blocks

- Water treatment and housing estate

4. Process water

From the treated water storage tank the fresh process water is fed to the plant cold water storage basin.

4.1 Recycled cooling water for the plant

Cooling of the equipment by water is done in close circuit through a cooling tower, using various purpose tanks, pumps, etc.

4.2 Non recoverable water

This water is supplied from the process water tank(s) and it includes:

- Spray water for cement mill.
- Spray water for the spray towers placed before the electrostatic precipitators of the kiln and by-pass.
- Water lost in the empty bag store humidifiers and other purposes.
- Miscellaneous water losses, including car and heavy equipment washings located at the garage.

Sub-section 302 - Compressed air production and distribution

1. Production

The first compressor room is located in the neighbourhood of the homogenizing silos which consumes the largest proportion of compressed air.
The second compressor room is located near the cement silos in order to supply compressed air these silos and to the packing plant.

To the exception of the compressor for the garage, workshops and quarries, all the other compressors are located in the two compressor rooms above mentioned.

Quarry, workshops and garage have their own independent compressors.
The quarry compressors are to be driven by Diesel engines, the other independent compressors are to be driven by electrical motors.

The compressor rooms are equipped with forced ventilation and air filters in order to prevent dust ingress in the premises and to ensure an acceptable air temperature in the rooms.

2. Distribution
Pipings, fittings and valves will be installed in

order to distribute compressed air to wherever it is required.

Compressed air is also available in each individual building at all floor levels for cleaning or for using pneumatic tools.

Sub-section 303 - Heavy fuel oil storage and distribution

1. Storage
The heavy fuel oil is received at the plant by tank-trucks.

The unloading which comprises pumps, duplex filters and heating system for the heavy fuel oil discharge the oil into two storage tanks.

2. Distribution

The heavy fuel oil withdrawal system is equipped with adequate steam heating system for the pumping of heavy fuel oil to the different utilization places.

Sub-section 304 - Diesel oil and petrol storages and distribution

The diesel oil is received at the plant by tank trucks and unloaded through pump and filter into a storage tank.

Withdrawal pumps supply diesel oil to the emergency diesel generator set daily tank, and pumping station for supplying fuel to the daily needs of quarry equipment and vehicles.

A service tank for petrol will be also installed with appropriate pumping station.

Table 5-1 Principal Specification of the Plant Equipment (MAFRAQ)

Equipment	System	Specification
Raw material crushing		
- Limestone crusher	Double shaft hammer crusher	500 t/h, 375 kW x 2
- Additive crusher	1ry: Jaw crusher, 2ry: Cone crusher	100 t/h, 1ry: 75 kW, 2ry: 150 kW
- Gypsum crusher	Jaw crusher	20 t/h, 37 kW
Raw material storage		
- Limestone	Chevron method mix bed with stacker and reclaimer	20,000t x 2
- Additive	Open storage pile	
- Gypsum	Stockpile partly covered by open-sided structure	7,500t
Raw material grinding	Vertical Roller mill	135 t/h, IS-2800 1600 kW
Raw meal homogenizing	IHI continuous type, concrete made	Storage silo : 3,800t x 2 Homo. silo : 1,200t x 1
Clinker burning	NSF system	1,700 t/d, IHI-NSF, 3.8m dia. x 54m
Clinker cooling	Horizontal grate cooler	1,700 t/d, 2 stage, FB 830/1030
Clinker storage	Concrete made	8,500t x 2
Cement grinding	Closed circuit compound with O-Sepa.	90 t/h, 4.2m dia. x 13.5 ml, 3,200 kW
Cement storage	Concrete silo	7,000t x 4
Cement packing and loading	8-spout rotary packer Bulk loading with load cell	100 t/h x 3, 5-loading line 100 t/h x 2
Cooling water supply	Closed circuit with cooling tower	220 t/h
Fuel storage	Cone roof tank	Heavy oil : 2,500 kl x 2 Diesel oil : 500 m3 x 1
Steam supply	Packaged boiler	2 t/h x 1
Compressed air supply	Reciprocating compressor	19.6 m3/min x 3 (2-R. mill area, 1-C. mill area)

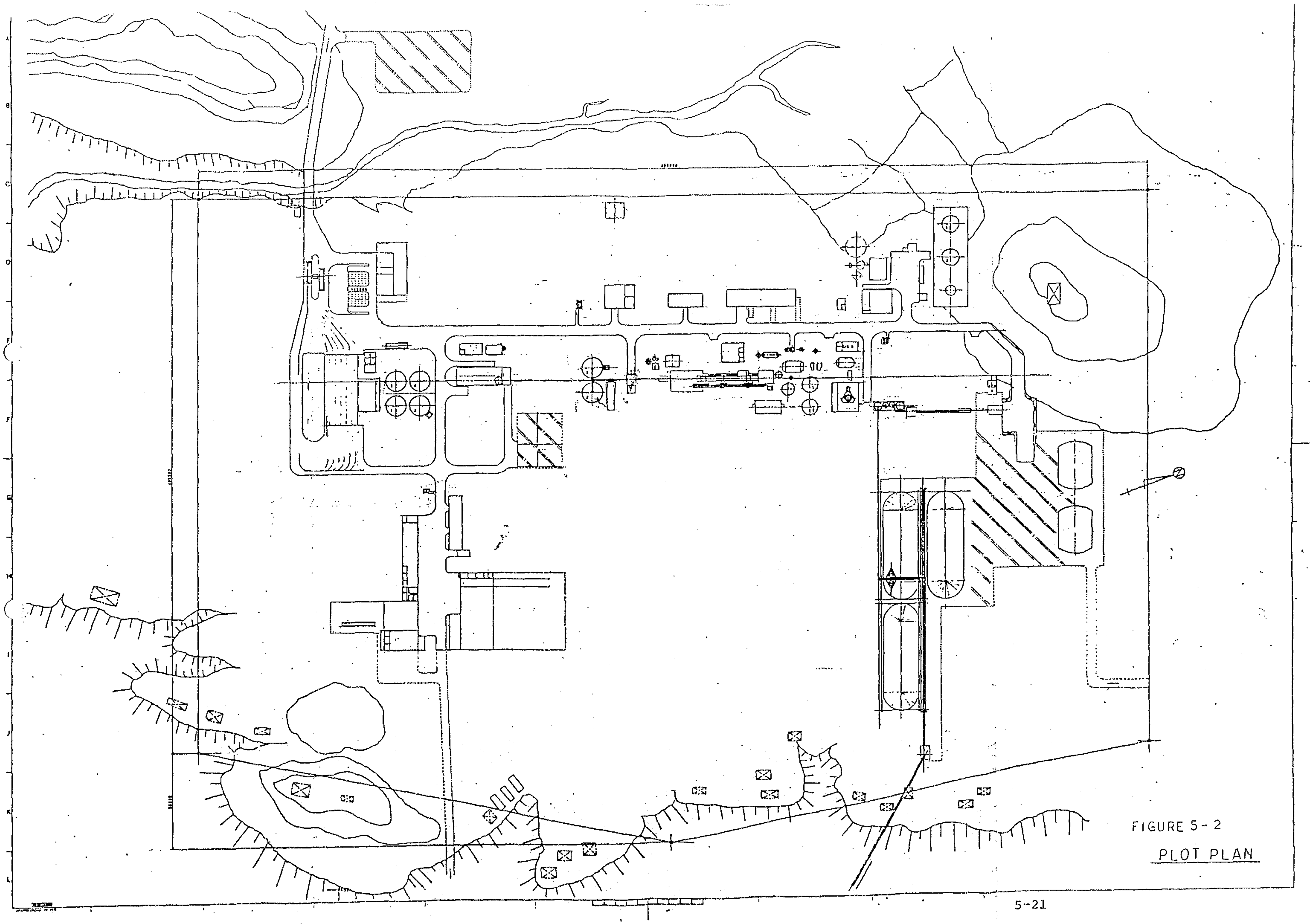


FIGURE 5-2

PLOT PLAN

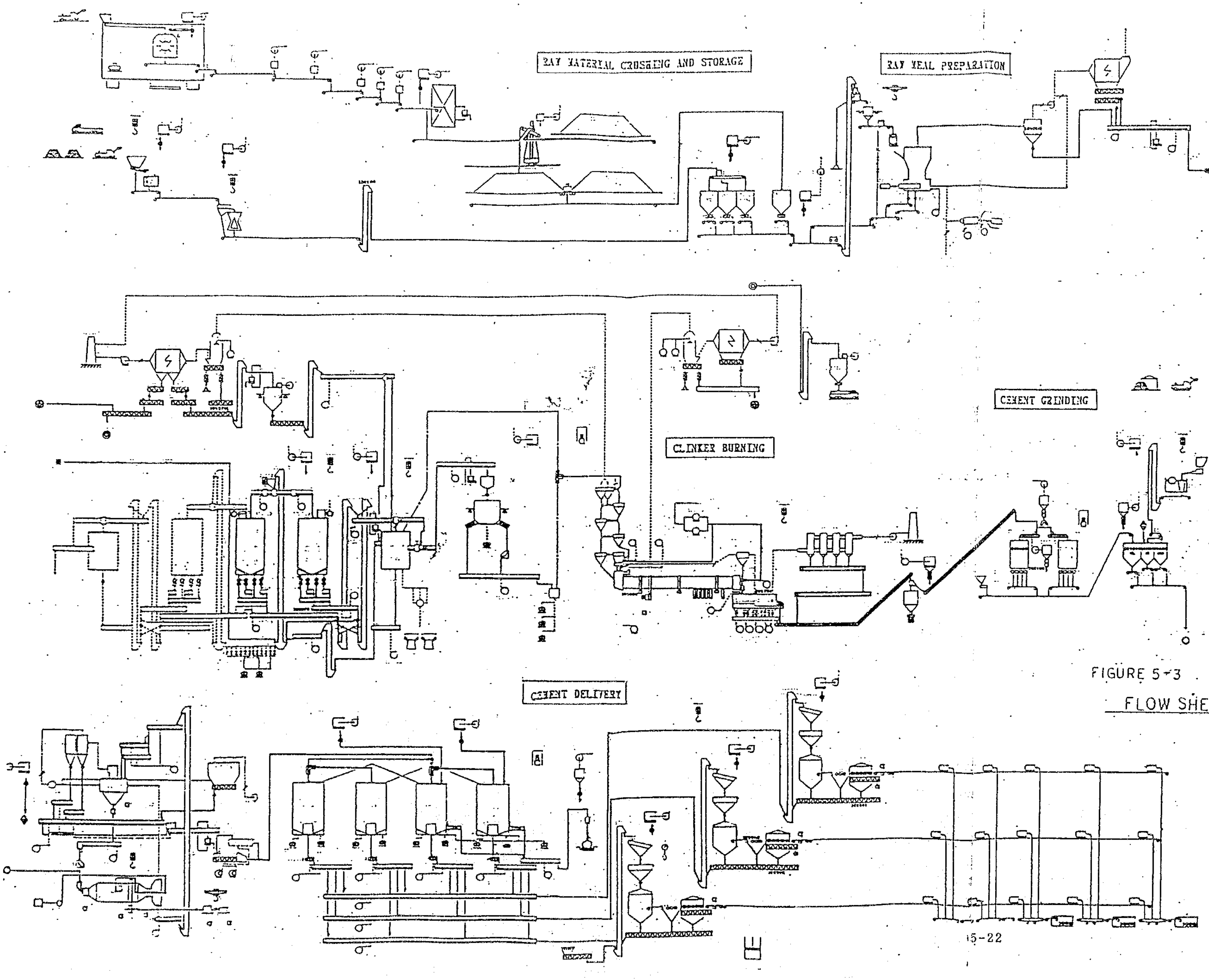


FIGURE 5-3

FLOW SHEET

5.2 Construction Schedule

Construction of the plant is executed by Basse Sambre/E.R.I.-S.A., Belgium as the consultant and Ishikawajima Harima Heavy Industries Co., Ltd., Japan as the contractor.

Construction was started January, 1990 and is now going well on schedule generally and it is scheduled to start commissioning in November, 1992 and commercial production in March, 1993.

Scope of work of the contractor is full turn key base of construction from raw material quarry opening to produced cement despatch including plant erection and civil work. Supporting facilities such as administration offices, stores, workshop and operator's buildings and housings for employees are also included.

However supply of utilities such as water supply and electric power supply are excluded from the contractor's scope of work and these two kinds of utilities are supplied by Yemen governmental authority.

Construction cost for the contractor is financed by Japanese government soft loan.

5.3 Acquisition of Raw Materials of Utilities

5.3.1 Acquisition of Raw Materials

1) Quarry

Three kinds qf raw material (limestone, volcanic rock and sandstone) are provided for the 1st 500,000t cement plant of Mafraq

The each function of raw material is;

- Limestone for CaO resource
- Volcanic rock for SiO_2, Al_2O_3, Fe_2O_3 resource
- Sandstone for SiO_2 resource

Outline of each quarry is shown in Table 5-2.

Table 5-2 Outline of each quarry.

	* Location	Confirmed ore reserves (million tons)	Chemical composition (%)				
			SiO_2	Al_2O_3	Fe_2O_3	CaO	Ig-loss
Limestone	1.5km away from plant site in east direction	47.0	8.0	1.2	0.8	48.8	39.5
Volcanic rock	2 km away from plant stie in north west direction	1.9	49.1	12.6	11.9	7.8	7.0
Sandstone	1.5 km away from plant site in north east direction	1.2	91.4	1.9	2.1	1.0	1.3

* Location: refer to Figure 5-4

* Chemical compositon: average value of all drilling stamples

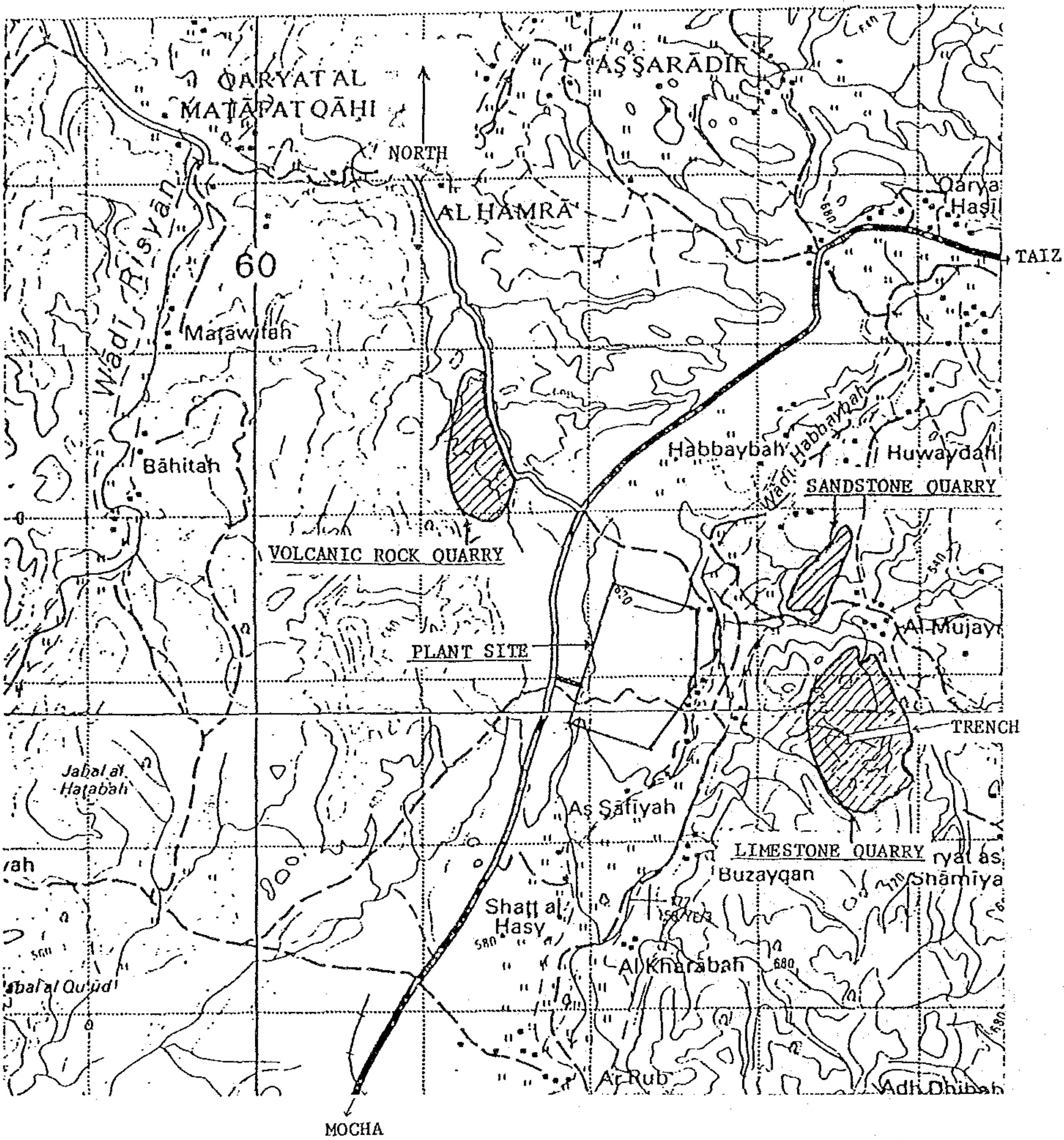
2) Mining Method

The mining method and arrangement of main heavy equipment is shown in Table 5-3

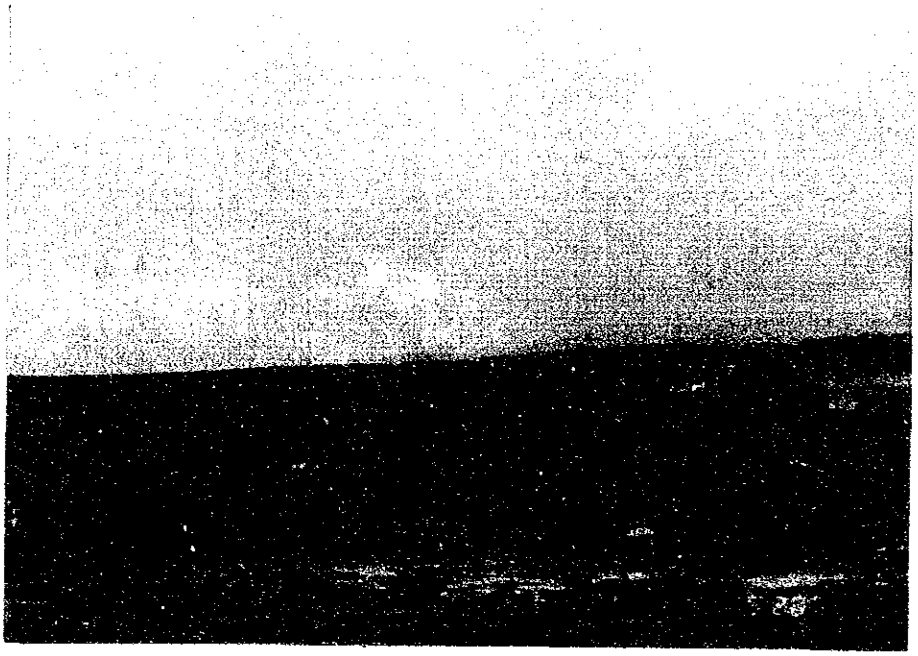
Table 5-3 The mining method and arrangement of main heavy equipment

Quarry	Excavation	Loading	Hauling	Auxiliary work
Limestone quarry	Blasting (Bench cut method) Wagon drill with mobile compressor 2 sets	Load and carry method front end loader 2		Bulldozer 1 portable hammer drill 4
Volcanic rock quarry	Ripping and dozing Bulldozer 1	front-end -loader 2	Dump truck 3	
Sandstone quarry	Blasting wagon drill with mobile compressor 1			

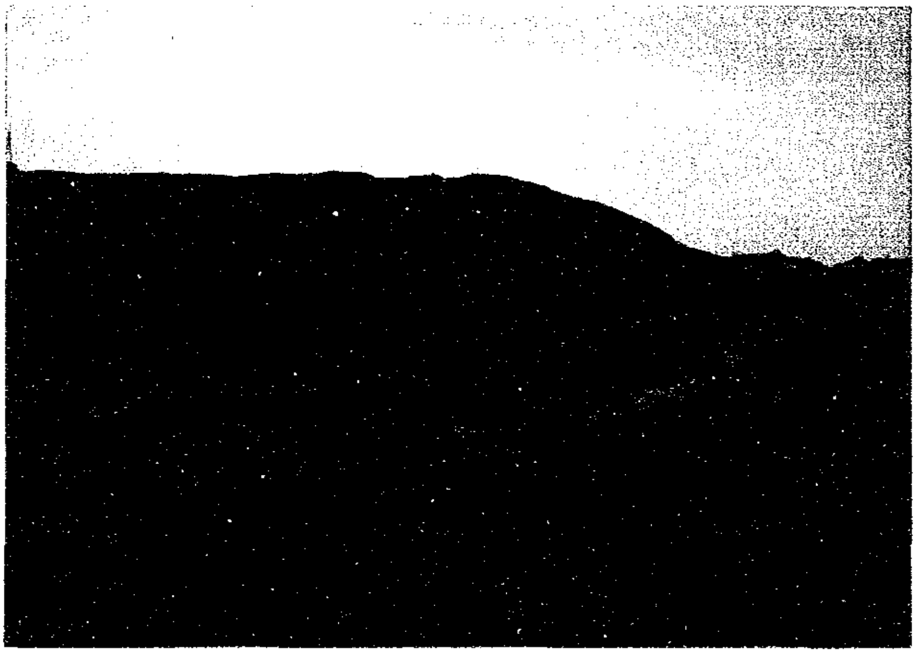
Figure 5-4 LOCATION OF EACH QUARRY



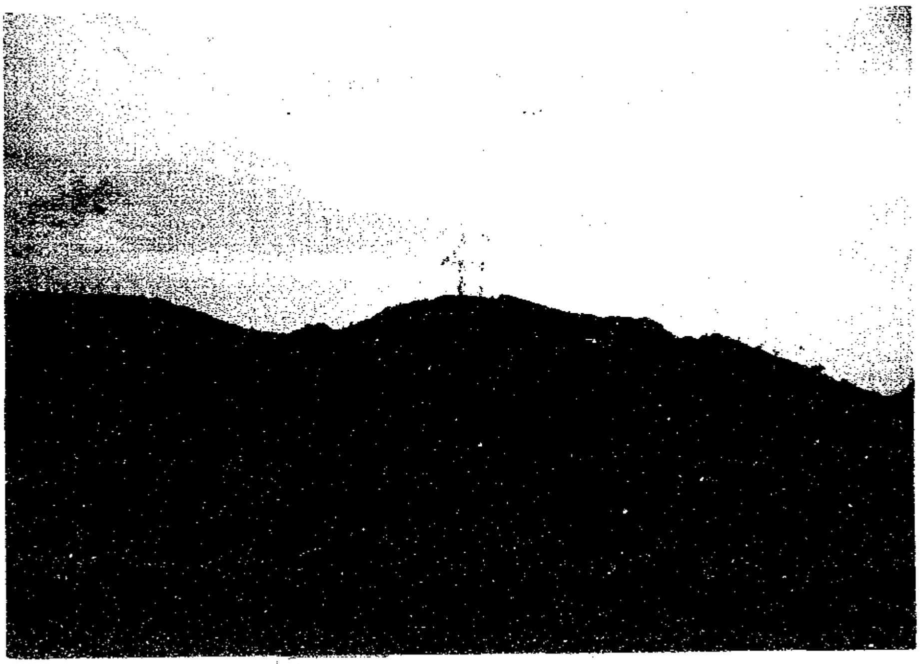
LIMESTONE QUARRY



VOLCANIC ROCK QUARRY



SANDSTONE QUARRY



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5.3.2 Water Supply

1) Water demand for Plant

Maintenance operation of the Mafraq Cement Plant requires industrial water, such as cooling water, which is consumed on the production line, and living water supply to employees. The demand is calculated as follows.

Industrial water	:	500 m^3/day
Living water	:	200 m^3/day
Total	:	700 m^3/day

Plant expansion is planned at YCC. An increase in the water demand due to this expansion is the object of a series of investigations looking for 500 m^3/day.

2) Present Situation of Water Supply

Mafraq Cement Plant is located on the river terrace composed of Wadi Ar Rub originating from Habashi Mountain (2,359 meters), which forms the central mountainous region located 12km SE of Taizz. Annual precipitation is small at 200mm to 300mm and Perennial rivers do not exist. There are no sources of water in this area other than accumulated rain water or groundwater developments. However, in Yemen, where precipitation is small and evapotranspiration is high, utilization of rain water to support life in villages is often seen. Therefore, the utilization of water for large scale industrial use is unrealistic. The investigation of ground water development as water source for this plant was conducted as follows.

- As requested by YCC, the General Department for Water Resources of the Ministry of oil and Mineral Resources conduced a study from February to August in 1987.

- Two candidate sites were selected after field investigation.

  No.1: Wadi Rohaba flows down from Habashi Mountain 4 km NE of the plant site, and turns south flowing into Wadi Ar Rub.

  No.2: As Saradif is 4 km north of the plant site and the valley bottom plain is located at midstream of Wadi Risyan.

- Test drilling was conducted by a local drilling company at the candidate sites, however, and aquifer was not confirmed at either site.
  The depth of test drilling was 200m and 300m respectively.
  The existence of crack was confirmed at No.1 and now a formal pumping test is under planning.

- 200m test drilling was conducted at the 3rd candidate site of As Safiyah located 400 meters from the SE corner of the plant site. This site was not successful either.

- Finally, as a 4th candidate, a 200m test drilling was conducted at Al Barodah located approximately 10 km south of the plant site. This site also proved not to have possibilities for groundwater development.

3 Policy of Water Source Development

As mentioned above, the development of deep layer groundwater was very difficult. While these tests were being conducted, water for plant construction was available through shallow wells drilled into river beds

and banks of Wadis. This water was dependent on th purchase of existing wells to which water rights were added, as well as, water sold by farmers. This means that negotiation with farmers is possible, even though shallow layer groundwater has been used as the vested water rights of farmers for a wide range of purposes. The selling and buying of existing wells present no legal problems. Drilling a new well is legal if it is located at least 500m away from existing wells.
The construction of the plant was being carried out and its completion was nearing, therefore, YCC decided on the following policies in October and November of 1991.

a) First stage (Short term):
In order to secure the necessary original water quantity of 700 m^3/day, shallow layer groundwater would be obtainable from the water bearing beds of Wadis and alluvial deposits of river terraces.

b) Second stage (Long term):
Unless it was proved that the usage of shallow layer groundwater was sustainable and did not affect agricultural water at the first stage, development investigation of deep layer groundwater would be conducted again.

4) Development of Shallow Layer Groundwater

At the first stage, the investigation to develop shallow layer groundwater was conducted from December 1991. A field investigation was conducted by El-Yemen Hydro Consultants of Yemen, and a report was submitted. The investigation was conducted with electric prospecting at 6 points in the targeted area. Their results suggested that shallow layer groundwater development through shallow wells was possible in the following areas.

a) Development in the surrounding area of the plant site, Wadi Ar Rub, and the alluvial plain including its tributaries.

b) Lower stream area of Wadi Risyan including the As Saradif area.

However, there are existing dug wells for irrigation in these agricultural areas, so it is difficult to obtain all of the water from the same area. Therefore, well construction will be planned dividing the above two rivers systems, and it will be planned as far a way as possible from any existing wells. Development depth of groundwater is targeted at 35m to 60m through the alluvial deposits of Wadis.
As well, as a simple resolution method, the purchase and improvement of existing wells from farmers were recommended.
From this result, securing water sources by the following policies were decided and the project was underway. The location of wells are shown in Figure 5-5.

No.1 Well: (E) A shallow well was established at the depth of 15m and with a 2m (L) x 2m (W) in the alluvial lowlands of As Saradif and mid-stream of Wadi Risyan. At the time of investigation (March 17, 1992), 4.5m was drilled and 1.8m backfilled.
As a result of the plain pumping test, the pumpage was assumed as follows.

Pump capacity: 522 l/min
Water level draw down: 74cm/20min
(3.6cm/min)

Conductivity: 2,800 micromoms/cm
$(0.522m^3 x 20min) - (2m x 2m x 0.74m) - 20min = 0.374m^3/min$

This is the pumpage pumped from the aquifer at a depth up to 2.7m. Pumping is thought possible at 374 l/min or $22m^3/hr$. The distance to the plant site is approximately 3km and the level difference is 40m to 50m lower.

No.2 Well: (F) The purchase of the existing well at Al Hamra is planned, which is along the access route to the No.1 well and on the traverse of Wade Risyan.

(Well details) Depth : 6.4m
Static water level : 2.90m
Diameter of delivery pipe
of vertical turbine pump: 2 inches
Conductivity : 2,600 micromoms/cm

No.3 Well: (G) A 50m deep dug well is planned at As Safiyah, which is adjacent sough of the plant site and the river terrace of Wadi Ar Rub.

No.4 Well: (D) A sand aquifer was not found in the borehole drilled as the No.1 test well during the first test boring. However, there were many cracks and a groundwater potential is expected. For this reason a pumping test is planned by renting a water motor pump from the Ministry of Agricultural. This well will be used if groundwater is confirmed.

5) Discussion

Although the reason for location selection of test boring is unclear, only confined groundwater has been found in cracks. Therefore, the success ratio of groundwater development has not reached even 50%.

Usually good conditioned groundwater exists in the fracture zones accompanied by faults. In this case, Basalt dick is consistently seen along with cracks, as is often seen in a Limestone quarry. This implies that the aquifer is said not to be effective.
Clearly, the development of deep layer groundwater near the plant site is a difficult task. Contrary, the development of shallow layer groundwater is relatively easy and is often used for irrigation water for agriculture.

Wadi Ar Rub dips just east of the plant site and joins the traverse of Wadi Rahaba, originating in Habashi Mountain. The basin area up to the plant is approximately $220km^2$.
As well, the upper stream basin area up to valley bottom plain As Saradif, located mid-stream of Wadi Risyan, is approximately $260km^2$. The annual precipitation of this area is 200mm to 300mm and is sufficient to replenish shallow layer groundwater.
Possible development amount of groundwater will be determined from the alluvial deposit layer thickness (capacity of aquifer) and how much it is used for agricultural water.
According to the report of Dar El-Yemen Hydro Consultants, the thickness of the alluvial layer is 10m to 20m and 45m at its thickest.

The number of existing wells in the 2 large wadis has not been counted at the present time, but a considera-

ble number has been confirmed.
Some of the wells will go dry by the end of the dry season (every year February to March).
This is due to a drawdown of the groundwater level through the pumping of groundwater and flaw, and the bottom of wells can be seen. Wells are replenished through precipitation.
As YCC's development policy, the present water supply problem can be resolved through shallow wells, while avoiding trouble with farmers by purchasing water rights, as well as, by maintaining harmony with agricultural water needs.
The development of deep layer groundwater will be considered in the future, but securing a continuous, stable water source is essential for this project, making investigation and development necessary at an early stage.

6) Water Supply Plan

Summarized water supply plan by YCC at the time as investigation is as follows.

<Water source>

* Shallow wells (dug wells) for shallow ground water.					
	River System	LOCATION Name of Location	Distance to Plant	*1 Height	Assumed Yield
No.1 Well	W. Risyan	As Saradif	3 km	590m	*2 20-30m³/h
No,2 Well	W. Risyan	Al Hamra	2.5km	600m	*3 15-20
No.3 Well	W. ArRub	As Safiyah	1 km	590m	*4 25-40
Total					60-90m³/h

* 1: read from map with scale of 1:50,000
* 2: assumed figure from simple pumping test
* 3: assumed figure from pump discharge opening
* 4: assumed from the date of existing wells

* No.1 deep well of test boring will be used if development is possible.

<Pumping facilities>

A vertical turbine pump will be established at each well. The depth of each well is 6.4m to 50m and the level difference from the plant site is roughly 40m to 50m. The total pump head is assumed to be no greater than 100m. Therefore water is sent directly by pump from wells to a reservoir at the plant site.

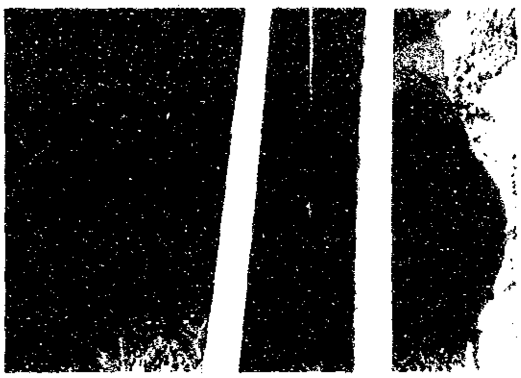
<Conduit>

Water is sent from wells to the plant site through a 2" to 3" water pipe.

Piping is buried in principle, however, exposed piping is necessary due to several rock outcroppings.

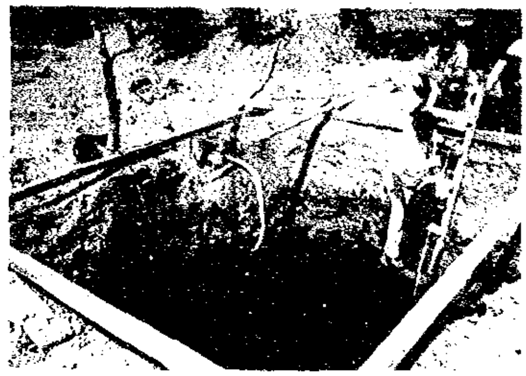
Route establishment and measurements were completed and planning was at the design stage. As well, it is believed that after several days information about construction tenders would be given.

Existing dug-well



Dry well (12.5 m)

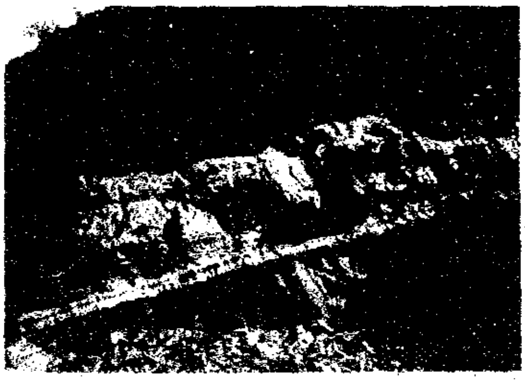
Exploration boring(No.1)



Under-construction
of dug-well

Arrengement of purchase
existing dug-well

Alluvium deposit
wadi Ar Rub



.Amran limestone/Basalt

Tawilah Sandstone
in Al arfah

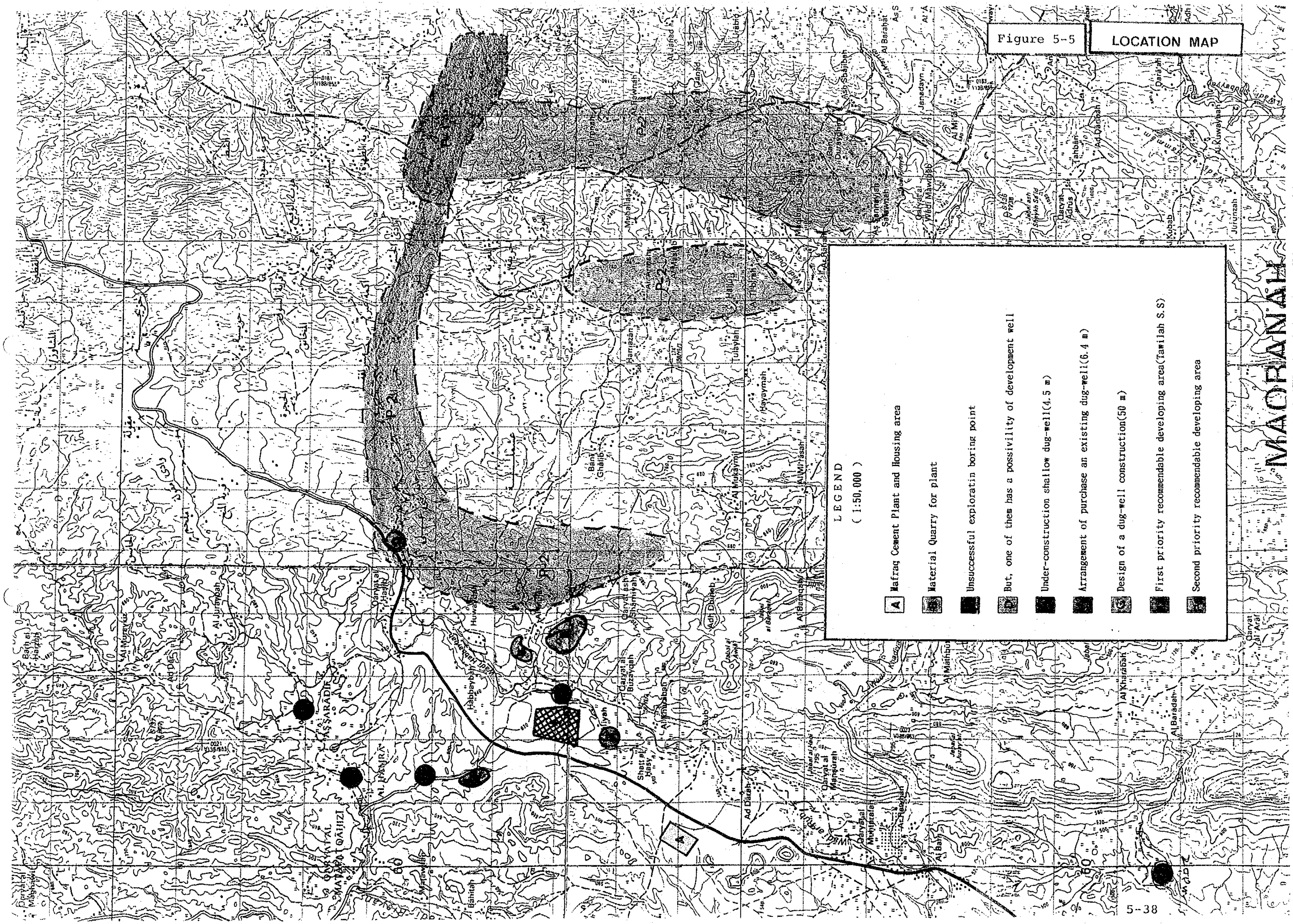


Figure 5-5 LOCATION MAP

5.3.3 Electric Power Supply

1) Electric Power for Mafraq Cement Plant

Electric power for Mafraq Cement Plant is supplied from Al-Barh Substation. This substation is in direction of West and at a distance of about 5 km from plant site.

This Al-Barh Substation is one of the substations for covering the electric power distribution system in Yemen. (Refer to Figure 5-6 "Transmission network in Yemen".)

In this substation, 2 sets of 132/33 kV, 25 MVA transformer and 1 set of 33 kV switchgear are provided. 33 kV switchgear is consisting of 2 sets of incoming and 4 sets of distribution line. (Refer to Figure 5-7 "Single line diagram Al-Barh substation".) These dis tribution lines are planned to use as follows:

1 - General User
2 - Mafraq Cement Plant
1 - Spare

2) Specification for Electric Power in Mafraq Cement Plant

Specification of supplied electric power to Mafraq Cement Plant from Al-Barh substation is as follows:

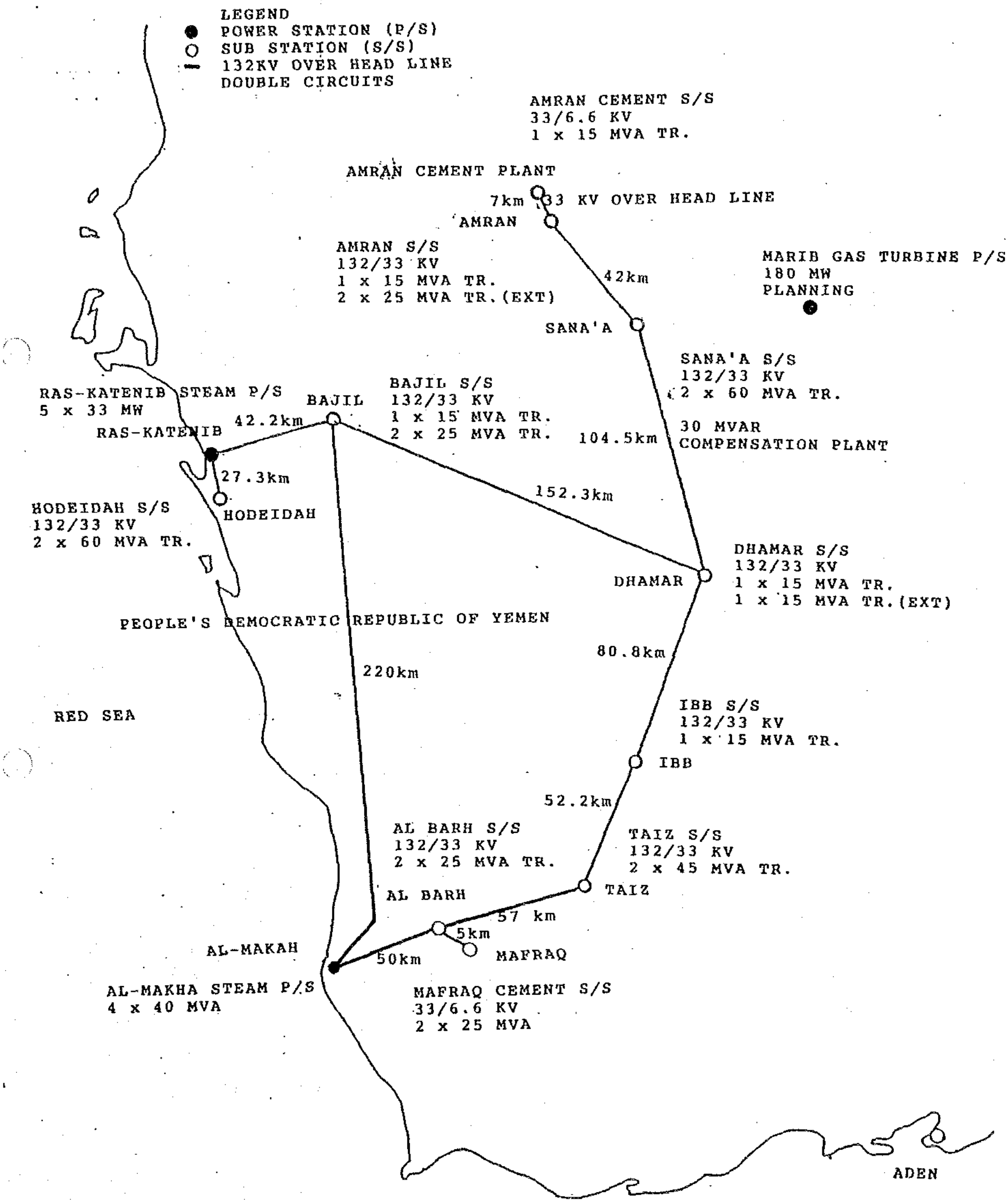
Source	:	33 kV, 3 Phase, 50 Hz
Line	:	2 lines
Permitted capacity	:	25 MVA max.

Electric power used in the plant is as follows:

AC Motors	:	201 kW and over	6.6 kV	3 Phase
		Up to 200 kW	280V	3 Phase
		Special	220V	3 Phase (Special case)

DC Motors	:	21 kW and over 440V
		Up to 20 kW 220V
Space heater	:	AC 220V Single Phase
Lighting	:	System 380V 3 Phase 4 Wire
		Branch 220V 1 Phase 2 Wire
Socket outlet	:	13A 2P+1E AC 220V 1 Phase
		63A 3P+1E AC 380V 3 Phase
Control circuit	:	33 kV SW/GR DC 110V
		6.6 kV SW/GR DC 110V
		380V SW/GR DC 110V
		Motor Control Center AC 220V
		For Automation (PLC. etc.)
		DC 48V or AC 220V
Instrument	:	Power AC 100V
		Signal DC 24V

FIGURE 5-6 TRANSMISSION NETWORK



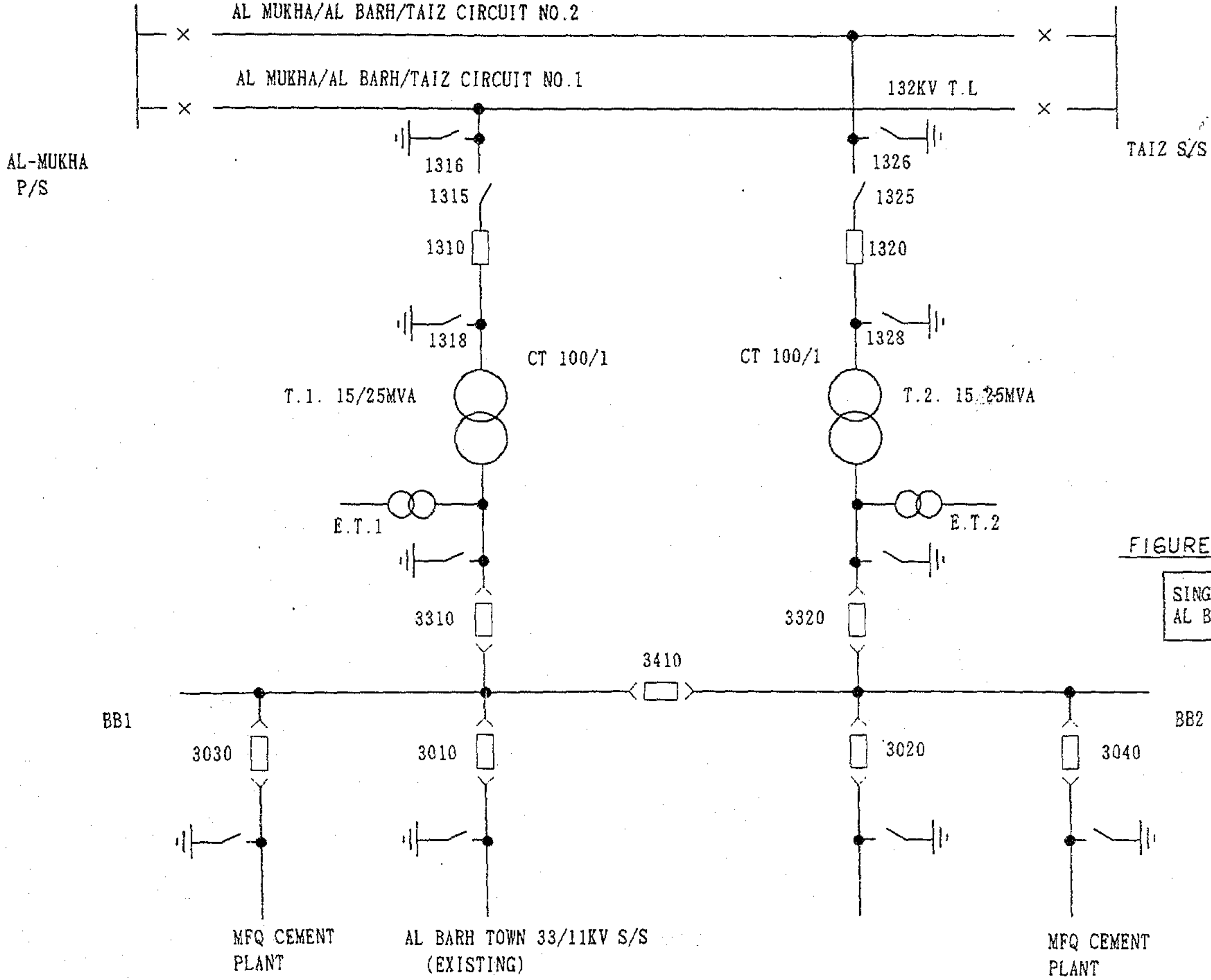


FIGURE 5-7

SINGLE LINE DIAGRAM
AL BARH SUB STATION

5.3.4 Fuel Oil Supply

1) Fuel Oil Consumption

Following two kinds of fuels is used for the plant.

Heavy fuel oil is used for clinker burning and in the hot gas generator of the raw material grinding section.

Average consumption are calculated as follows:

Clinker burning	= 6.20 tons/hour
Hot gas generator	= 1.24 tons/hour
Total	= 7.44 tons/hour x 24 hours
	= 178.56 tons/day

Diesel oil is used for steam boiler plant and emergency power generating set.

Average consumption are calculated as follows:

Steam boiler plant	= 0.15 ton/hour
Emergency power generating set	= (0.25 ton/hour)
Total	= 0.15 ton/hour x 24 hours
	= 3.6 tons/day

Both fuels are supplied to the plant by track tank lorry from the Mareb Oil refinery and storaged to the fuel oil tank in the plant.

Each tank have the following capacities:

Heavy oil storage : 2500 m^3 x 2 sets
Diesel oil storage: 500 m^3 x 1 set

2) Specifications of Fuels

Specifications of fuels are as follows:

Heavy fuel oil

				TEST METHOD
Ash	% w	max.	0.05	ASTM D 482
Calorific value gross	Btu/b	min.	18000	Calc. USB of Standards No.97
Carbon residue, conradson	% w	max.	12	
Flash point, PMCC	Deg.C) (Deg.F)	min.	66 (150)	ASTM D 93
Fire point C.O.C.	Deg.F	min.	200	ASTM D 92
Pour point	Deg.F	max.	40	ASTM D 97
Sediment	% w	max.	0.05	ASTM D 173
Sediment and water	% w	max.	0.5	ASTM D 1796
Specific gravity(a)		min.	0.928	ASTM D 1298
Sulphur	% w	max.	2.5	ASTM D 1551
Viscosity, Kinematic	cSt	min.	68	ASTM D 445
Water	% w	max.	0.05	ASTM D 95

Diesel Oil

				TEST METHOD
Ash	% w	max.	0.01	ASTM D 482
Carbon residue,	% w	max.	0.10	ASTM D 189
Either: Cloud point	Deg.C	max.	5	ASTM D 2500
Pour point	Deg.C	max.	zero	ASTM D 97
Or : Cloud point	Deg.C	max.	11	ASTM D 2600
CFPP	Deg.C	max.	+3	IP 309
Colour, ASTM		max.	2.5	ASTM D 1600
Diesel index		min.	53	IP 21
Flashpoint PMcc	Deg.C	min.	66	ASTM D 93
Sediment	% w	max.	0.01	ASTM D 473
Specific gravity (a)		min.	0.820	ASTM D 1298
Sulphur	% w	max.	1.0	ASTM D 1551
Viscosity, kinematic	cSt	min.	0.0	ASTM D 445
Water	% w	max.	0.1	ASTM D 1744

6

6

CONTENTS

6.1 Raw Materials

This report is completed based on "Final Report for Geotechnical Investigation works of 500,000 ton/year MAFRAQ CEMENT PLANT PROJECT of Ministory of Economic Supply and Trade SANA'A YAR Volume III Description of Quarry Opening " and JICA own investigation.

6.1.1 Limestone Deposit

1) Geological Structure and Stratigraphy

The geological structure in this area is shown in Figure 6-1, Figure 6-2 and Figure 6-3.

In tectonic zone-1 almost all of the layers accumulate horizontally, though they are divided into some blocks by faults and dykes.
The dip of faults and dykes is nearly vertical.
The thickness of a dyke is usually less than 3 m; however, some of them exceed 8 m.
In tectonic zone-2A the layers in this area dip slightly southwest and are also divided into some blocks by faults and dykes.

The geological investigation in tectonic zone 1 (northern part of BH16) and tectonic zone 2A was carried out by the following procedure;

(1) Determining the geological column

Figure 6-1

GEOLOGIC COLUMN OF LIMESTONE AREA

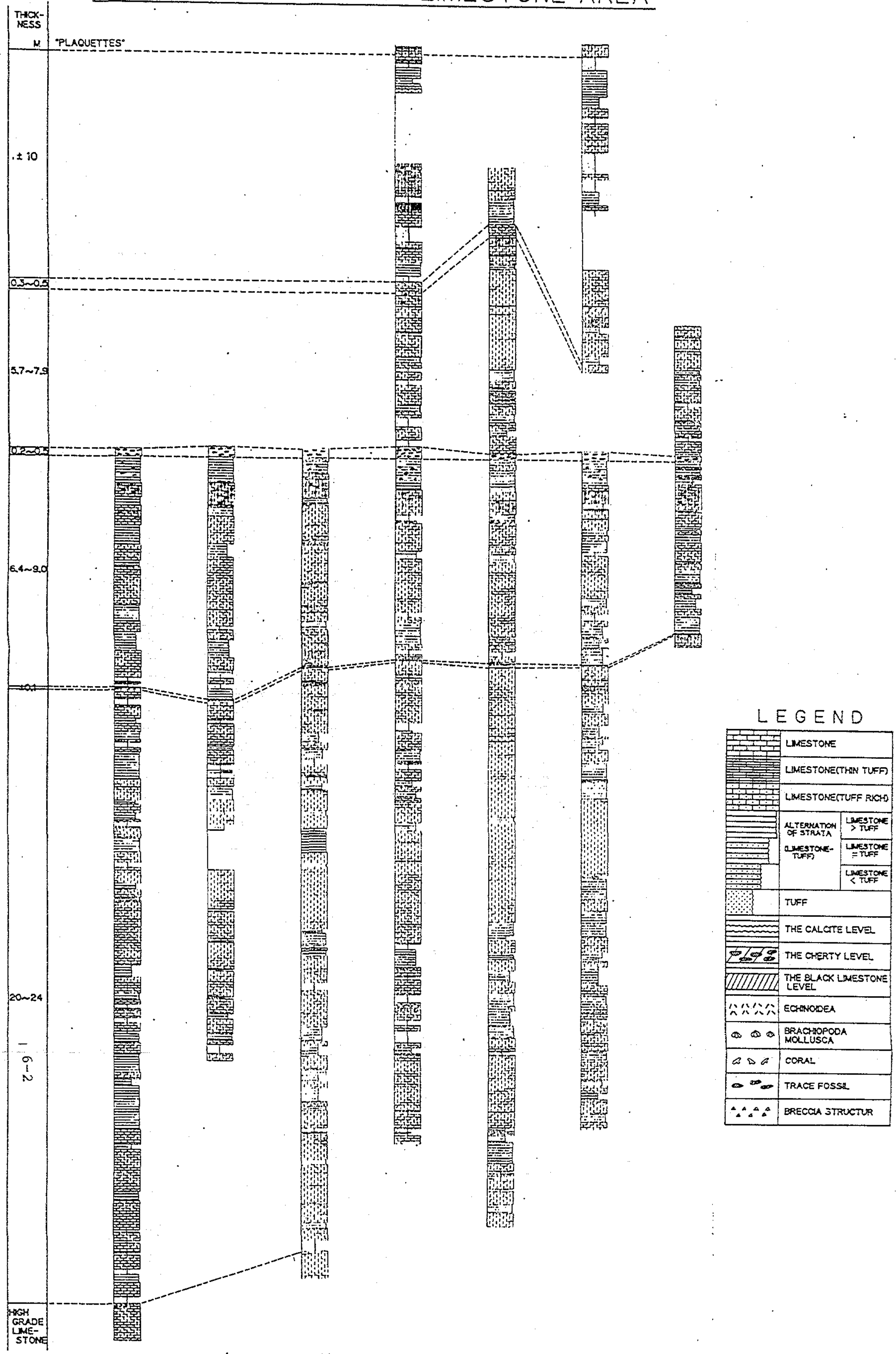


Figure 6-2

GEOLOGICAL MAP OF LIMESTONE AREA

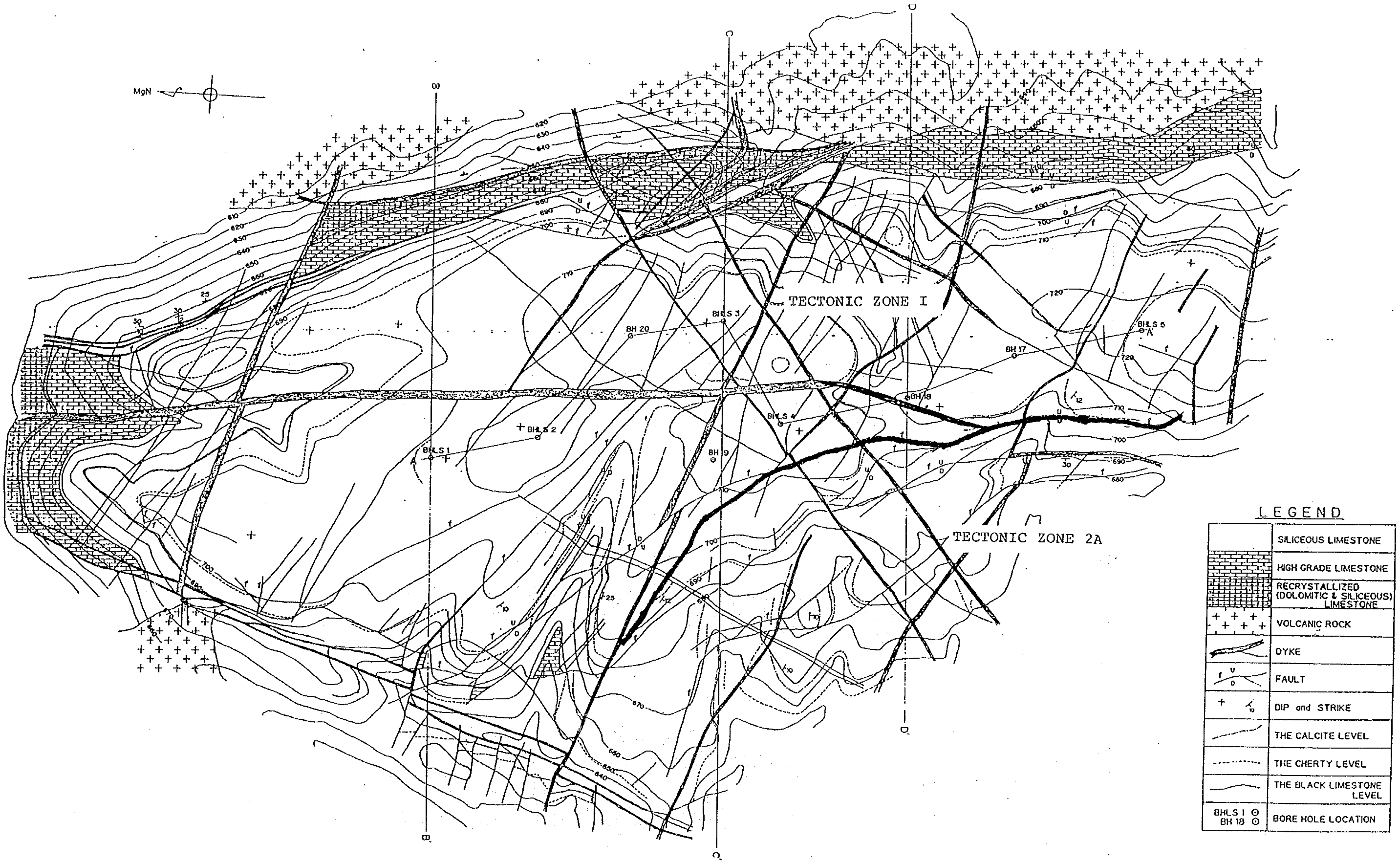
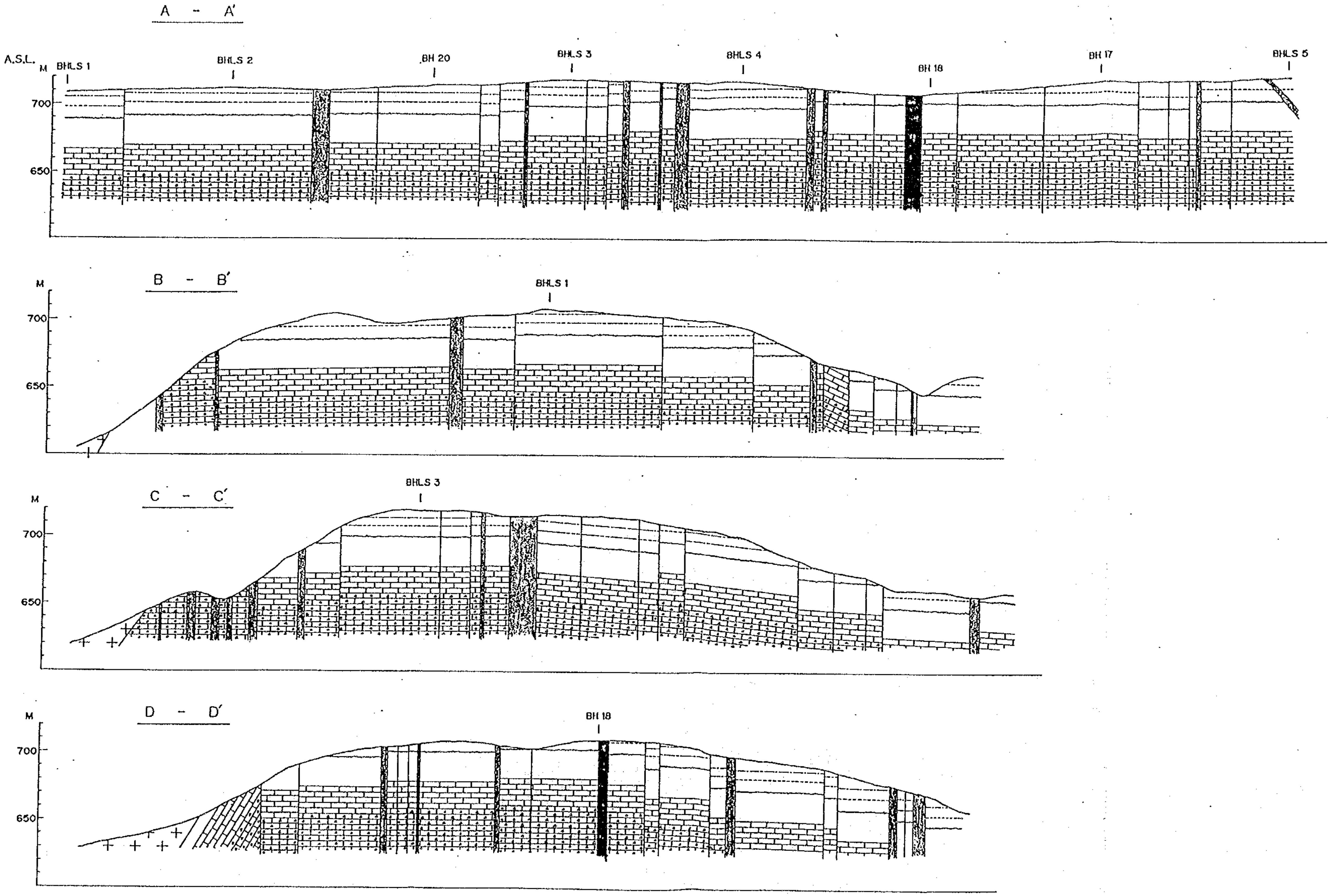


Figure 6-3

GEOLOGICAL PROFILE OF LIMESTONE AREA



(2) According to the geological column, the layers which are suitable for key beds were selected.

a) the calcite layer

b) the charty layer

c) the black limestone layer (very thin)

d) the coral layer in high grade limestone (approximately 7m below the boundary between H.G.L. and silicious limestone)

(3) The location of the key beds, faults and dykes was surveyed.

Stratigraphy of this area is shown in Figure 6-4

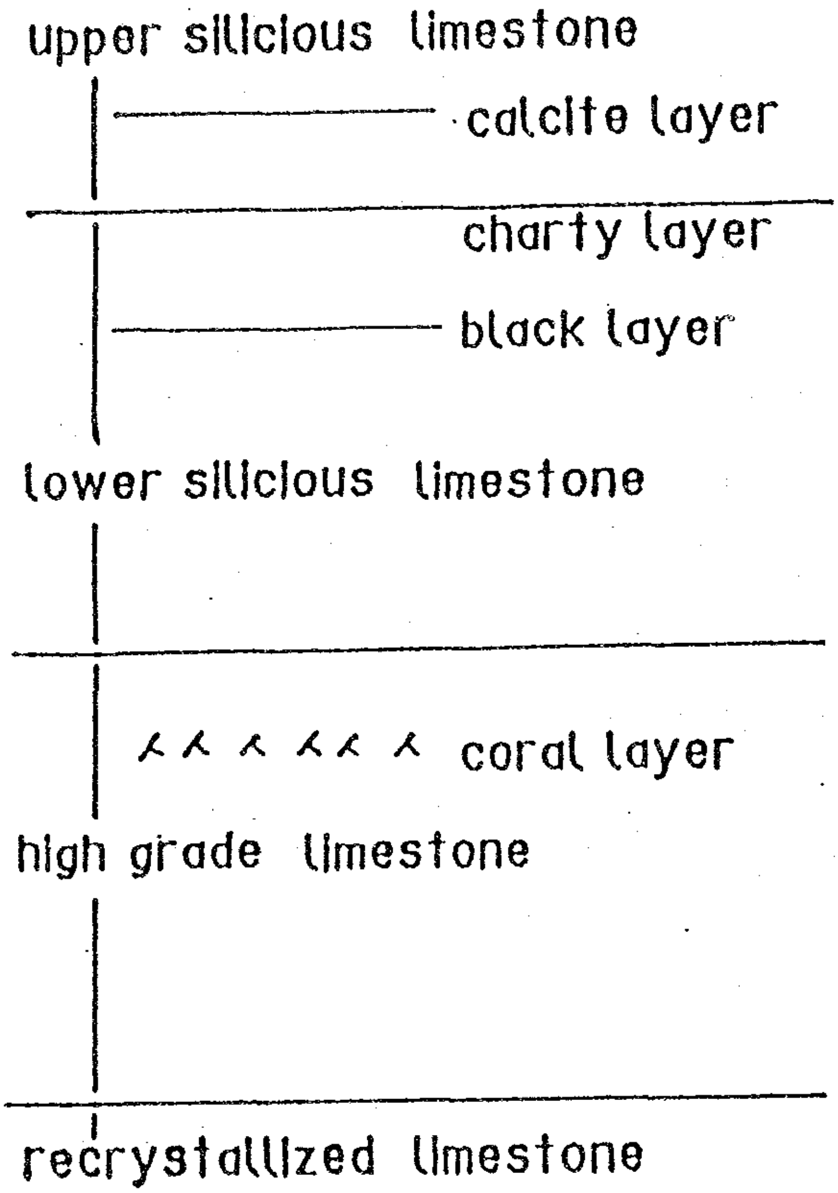
The order of the layers from bottom to top is;
recrystallized limestone, high grade limestone,
lower silicious limestone upper silicious limestone
Recrystallized limestone is not suitable as a raw material because of its high magnasium content.

2) Chemical Analysis of Drilling Core Samples

The sample for analysis was taken from one sample per every 5m of drilling and the chemical analysis result is shown in Table 6-1.

The CaO content of each sample is shown in Figure 6-5.

Figure 6-4 Stratigraphy of Limestone Area



No.	Sample No.	CHEMICAL COMPOSITION OF RAW MATERIAL (%) SiO2	TiO2	Al2O3	Fe2O3	MnO	MgO	CaO	K2O	Na2O	Ig-loss	P2O5	Cl⁻	SO3	Total
1	Ls1- 1	6.20	0.14	0.92	0.76	0.03	0.82	50.65	0.45	0.19	39.40	0.08	0.00	0.04	99.68
2	〃 - 2	3.05	0.08	0.90	0.79	0.02	3.34	49.35	0.30	0.03	41.65	0.09	0.00	0.06	99.66
3	〃 - 3	7.60	0.11	0.90	0.61	0.02	0.75	49.10	0.43	0.03	40.10	0.11	0.00	0.06	99.82
4	〃 - 4	15.05	0.17	1.34	0.79	0.02	0.81	44.15	0.98	0.04	36.30	0.13	0.00	0.05	99.83
5	〃 - 5	7.60	0.18	1.71	0.96	0.02	0.78	48.50	0.79	0.08	38.90	0.10	0.00	0.06	99.68
6	〃 - 6	7.80	0.03	0.67	0.68	0.02	0.74	49.65	0.56	0.20	39.30	0.13	0.00	0.04	99.82
7	〃 - 7	15.00	0.04	0.83	0.98	0.03	1.09	44.30	1.20	0.20	35.85	0.12	0.00	0.05	99.69
8	〃 - 8	9.00	0.12	1.37	0.72	0.03	0.70	48.50	0.60	0.07	38.45	0.12	0.00	0.06	99.74
9	〃 - 9	8.45	0.14	1.65	0.92	0.02	0.72	47.90	0.77	0.04	38.80	0.14	0.00	0.05	99.60
10	〃 -10	3.70	0.02	0.41	0.69	0.02	0.65	51.80	0.30	0.08	41.60	0.13	0.00	0.06	99.46
11	〃 -11	1.20	0.00	0.42	0.19	0.02	0.60	54.25	0.10	0.01	42.95	0.09	0.00	0.03	99.86
12	〃 -12	1.30	0.03	0.25	0.29	0.02	0.68	53.80	0.13	0.11	43.00	0.08	0.00	0.04	99.73
13	〃 -13	1.90	0.06	0.42	0.33	0.03	0.77	53.30	0.31	0.08	42.35	0.11	0.00	0.04	99.70
14	〃 -14	5.15	0.06	0.72	0.42	0.03	1.28	50.35	0.44	0.01	41.05	0.10	0.00	0.03	99.64
15	〃2- 1	7.65	0.09	1.30	0.67	0.02	0.95	49.30	0.59	0.01	38.95	0.09	0.00	0.07	99.69
16	〃 - 2	9.20	0.10	1.09	0.57	0.01	1.29	48.65	0.26	0.00	38.45	0.13	0.00	0.07	99.82
17	〃 - 3	5.80	0.06	0.81	0.48	0.02	0.65	51.45	0.46	0.01	39.80	0.10	0.00	0.06	99.70
18	〃 - 4	14.30	0.20	2.47	0.84	0.02	0.69	44.80	1.17	0.03	35.00	0.10	0.00	0.06	99.68
19	〃 - 5	14.75	0.21	2.88	0.95	0.02	0.82	43.40	1.02	0.05	35.40	0.09	0.00	0.04	99.63
20	〃 - 6	6.90	0.08	0.79	0.42	0.02	0.59	50.45	0.45	0.07	39.85	0.03	0.00	0.05	99.70
21	〃 - 7	12.00	0.20	2.38	0.82	0.03	1.35	44.40	0.94	0.02	37.50	0.07	0.00	0.04	99.75
22	〃 - 8	11.85	0.16	1.92	0.75	0.02	0.67	45.85	0.78	0.11	37.40	0.07	0.00	0.03	99.61
23	〃 - 9	5.80	0.08	0.91	0.41	0.02	0.54	51.45	0.54	0.02	40.00	0.05	0.00	0.04	99.86
24	〃 -10	1.50	0.04	0.30	0.43	0.02	0.56	54.20	0.10	0.00	42.50	0.05	0.00	0.09	99.79
25	〃 -11	1.25	0.06	0.51	0.27	0.02	0.50	54.00	0.09	0.01	42.85	0.11	0.00	0.04	99.71
26	〃 -12	1.40	0.01	0.21	0.22	0.02	0.80	53.75	0.16	0.10	42.95	0.07	0.00	0.05	99.74
27	〃 -13	3.45	0.04	0.31	0.35	0.03	0.38	53.25	0.37	0.02	41.30	0.07	0.00	0.06	99.63
28	〃3- 1	5.95	0.13	1.20	1.00	0.04	1.19	49.75	0.58	0.03	39.80	0.03	0.01	0.07	99.78
29	〃 - 2	7.50	0.19	1.16	1.03	0.02	5.12	44.15	0.62	0.03	39.80	0.03	0.01	0.06	99.72
30	〃 - 3	10.35	0.10	1.21	0.87	0.02	2.45	45.55	0.51	0.02	38.70	0.03	0.01	0.04	99.86
31	〃 - 4	10.65	0.16	1.33	0.81	0.01	0.83	47.30	0.52	0.02	38.00	0.04	0.01	0.05	99.73
32	〃 - 5	9.25	0.13	1.51	1.49	0.02	1.05	47.60	0.43	0.03	38.20	0.04	0.00	0.05	99.80
33	〃 - 6	9.10	0.00	0.50	0.59	0.02	0.99	48.90	0.28	0.01	39.20	0.03	0.00	0.03	99.65
34	〃 - 7	13.00	0.20	2.09	1.30	0.02	1.22	45.20	1.06	0.05	35.50	0.04	0.00	0.05	99.73
35	〃 - 8	10.30	0.15	1.80	1.35	0.02	0.83	46.85	0.85	0.06	37.50	0.04	0.00	0.08	99.83
36	〃 - 9	9.65	0.21	2.53	1.66	0.02	0.96	46.30	0.74	0.07	37.50	0.02	0.00	0.04	99.70
37	〃 -10	4.55	0.01	0.11	0.11	0.01	0.73	52.40	0.09	0.01	41.85	0.02	0.01	0.07	99.97
38	〃 -11	1.80	0.18	1.22	0.43	0.02	1.23	52.85	0.12	0.01	41.80	0.02	0.01	0.06	99.75
39	〃 -12	3.50	0.00	0.22	0.22	0.02	0.54	53.10	0.11	0.01	42.00	0.02	0.01	0.06	99.81
40	〃 -13	5.20	0.09	0.33	0.44	0.03	0.95	51.45	0.22	0.01	41.20	0.02	0.00	0.05	99.99
41	〃 -14	7.00	0.09	1.12	0.71	0.03	2.71	48.10	0.71	0.02	39.30	0.02	0.00	0.06	99.87
42	〃4- 1	10.00	0.00	1.63	1.11	0.02	2.59	46.25	0.95	0.03	37.10	0.03	0.01	0.12	99.84
43	〃 - 2	17.10	0.11	1.05	0.72	0.01	1.01	44.85	0.48	0.01	34.45	0.01	0.00	0.05	99.85
44	〃 - 3	9.60	0.07	1.12	0.57	0.01	1.14	48.05	0.42	0.01	38.70	0.02	0.01	0.07	99.79
45	〃 - 4	15.15	0.21	2.49	1.30	0.02	1.23	43.10	1.38	0.05	34.75	0.02	0.01	0.07	99.78
46	〃 - 5	12.25	0.11	1.71	1.10	0.02	0.94	46.30	0.89	0.04	36.85	0.47	0.01	0.06	100.75
47	〃 - 6	9.50	0.06	1.39	0.71	0.02	1.01	47.90	0.70	0.02	38.40	0.02	0.01	0.05	99.79
48	〃 - 7	10.50	0.15	1.59	0.88	0.01	0.94	46.85	0.83	0.02	37.80	0.10	0.00	0.05	99.72
49	〃 - 8	14.10	0.21	2.27	1.34	0.01	1.50	43.45	1.31	0.05	35.40	0.09	0.00	0.08	99.81
50	〃 - 9	6.65	0.08	1.02	0.60	0.01	0.97	49.85	0.50	0.03	39.95	0.03	0.00	0.05	99.74
51	〃 -10	3.65	0.00	0.36	0.19	0.01	1.15	51.90	0.12	0.02	42.15	0.02	0.00	0.06	99.63
52	〃 -11	1.90	0.00	0.26	0.50	0.01	0.96	54.00	0.11	0.02	41.95	0.02	0.00	0.07	99.80
53	〃 -12	2.20	0.20	0.14	0.17	0.02	0.63	53.25	0.16	0.03	42.80	0.08	0.01	0.06	99.75
54	〃 -13	5.95	0.10	0.71	0.49	0.03	2.74	49.25	0.44	0.02	39.90	0.02	0.01	0.04	99.70
55	〃5- 1	10.30	0.18	1.20	0.70	0.02	3.81	44.70	0.65	0.11	38.05	0.06	0.01	0.09	99.88
56	〃 - 2	11.60	0.19	1.42	0.59	0.02	1.12	48.20	0.44	0.03	36.20	0.07	0.01	0.05	99.94
57	〃 - 4	7.55	0.16	1.21	0.67	0.02	0.81	49.40	0.61	0.25	38.85	0.07	0.00	0.19	99.79
58	〃 - 5	12.30	0.21	1.79	1.25	0.03	0.88	45.90	0.81	0.60	35.45	0.08	0.01	0.68	99.99
59	〃 - 7	12.90	0.35	1.74	1.60	0.04	1.08	46.30	0.50	0.50	34.70	0.06	0.00	0.05	99.82
60	〃 - 8	9.50	0.54	1.62	3.14	0.04	1.49	45.55	0.16	0.39	37.35	0.07	0.00	0.10	99.95
	Σx	479.35	7.08	69.44	45.95	1.27	70.32	2,925.10	32.59	4.23	2,342.80	4.30	0.17	4.13	
	Σx/n	7.99	0.12	1.16	0.77	0.02	1.17	48.75	0.54	0.07	39.05	0.07	0.00	0.07	99.78
	σx(n-1)	4.2367	0.0932	0.6845	0.4820	0.0074	0.8557	3.2799	0.3316	0.1132	2.4460	0.0645	0.0045	0.0838	
	a(CaO)	66.6910	0.9175	9.5426	5.4899	0.0260	5.9545		4.5944	0.4410	6.0710	0.1472	0.0124	0.2259	
	b(〃)	-1.2041	-0.0164	-0.1720	-0.0969	-0.0001	-0.0981		-0.0831	-0.0076	0.6764	-0.0016	-0.0002	-0.0033	
	r(〃)	-0.9322	-0.5758	-0.8240	-0.6594	-0.0414	-0.3761		-0.8219	-0.2197	0.9069	-0.0802	-0.1226	-0.1302	

Table 6-1 Chemical analysis data of all limestone core

The correlation between CaO and other components are shown as follows.

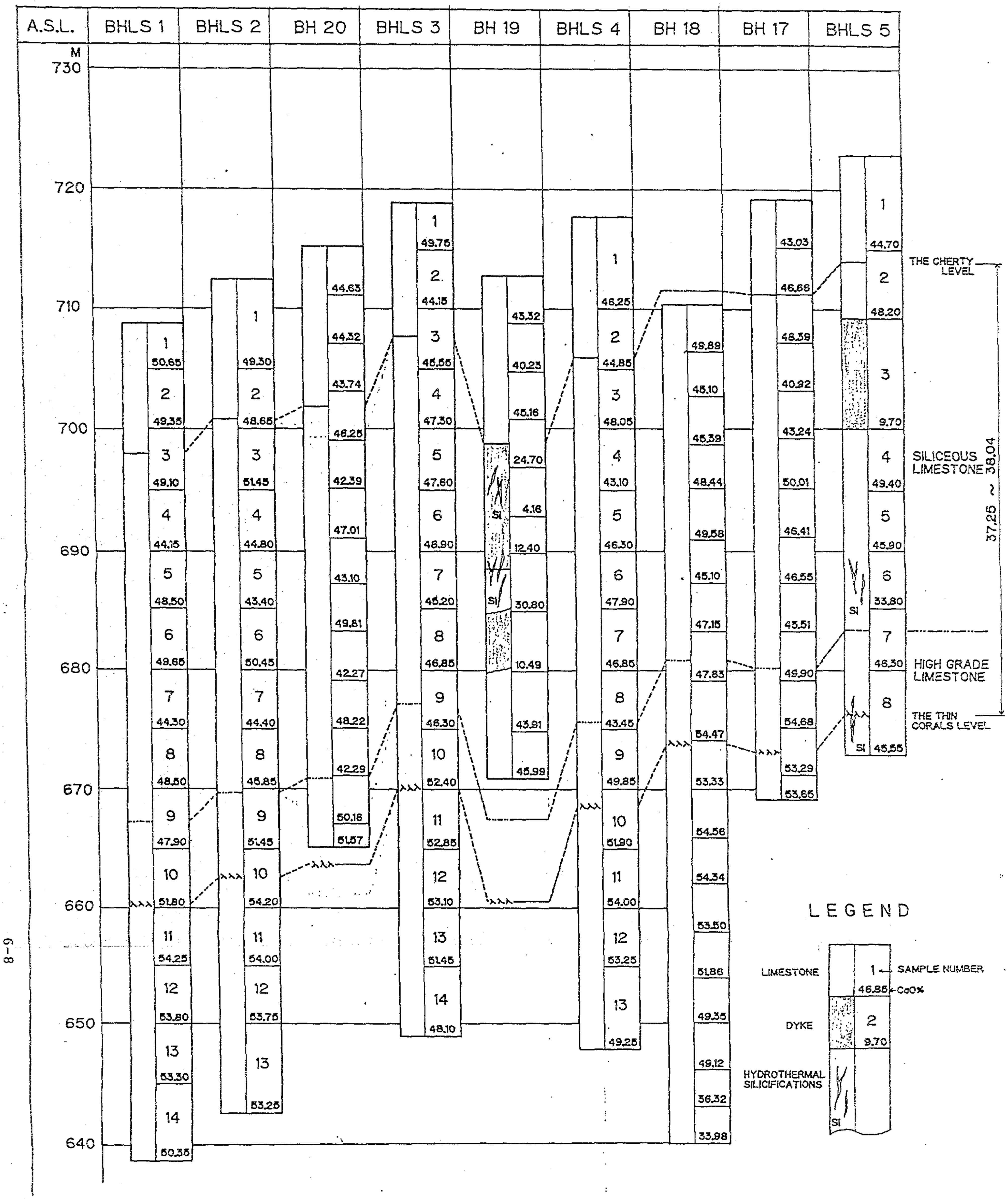
each component (%) = a + b × CaO

ex. $SiO_2 = 66.6910 - 1.2041 \times CaO$

$TiO_2 = 0.9175 - 0.0164 \times CaO$

Figure 6-5

BORE-HOLE LOGS and CaO CONTENT



3) Distribution of CaO Grade in the Limestone Deposit

Between two boring logs, the CaO content in layers a certain depth from the key bed are not similar. Therefore, it is assumed that the CaO content in a certain layer was not homogeneous when the layer was accumulated.

(Figure 6-5) can be rearranged along the surveyed elevation of the key bed (charty level). (refer to Table 6-2)

Since

- The layers accumulate horizontally
- The layers moved mainly in the vertical direction by faults
- The sample for chemical tests did not include the material polluted by dykes. (except LS-5)
- The elevation of the charty level in the whole area has been determined.

The distribution of the CaO content in the whole limestone area was estimated by the following procedure.

1) The whole area is divided into 13 x 25 grids (40mx40m).

2) The CaO content (all of a 5m thick average) at each inverse distance squared method.

3) The CaO content of the working face is estimated when the bench height is set at 15m.
By considering the elevation and the charty levels elevation, it is possible to obtain the average CaO (%) in each 15m thickness at every cross point of the grids.

Table 6-2 BORE-HOLE LOGS AND CaO CONTENT (Rearranged)

BOREHOLE No. = LS-1 — ELEVATION of BOREHOLE = 708.20 — ELEVATION of CHARTY LEVEL = 698.05

BOREHOLE ELEVATION (A.S.L.)	CaO CONTENT (%)	RELATIVE ELEVATION to CHARTY LEVEL	CaO CONTENT (%)
	50.65		
+705.00			50.21
	49.35	+703.05	
+700.00			49.25
	49.10	+698.05	
+695.00			47.18
	44.18	+693.05	
+690.00			45.86
	48.50	+688.05	
+685.00			48.95
	49.65	+683.05	
+680.00			47.56
	44.30	+678.05	
+675.00			45.94
	48.50	+673.05	
+670.00			48.27
	47.90	+668.05	
+665.00			49.42
	51.80	+663.05	
+660.00			52.76
	54.25	+658.05	
+655.00			54.07
	53.80	+653.05	
+650.00			53.61
	53.30	+648.05	
+645.00			52.15
+638.70	50.35	+643.05	

LS-2 — ELEVATION of BOREHOLE 712.50 — ELEVATION of CHARTY LEVEL 700.80

BOREHOLE ELEVATION (A.S.L.)	CaO CONTENT (%)	RELATIVE ELEVATION to CHARTY LEVEL	CaO CONTENT (%)
	49.30		49.30
+705.00		+705.80	
	48.65		48.75
+700.00		+700.80	
	51.45		51.00
+695.00		+695.80	
	44.80		45.86
+690.00		+690.80	
	43.40		43.62
+685.00		+685.80	
	50.45		49.32
+680.00		+680.80	
	44.40		45.37
+675.00		+675.80	
	45.85		45.62
+670.00		+670.80	
	51.45		50.55
+665.00		+665.80	
	54.20		53.76
+660.00		+660.80	
	54.00		54.03
+655.00		+655.80	
	53.75		53.79
+650.00		+650.80	
	53.25		53.30
+642.00		+642.30	

BH20 — ELEVATION of BOREHOLE 715.28 — ELEVATION of CHARTY LEVEL 701.90

BOREHOLE ELEVATION (A.S.L.)	CaO CONTENT (%)	RELATIVE ELEVATION to CHARTY LEVEL	CaO CONTENT (%)
+711.28	44.63		
	44.32		
+707.28			44.44
	43.74	+706.90	
+703.29			44.43
	46.25	+701.90	
+699.28			44.41
	42.39	+696.90	
+695.28			45.51
+691.28	47.01	+691.90	
	43.10		44.09
+687.28		+686.90	
+683.28	49.81		47.73
	42.27	+681.90	
+679.28			45.[illegible]
	48.22	+676.90	
+675.29			44.21
+671.28	42.29	+671.90	
	50.16		49.29
+667.28		+666.90	
+665.28	51.57		51.57

LS-3 — ELEVATION of BOREHOLE 718.90 — ELEVATION of CHARTY LEVEL 707.60

BOREHOLE ELEVATION (A.S.L.)	CaO CONTENT (%)	RELATIVE ELEVATION to CHARTY LEVEL	CaO CONTENT (%)
	49.75		
+715.00			47.62
	44.15	+712.60	
+710.00			44.34
	44.55	+707.60	
+705.00			45.87
	47.30	+702.60	
+700.00			47.44
	47.60	+697.60	
+695.00			48.22
	48.90	+692.60	
+690.00			47.12
	45.20	+687.60	
+685.00			45.99
	46.85	+682.60	
+680.00			46.59
	46.30	+677.60	
+675.00			49.23
	52.40	+672.60	
+670.00			52.62
	52.85	+667.60	
+665.00			52.97
	53.10	+662.60	
+660.00			52.31
	51.45	+657.60	
+655.00			49.84
+648.90	48.10	+652.60	

BH19 — ELEVATION of BOREHOLE 712.80 — ELEVATION of CHARTY LEVEL 698.80

BOREHOLE ELEVATION (A.S.L.)	CaO CONTENT (%)	RELATIVE ELEVATION to CHARTY LEVEL	CaO CONTENT (%)
	43.32		43.32
+708.80		+708.80	
	40.23		41.22
+704.80		+703.80	
+700.80	45.16		45.16
		+698.30	

LS-4 — ELEVATION of BOREHOLE 717.80 — ELEVATION of CHARTY LEVEL 705.95

BOREHOLE ELEVATION (A.S.L.)	CaO CONTENT (%)	RELATIVE ELEVATION to CHARTY LEVEL	CaO CONTENT (%)
			46.25
	46.25	+710.95	
+710.00			45.12
	44.85	+705.95	
+705.00			47.44
	48.05	+700.95	
+700.00			44.04
	43.10	+695.95	
+695.00			45.69
	46.30	+690.95	
+690.00			47.60
	47.90	+685.95	
+685.00			47.05
	46.85	+680.95	
+680.00			44.10
	43.45	+675.95	
+675.00			48.63
	49.85	+670.95	
+670.00			51.51
	51.90	+665.95	
+665.00			53.60
	54.00	+660.95	
+660.00			53.39
	53.25	+655.95	
+655.00			50.01
+650.00	49.25	+650.95	

BH18 — ELEVATION of BOREHOLE 710.43 — ELEVATION of CHARTY LEVEL 711.60

BOREHOLE ELEVATION (A.S.L.)	CaO CONTENT (%)	RELATIVE ELEVATION to CHARTY LEVEL	CaO CONTENT (%)
			49.89
	49.89	+706.60	
+706.43			45.23
+702.73	45.10	+701.60	
	45.10		45.22
+698.63		+696.60	
+695.03	45.39		47.46
	48.49	+691.60	
+690.83			48.95
+687.13	49.88	+686.60	
	45.10		45.72
+683.13		+681.60	
+679.03	47.15		50.66
	54.47	+676.60	
+674.13			53.89
	53.33	+671.60	
+670.03			54.20
+666.03	54.56	+666.60	
	54.34		54.30
+662.03		+661.60	
+658.03	53.50		53.00
+654.03	51.86	+656.60	

BH17 — ELEVATION of BOREHOLE 719.19 — ELEVATION of CHARTY LEVEL 713.00

BOREHOLE ELEVATION (A.S.L.)	CaO CONTENT (%)	RELATIVE ELEVATION to CHARTY LEVEL	CaO CONTENT (%)
	43.03		
+715.19			44.62
	46.66	+713.00	
+711.19			47.76
	48.39	+708.00	
+707.19			42.22
+703.19	40.98	+703.00	
	43.24		44.85
+699.19		+698.00	
	50.01		48.43
+695.19		+693.00	
+691.19	46.41		46.47
	46.55	+688.00	
+687.19			45.85
+683.19	45.51	+683.00	
	49.90		51.04
+679.19		+678.00	
	54.68		54.07
+675.19		+673.00	
	53.29		
+671.19			
	53.65		
+669.19			

← Charty Level

The values of the CaO contents were plotted on the maps, and isograde lines were drawn joining the plotted points, forming an ore grade map.
The CaO content in a 15m thickness is shown on the ore grade map.
(Figure 6-6, 6-7, 6-8, 6-9)

Figure 6-6 ORE GRADE MAP OF LIMESTONE AREA

(+709M)

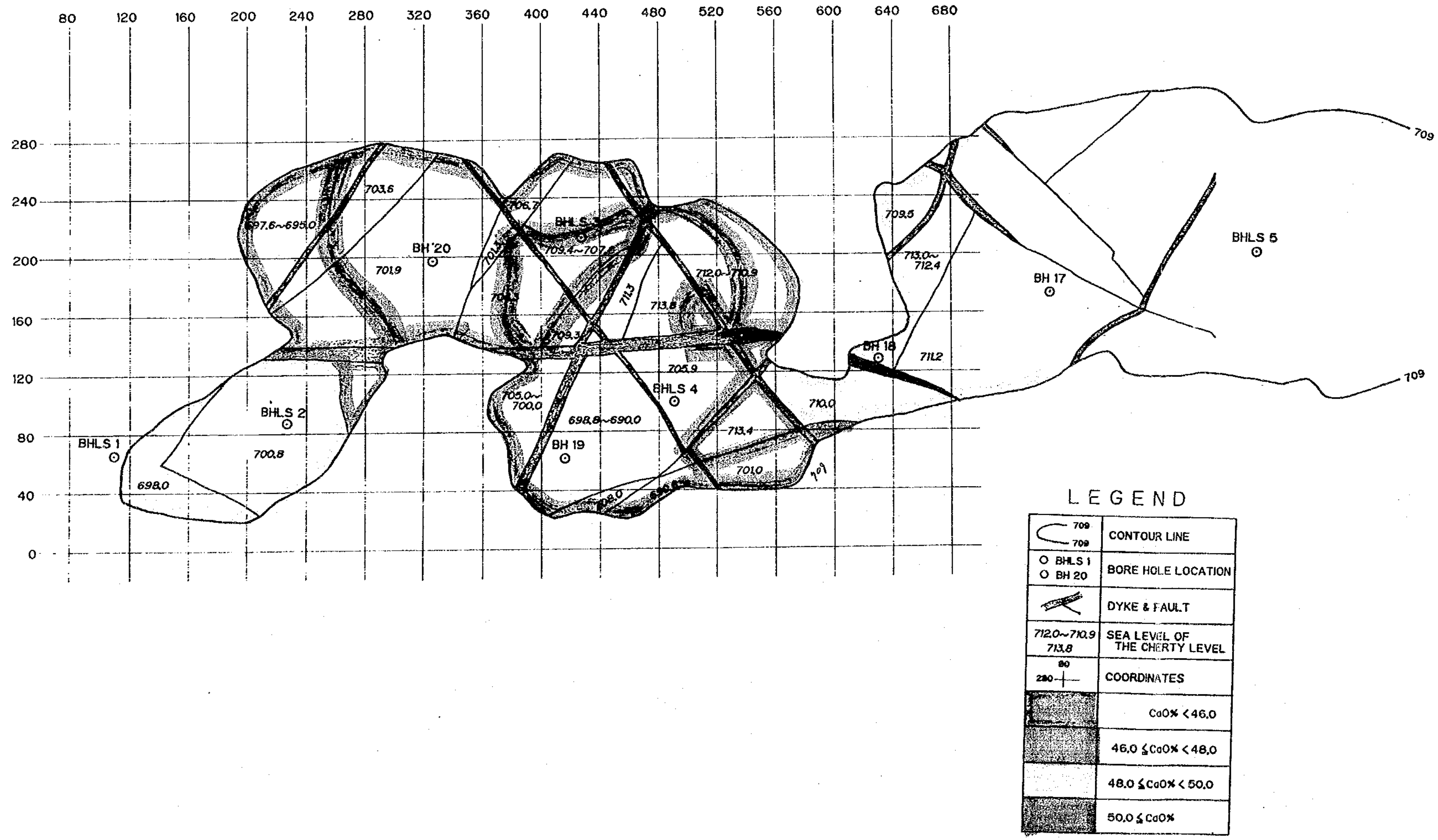


Figure 6-7 ORE GRADE MAP OF LIMESTONE AREA

(694M~709M)

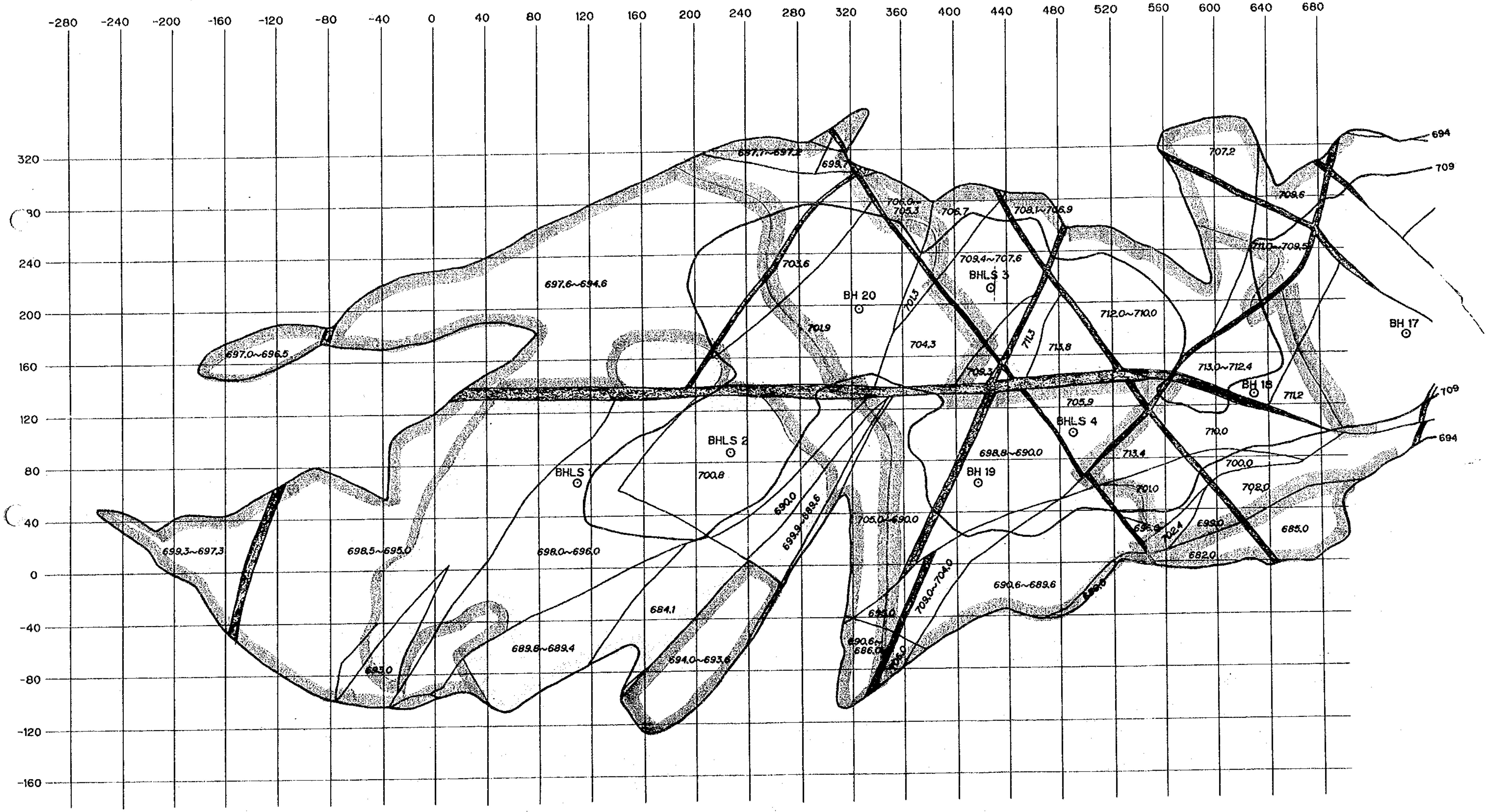


Figure 6-8 ORE GRADE MAP OF LIMESTONE AREA

(679M~694M)

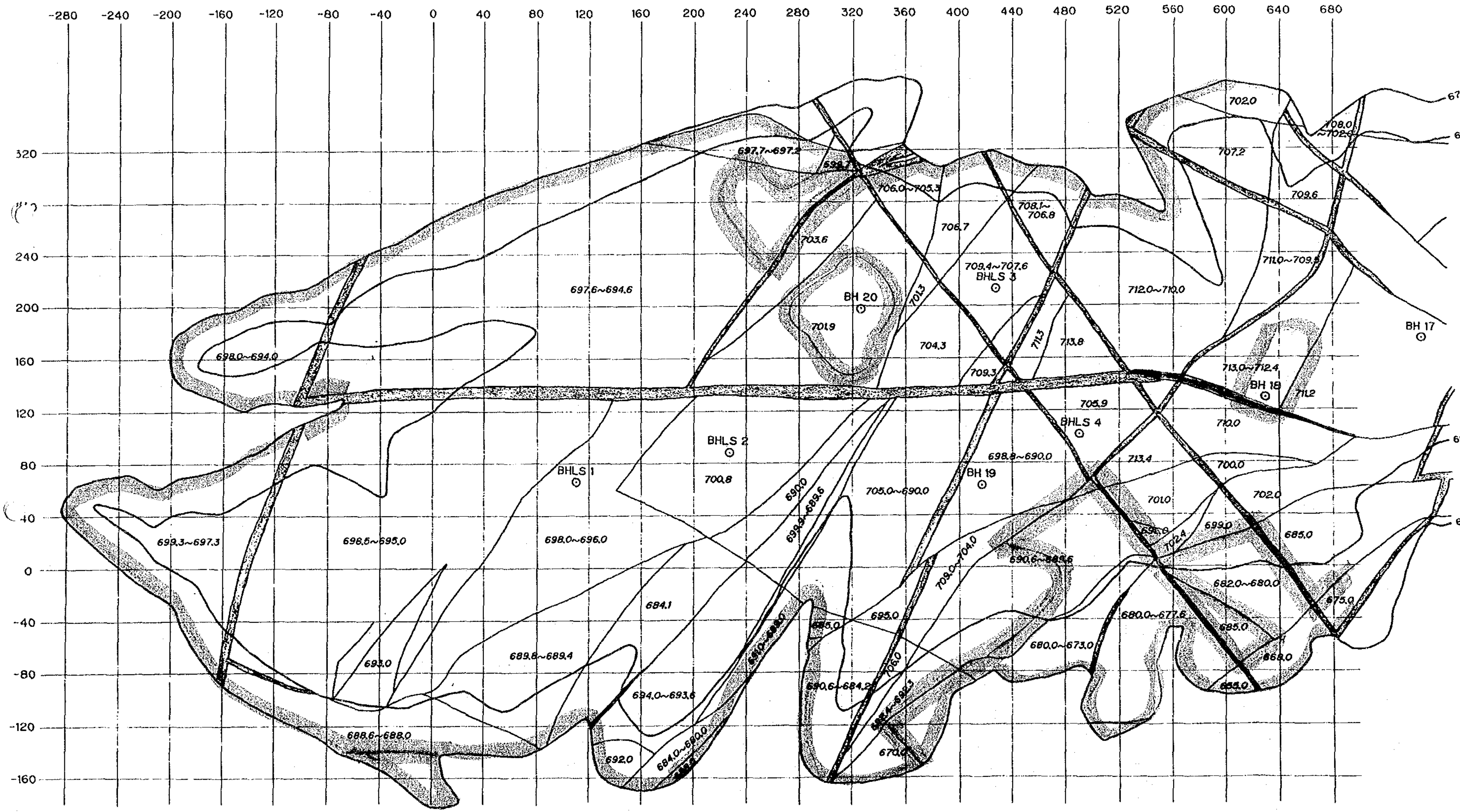
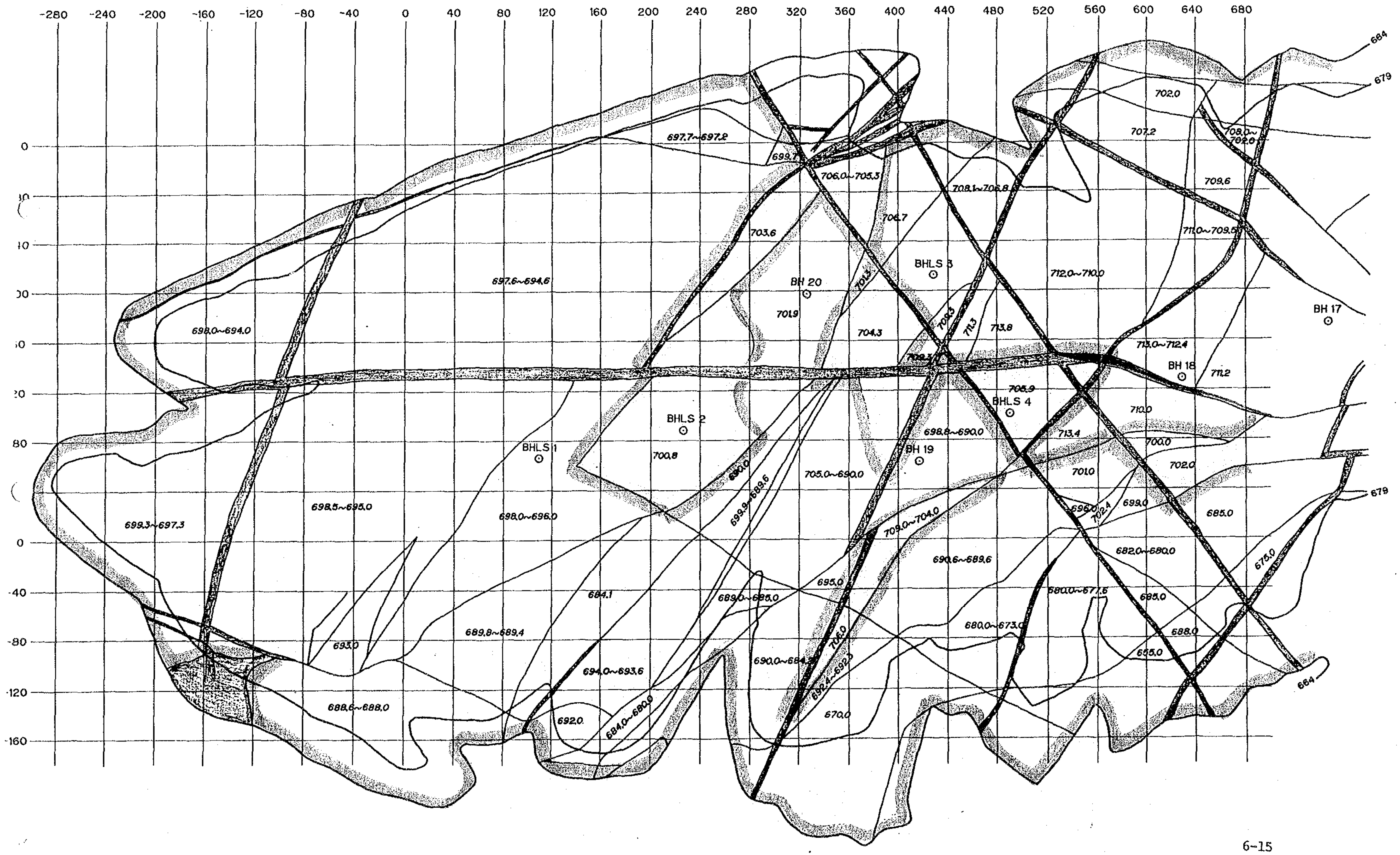


Figure 6-9 ORE GRADE MAP OF LIMESTONE AREA
(664M~679M)



4) Calculation of ore reserve

According to the square of each CaO grade shown on the ore grade map, the ore reserves in each grade was estimated by the following equation.

$$V = \frac{h}{3} \times (S_1 + S_2 + \sqrt{S_1 \times S_2})$$

$$W = V \times 2.7$$

S_1 = square of upper flat (m^2)

S_2 = square of lower flat (m^2)

h = the difference in heights between upper flat and the lower flat (m)

V = volume (m^3)

w = ore reserves (t)

2.7 = specific gravity (t/m^3)

The result of the calculation is shown on Table 6-3.

Table 6-3 ORE RESERVE OF LIMESTONE

Quantity to be quarried	CaO (%) <46	46≦ <48	48≦ <50	50≦	Total	CaO (%) <46	46≦ <48	48≦ <50	50≦	Total
	(m3)					※3 (×1000t)				
+709m	168,600	81,900	18,500	0	269,000	455	221	50	0	726
709～694	697,600	1,134,200	535,300	0	2,367,100	1,884	3,062	1,445	0	6,391
694～679	348,200	3,930,500	0	0	4,278,700	940	10,612	0	0	11,552
679～664	0	4,470,800	538,100	599,100	5,608,000	0	12,071	1,453	1,618	15,142
664～649	6,695,000				6,695,000	18,077				18,077
Total					19,217,800					51,888
※1 For Raw Material					17,296,020					46,699
※2 For Waste					1,921,780					5,189

※1: Total Quantity to be quarried × 90%.

※2: Total Quantity to be quarried × 10%.

※3: Specific Gravity of Limestone = 2.7 (t/m3).