.20	41.20	36.17	1.00	36.80	27.47	4.23
48.55	46.82	1.00	44.70	44.58	0.80	37.00	22.99	0.60
50.95	29.72	1.01	46.15	36.17	0.20	38.20	28.88	0.20
51.40	40.09	0.60	43.60	40.37		40.70	24.95	0.40
52.70	24.39	1.01	50.22	35.61	0.80	42.20	42.06	0.60
53.20	39.53	0.40	53.35	25.51		43.00	19.34	3.22
53.20	38.97	0.40	54.25	26.35	0.60	46.90	41.20	0.80
55.85	39.81	1.61	57.60	30.84	1.40	50.25	40.93	2.01
59.90	40.66	1.21	59.40	23.83	0.40	50.70	25.51	2.82
61.67	28.88	0.80	61.45	33.64	0.60	52.70	34.20	1.00
65.15	49.35	1.41	63.00	35.89	1.00	53.05	20.18	5.64
65.90	32.52	1.21	66.50	32.52	1.20	55.35	33.64	1.41
67.00	44.30	0.20	68.50	31.96	0.80	57.58	32.24	1.00
67.90	24.11	1.21	71.15	32.52	2.01	60.75	21.87	0.60
75.70	47.38	0.20	71.80	25.51	1.20	64.05	19.34	1.00
79.65	47.38	1.21	73.20	35.85	0.80	67.50	25.79	1.20
83.15	42.62	0.80	77.85	29.44	1.81	70.00	30.40	2.01
86.45	32.52	1.61	81.15	30.00	2.81	71.85	42.90	1.00
89.50	30.56	1.61	84.20	38.81	2.01	76.10	30.28	0.60
90.90	28.60	1.41	85.30	31.40	3.21	79.80	31.12	3.42
94.40	34.48	1.20	87.75	37.01	1.20	83.75	45.42	1.00
97.45	40.37	0.80	90.90	34.20	0.60			
99.35	38.97	1.81	92.65	39.53	1.41			
101.95	35.05	1.81	95.45	43.46	1.20			
103.30	34.76	1.00	99.70	29.44	1.20			
103.90	28.32	1.61	102.10	36.73	1.00			
104.18	39.25	1.20	104.95	21.87	1.61			
106.15	28.88	2.01	107.10	30.28	0.80			
110.15	38.97	2.82	108.30	24.11	1.41			
112.75	39.25	1.11						
114.70	37.85	1.00						

Bore hole no. 2		
Depth (m)	Cao (%)	Mgo (%)
116.50	34.48	
0.60		
119.60	34.48	
2.21		
123.15	28.32	1.81
127.45	21.78	1.41
128.45	25.16	1.81
132.05	23.55	1.21
136.60	45.14	1.61
138.60	20.57	2.21
139.25	40.09	1.21
140.85	22.71	3.22
142.60	32.52	2.41
144.60	21.03	2.01
149.05	25.79	6.04

ANNEXE IV

Bore hole no. 5	Bore hole no. 6	Bore hole no. 7	Bore hole no. 8

Depth Mgo (m) (%)	Cao (%)		Depth Mgo (m) (%)	Cao (%)		Depth (m)	Cao (%)	Mg (%	Depth Mgo (m)	Cao (%)	(%)
						5.50	36.45	0.8			
						6.70	48.22		5.75	45.42	0.8
6.10	49.91		8.30	24.84		1.61			6.50	34.20	0.0
1.41			2.01			8.40	28.04	1.6	8.75	42.06	0.
8.52	28.32		13.87	28.64		12.20	49.35	1.2	10.10	26.91	0.4
1.20			2.01			15.25	49.35	0.8	10.30	26.07	0.2
11.85	44.86		16.30	49.00	2.0	18.00	45.98	0.8	13.20	-	
0.81			19.30	49.07	2.0	18.75	45.98	0.8	13.80	22.43	0.2
13.80	39.25		22.75	46.96	1.5	20.85	44.86	1.2	15.60	-	
0.60			25.45	50.17	0.5	24.10	48.78	1.0	18.00	-	
15.25	46.54		29.55	46.96	0.5	25.45	40.93	1.2	19.30	48.22	1.2
0.20			32.80	22.72	1.5	27.40	41.49		24.40	34.20	2.2
18.60	50.19	0.4	36.10	44.96	1.5	1.20			25.60	44.30	
21.10	48.78	0.8	39.65	50.45	2.5	29.90	49.35	1.6	4.03		
22.45	39.81	0.4	44.15	44.46	2.0	30.50	35.89	0.8	25.80	-	
23.65	32.80	0.2	47.75	51.15	1.5	34.30	50.47	0.8	29.95	49.91	2.0
26.20	43.74	0.8	50.60	49.05	1.5	37.95	50.47	0.8	33.55	50.07	0.4
27.45	45.42	0.2	53.35	43.45	2.0	38.20	44.02	0.8	36.50	50.47	0.6
29.50	43.46	0.4	55.30	29.44	3.0	42.45	17.10	0.2	39.80	50.75	1.4
31.00	44.02	0.2	55.85	25.53	2.5	45.65	14.02	0.2	42.85	50.75	0.8
33.60	42.34	0.8	57.40	44.16	3.5	48.90	47.66	0.6	44.05	49.63	0.8
36.70	28.04	1.0	57.95	30.14	2.0	50.20	41.20	1.0	46.55	29.72	0.2
38.60	28.88	1.0	61.40	46.96	2.5	50.95	51.87	0.6	49.85	20.75	0.8
39.85	38.97	0.8	64.30	25.75	1.5	54.25	49.91	0.6	53.20	49.07	1.0
41.00	30.28	0.6	67.10	45.55	1.5	56.60	50.75	0.6	56.95	47.95	
43.25	40.66	1.8	71.10	48.25	2.5	57.80	48.78	1.8	58.75	36.17	0.6
44.05	30.56	0.6	74.20	51.85	1.5	60.45	50.19	1.6	59.85	44.85	0.4
46.20	28.04	1.0	77.55	44.85	3.0	62.55	48.50	1.0	60.15	40.10	0.6
47.55	25.79	0.6	80.85	43.46	1.0	63.50	43.46	1.0	61.30	40.38	0.4
50.75	34.76	1.6	82.30	39.95	3.5	65.85	47.94	1.0	61.80	31.40	1.0
51.85	27.48	2.4	83.50	45.70	0.8	67.15	43.74		62.10	31.59	0.2
54.65	39.54	1.4	84.00	31.54	2.5	69.15	25.51	0.6	62.95	37.29	1.2
56.90	29.16	0.4	88.85	40.65	2.0	71.65	49.63	1.6	64.30	41.78	1.0
61.00	35.05	2.5	91.55	30.00	1.8	74.00	49.63	1.5	65.70	17.66	0.2
61.82	26.92	1.4	92.70	18.78	0.8	74.55	36.73	3.1	69.85	49.63	0.6
66.20	37.85	2.5	96.25	36.17	0.6	75.70	47.10	1.5	73.50	41.77	1.2
70.50	26.64	3.0	97.85	37.29	1.4	77.15	31.68	1.5	77.45	41.77	0.6
73.75	24.52		100.00	42.00	3.4	78.25	48.50	0.2	78.35	25.51	1.4
3.52			105.05	33.08	0.6	81.86	47.10	1.6	79.75	46.82	1.4
76.25	41.50		108.60	33.08		84.70	44.86	1.6	80.10	45.70	2.6
2.21			6.04			86.05	36.45	2.7	83.10	40.09	1.8
76.80	24.11	7.4	111.20	32.24	2.6	86.80	46.26	1.8	83.45	38.69	3.4
79.30	26.92	1.4	113.65	36.73	1.2						
83.90	44.85	3.0									
84.50	29.45	2.0									

85.80 39.96 2.5 88.90 23.83 1.5 90.85 42.06 2.5 92.90 19.63 4.5			

Bore hole no. 5	Bore hole no. 6	Bore hole no. 7			Bore hole no. 8		
		Depth (m)	Cao (%)	Mgo (%)	Depth (m)	Cao (%)	Mgo (%)
		88.60	29.44	0.40	86.05	44.58	1.0
		90.00	39.26	1.01	86.30	42.90	1.8
		92.10	22.99		87.40	41.21	3.4
		92.55	22.71		88.20	27.47	0.4
		96.60	51.59		90.85	44.02	1.4
		99.35	44.86		93.20	22.99	0.4
		102.25	45.14		96.30	47.10	0.1
		105.00	48.79		97.90	42.90	0.6
		107.70	36.73		102.05	26.61	0.4
		108.40	40.10		106.00	39.16	2.0
		110.00	24.39		111.10	31.12	1.0
		111.45	30.56		113.85	26.35	2.6
		114.00	36.73		116.35	33.64	2.0
		116.00	31.97		120.70	29.72	1.6
		117.15	30.28				
		120.15	23.27				
		122.40	33.09				
		125.75	24.11				
		126.75	33.93				
		129.10	44.30				

		134.20 35.61 137.26 35.61	

ANNEXE V

Table Chemical analysis result of trenches by UBM (1)

Sample No.	Ignition loss	SiO_2	Al_2O_3	Fe_2O_3	Cao	Mgo

		9.24 42.61 3.47 3.76 9.58 2.55 4.54 6.71 4.86 6.12 21.54 16.60 51.22 20.52 9.96 16.87 12.62 9.57 9.52 10.45 9.18 14.95 14.03 14.63 14.37 18.06 44.81 12.40 11.19 10.97 9.46 13.88 3.41 51.16 3.62 4.14 6.35 5.78 11.40 7.56 21.27 3.72 3.14	1.54 3.16 0.39 0.46 1.08 0.40 0.71 1.12 0.63 0.73 4.16 1.50 6.35 2.54 1.48 1.78 1.52 1.36 1.96 1.02 0.85 2.12 2.32 1.80 1.31 1.54 2.24 1.12 1.14 1.58 1.89 1.04 0.54 4.25 0.50 0.69 1.04 0.67 0.99 1.00 1.65 0.54 0.51	0.84 0.39 0.76 0.73 0.77 0.65 0.77 0.80 0.75 0.76 1.40 0.85 0.48 0.95 1.10 0.82 0.82 0.96 0.95 0.85 0.96 1.00 1.41 1.14 0.80 1.33 0.56 0.90 0.86 0.78 0.70 0.76 0.69 0.66 0.77 1.01 1.29 0.85 0.77 0.77 1.04 0.78 0.74	47.32 28.61 51.85 52.59 48.24 53.05 51.29 49.74 50.75 50.41 38.29 42.53 21.26 39.85 46.94 42.61 45.75 47.42 45.56 46.56 47.30 43.54 42.46 41.78 44.42 42.31 28.17 45.14 47.19 46.43 48.21 46.13 51.94 22.44 51.89 50.95 49.48 49.86 47.16 49.44 42.04 52.52 52.21	1.42 0.79 0.97 0.69 0.58 0.58 0.58 0.93 0.45 0.87 0.94 1.27 0.71 1.31 0.92 1.05 1.04 0.15 1.00 1.00 1.18 1.24 1.36 1.56 0.93 1.31 0.64 1.45 0.95 0.57 0.87 0.80 0.78 0.60 1.14 0.66 1.00 0.95 0.73 0.52 0.37 0.63 0.63

Table Chemical analysis result of trenches by UBM (2)

Sample No.	Ignition loss	SiO_2%	Al_2O_3%	Fe_2O_3%	Cao%	Mgo%
42. D-3	41.58	3.72	0.54	0.78	52.52	0.63
43. D-4	41.93	3.14	0.51	0.74	52.21	0.63
44. D - 5	35.09	15.64	2.03	0.84	42.65	0.90
45. D - 6	38.55	9.62	0.74	0.88	48.44	0.78
46. D - 7	40.54	4.88	0.72	0.93	50.61	0.68
47. D - 8	39.89	6.65	0.92	0.86	49.87	0.88
48. D - 9	42.57	2.48	0.32	0.65	52.79	0.99
49. D -	36.47	14.83	1.79	1.33	43.49	1.12
10	41.73	3.85	0.43	0.69	52.31	0.69
50. D –	37.55	11.37	1.07	0.94	47.11	0.44
11	39.03	7.88	1.40	1.33	48.28	0.87
51. D -	9.53	62.98	10.98	0.94	10.04	0.62
12	8.46	60.78	15.06	1.11	8.42	0.77
52. D -	23.22	40.39	5.71	0.57	27.92	0.53
13	40.04	6.73	0.85	0.90	49.37	0.68
53. D -	39.99	7.02	0.70	1.00	49.36	1.70
14	40.63	5.55	0.65	0.72	50.96	0.45
54. D -	39.57	5.95	1.24	1.12	49.64	0.89
15	39.12	8.55	0.82	0.92	48.55	0.86
55. D -	41.38	4.04	0.55	0.74	51.70	0.67
16	40.52	5.97	0.67	0.86	50.38	0.75
56. D -	41.36	4.13	0.54	0.76	51.73	0.91
17	37.98	10.43	1.31	0.84	46.68	0.62
57. D-18-	37.22	11.81	1.06	0.95	46.34	1.23
1	38.59	9.57	1.29	0.98	47.13	0.85
58. D-18-	41.75	3.56	0.50	0.90	52.17	0.55
2	41.83	3.72	0.52	0.86	52.22	1.02
59. D -	41.83	3.73	0.43	0.72	52.28	0.47
19	27.90	33.86	1.99	0.15	33.87	0.48
60. D -	38.54	10.34	0.95	0.66	48.11	0.53
20	40.07	7.17	0.58	0.75	50.03	0.69
61. D -	38.55	9.09	1.04	1.01	48.31	1.15
21	41.42	4.24	0.59	0.72	51.67	0.69
62. D -	41.58	3.47	0.56	0.74	52.50	0.54
22	40.73	5.41	0.76	0.70	51.13	0.54
63. D -	39.06	7.60	1.10	0.99	49.85	0.59

23	41.18	4.97	0.50	0.65	51.37	0.71
64. D -	41.78	3.91	0.51	0.69	51.64	0.91
24	41.56	4.09	0.58	0.90	51.86	0.45
65. D -	32.72	22.81	2.10	1.17	39.35	0.57
25	41.24	4.89	0.53	0.76	51.67	0.32
66. D -	41.17	4.75	0.66	0.76	51.61	0.44
26	35.86	16.14	1.01	0.75	45.03	0.30
67. D -	35.29	16.79	1.91	0.75	43.87	0.25
27	40.36	6.35	0.81	0.73	50.78	0.27
68. D -						
28						
69. N - 1						
70. N - 2						
71. N - 3						
72. N - 4						
73. N - 5						
74. N - 6						
75. E - 1						
76. E - 2						
77. E - 3						
78. E - 4						
79. E - 5						
80. 19-1						
81. 19-2						
82. 19-3						
83. 19-4						
84. 19-5						
85. 19-6						
86. 19-7						
.						

Table Chemical analysis result of trenches by UBM (3)

Sample No.	Ignition loss	Sio_2%	Al_2o_3%	Fe_2o_3%	Cao%	Mgo%

87. 19-8	39.99	6.88	0.94	0.80	50.09	0.53
88. 19-9	42.39	2.82	0.40	0.69	52.66	0.53
89. 19-10	40.32	6.09	0.82	0.82	50.64	0.55
90. B - 1	40.26	5.73	0.96	0.87	50.73	0.61
91. B - 2	36.73	13.26	1.53	0.97	44.54	1.57
92. B - 3	41.34	4.23	0.54	0.79	51.59	0.92
93. B - 4	42.44	2.77	0.29	0.70	52.12	1.13
94. B - 5	41.57	4.35	0.53	0.81	50.38	1.82
95. B - 6	37.09	12.68	1.07	0.89	46.02	1.47
96. B - 7	23.10	40.84	3.34	0.12	28.31	0.66
97. B - 8	41.55	3.64	0.39	0.73	52.29	0.75
98. B - 9	40.93	5.04	0.67	0.71	50.99	1.00
99. B - 10	33.11	20.91	2.28	0.91	39.98	1.48
100.B - 11	37.91	10.66	1.15	0.71	47.56	0.73
101.B - 12	41.91	3.45	0.44	0.62	52.16	0.81
102.K - 1	41.61	3.75	0.56	1.16	51.51	0.80