6.1.2 Volcanic Rock Deposit

1) Geological Structure and Stratigraphy

The bed rock is basalt. It is covered with lava, agglomerate, tuff and allavium.
The southeast part of the volcanic rock quarry is separated by the fault.
Silt Sand and gravel are found in the area believed to have been a wadi in the Quarternary period. (Northen part of volcanic rock quarry and around Vr-2)
Refer to Figure 6-10.

2) Chemical Analysis of Drilling Core Samples

The result of the chemical analysis tests and the sampling locations are shown in Table 6-4, Table 6-5.

In the southeast part of the volcanic rock quarry area, the SiO_2 content is rather high.

In the whole area, it is assumed that tuff piles and breccia which are scattered on the surface (around Vr-2) include a lot of SiO_2.

Figure 6-10

GEOLOGICAL MAP OF VOLCANIC ROCK AREA

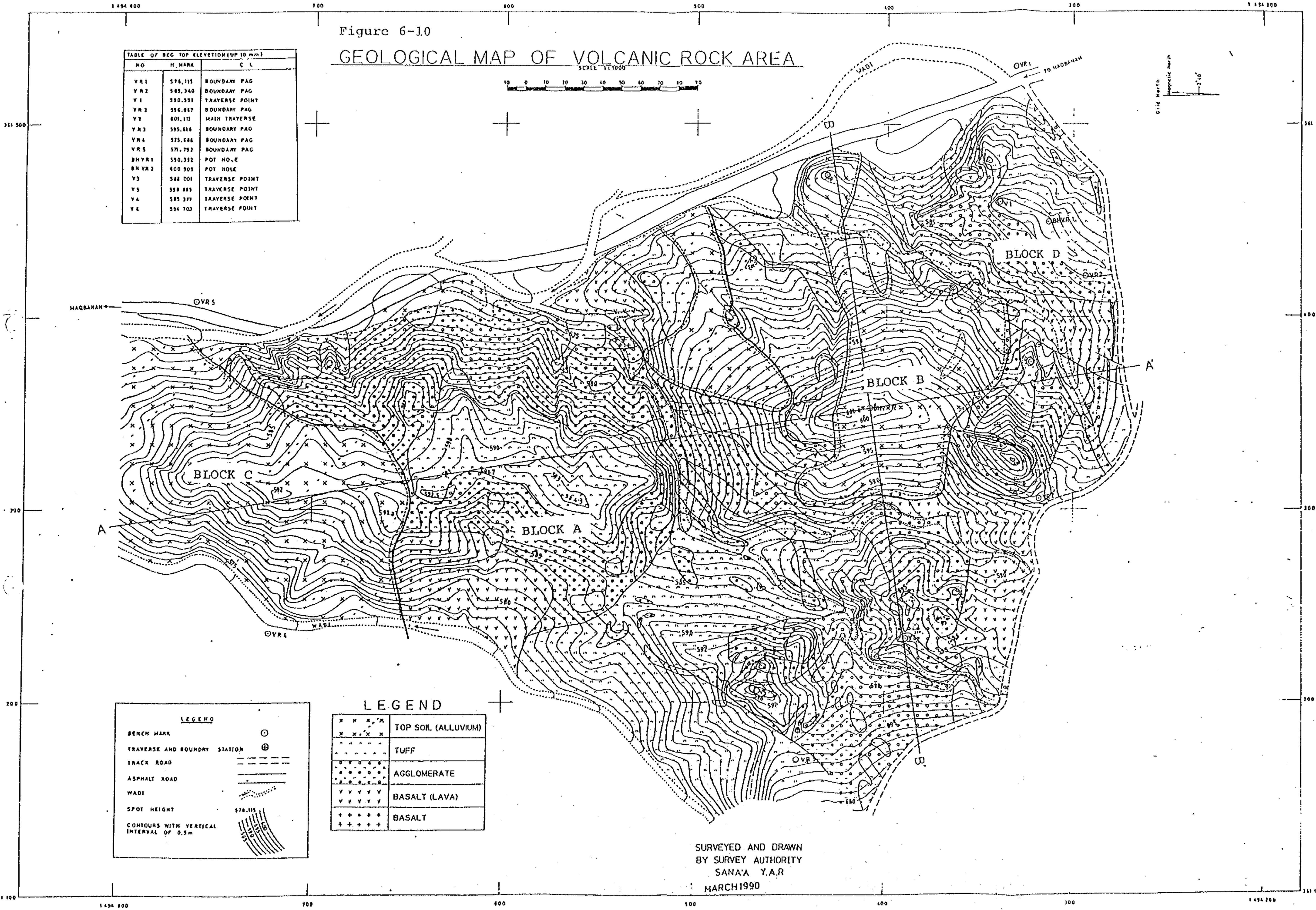


TABLE OF BEG TOP ELEVETION (UP 10 mm)		
NO	H. MARK	C L
VR1	578,115	BOUNDARY PAG
VR2	589,340	BOUNDARY PAG
V1	590.558	TRAVERSE POINT
VR2	556,967	BOUNDARY PAG
V2	601,113	MAIN TRAVERSE
VR3	595.616	BOUNDARY PAG
VR4	575,648	BOUNDARY PAG
VR5	571,792	BOUNDARY PAG
BHVR1	590,392	POT HOLE
BHVR2	600 909	POT HOLE
V3	568 001	TRAVERSE POINT
V5	598 895	TRAVERSE POINT
V4	585 377	TRAVERSE POINT
V6	554 703	TRAVERSE POINT

LEGEND

× × ×	TOP SOIL (ALLUVIUM)
^ ^ ^	TUFF
● ○ ●	AGGLOMERATE
V V V	BASALT (LAVA)
+ + +	BASALT

SURVEYED AND DRAWN
BY SURVEY AUTHORITY
SANA'A Y.A.R
MARCH 1990

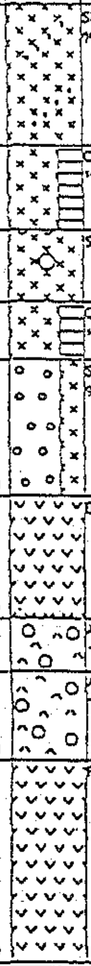
Vr−1

Table 6-4 Vr-1 Drilling log and chemical composition of each rock

Scale in m	Elevation in m	Depth in m	Thickness in m	Legend	Type of Rock	No.	SiO2	TiO2	Al2O3	Fe2O3	MnO	MgO	CaO	K2O	Na2O	Ig-loss	P2O5	Cl⁻	SO3	Total
	590.40	0.00																		
1 2 3	587.40	3.00	3.00	∴∴∴	Dacite tuff	Vr1- 1	67.10	3.11	11.45	0.92	0.19	2.32	5.80	0.84	2.18	5.13	0.60	0.01	0.03	99.68
4 5	585.00	5.40	2.40	○ ∴ ○	Agglomerate	〃 - 2	54.10	3.02	10.60	12.15	0.13	2.57	6.30	1.12	2.97	6.20	0.52	0.01	0.02	99.71
6 7 8	582.30	8.10	2.70	○ ∴ ○	Agglomerate	〃 - 3	48.00	3.04	12.40	11.75	0.19	3.65	8.30	0.27	2.09	9.65	0.42	0.01	0.01	99.78
9	580.80	9.60	1.50	∨∨∨∨	Basalt	〃 - 4	46.80	3.12	13.25	11.75	0.19	2.98	9.35	0.57	3.88	7.50	0.50	0.01	0.02	99.92
10 11 12 13	577.10	13.30	3.70	○ ∴ ○	Agglomerate	〃 - 5	53.15	2.69	10.00	11.15	0.13	2.49	8.20	0.56	2.75	8.25	0.48	0.01	0.06	99.92
14 15	575.40	15.00	1.70	∨∨∨∨	Basalt	〃 - 6	56.00	3.15	11.05	11.95	0.19	2.90	6.10	0.38	2.87	4.80	0.48	0.01	0.01	99.89
16 17	573.40	17.00	2.00	∨∨∨∨	Basalt	〃 - 7	48.80	2.05	12.45	12.00	0.10	2.72	7.90	1.11	4.17	7.90	0.55	0.00	0.02	99.77
18 19 20	570.40	20.00	3.00	∨∨∨∨	Basalt	〃 - 8	54.40	3.26	13.00	12.75	0.21	3.12	5.85	0.35	2.74	3.55	0.55	0.01	0.01	99.80

Vr-2

Table 6-5 Vr-2 Drilling log and chemical composition of each rock



Scale in m	Elevation in m	Depth in m	Thickness in m	Legend	Type of Rock	No.	SiO2	TiO2	Al2O3	Fe2O3	MnO	MgO	CaO	K2O	Na2O	Ig-loss	P2O5	Cl^-	SO3	Total
	600.90	0.00																		
1 2 3	597.90	3.00	3.00		Silt with gravel	Vr2- 1	49.10	2.75	12.60	9.65	0.10	3.05	7.60	2.51	2.89	8.95	0.40	0.05	0.17	99.82
4 5	596.10	4.80	1.80		Clayey silt	〃 - 2	45.70	2.92	12.35	11.15	0.10	3.78	7.30	2.66	1.95	11.30	0.36	0.06	0.20	99.83
6	594.60	6.30	1.50		Silt															
7	593.40	7.50	1.20		Clayey silt															
8 9 10	590.50	10.40	2.90		Silty gravel															
11 12 13	588.00	12.90	2.50		Basalt	〃 - 3	45.20	3.64	13.75	12.10	0.10	4.77	8.30	1.34	3.92	6.30	0.48	0.03	0.04	99.97
14	586.90	14.00	1.10		Agglo-merate	〃 - 4	43.20	3.53	13.35	13.10	0.16	4.44	8.05	1.51	4.19	7.95	0.40	0.02	0.01	99.91
15 16	585.00	15.90	1.90		Agglo-merate															
17 18 19 20	580.90	20.00	4.10		Basalt	〃 - 5	44.30	4.16	16.10	13.50	0.16	4.25	9.40	1.34	4.01	2.12	0.56	0.02	0.02	99.94
Surface Sample					Breccia		68.20	1.51	13.40	2.79	0.03	0.31	2.10	6.85	3.53	1.93	0.12	0.01	0.06	100.84
					Sand and gravel		47.30	1.81	11.43	6.29	0.19	3.07	16.60	2.45	2.07	10.20	0.30	0.02	0.02	101.75
					Silt		49.05	1.63	14.05	7.15	0.13	4.56	7.00	3.35	3.49	9.05	0.29	0.05	0.09	99.89

3) Ore Grade

The area was divided into two zones by fault.
The SiO_2 values of the most useful regions of each ignoious rock were assigned within each zone as shown in Table-4.

Table 6-6 SiO_2 content in each rock

rock	North west area of the fault	South east area of the fault
tuff	$SiO_2 = 67$	$SiO_2 = 67$
silt	$SiO_2 = 49$	----
agglomerate lava basalt	$44 = SiO_2 = 46$	$SiO_2 = 52$

The distribution of the rocks has already been determined and shown on the geological map.
Using Table 6-6 and the geological map, an ore grade map was constructed.

4) Calculation of Ore Reserve.

The result of the calculation is shown on Table 6-7.

Table 6-7 ORE RESERVE OF VOLCANIC ROCK

Quantity to be quarried	Block A	Block B		Block C	Block D	Total
	Si02 44~46%	44~46%	49%	49%	52%	
(m3)						
+595m	2,883	5,067	7,770			15,720
595~590	31,646	13,564	26,440			71,650
590~585	105,650	54,560	21,533	16,971	9,746	208,460
585~580	161,178	83,874	32,392	43,282	33,362	354,088
580~577			24,958			24,958
580~575	183,329	103,421		66,930	51,746	405,426
577~572		50,263				50,263
575~572	116,788	58,617		47,576	35,115	258,096
Total	601,474	369,366	113,093	174,759	129,969	1,388,661
For Raw Material	537,940	357,900	92,543	173,919	115,359	1,277,661
For Waste	63,534	11,466	20,550	840	14,610	111,000
※ (×1000ton)						
+595m	6.1	10.6	16.3			33.0
595~590	66.5	28.5	55.5			150.5
590~585	221.9	114.6	45.2	35.6	20.5	437.8
585~580	338.5	176.1	68.0	90.9	70.1	743.6
580~577			52.4			52.4
580~575	385.0	217.2		140.6	108.7	851.4
577~572		105.6				105.6
575~572	245.3	123.1		99.9	73.7	542.0
Total	1,263.1	775.7	237.5	367.0	272.9	2,916.2
For Raw Material	1,129.7	751.6	194.3	365.2	242.3	2,683.1
For Waste	133.4	24.1	43.2	1.8	30.7	233.1

※: Specific Gravity of Volcanic Rock = 2.1 (t/m3).

6.1.3 Sandstone Deposit

1) Geological Structure and Stratigraphy

There is basalt as a bed rock in the sandstone quarry area.
Yellowish and greenish tuff layers accumulate between the bed rock and the sandstone.

The relationship between tuff layers and sandstone layers is conformity.

The structure of this area is monocline, its dip is 20/-30/ E and its strike is N-S.

There is a big fault in the middle of the deposit and many thin dykes are to be found. (Figure 6-11)

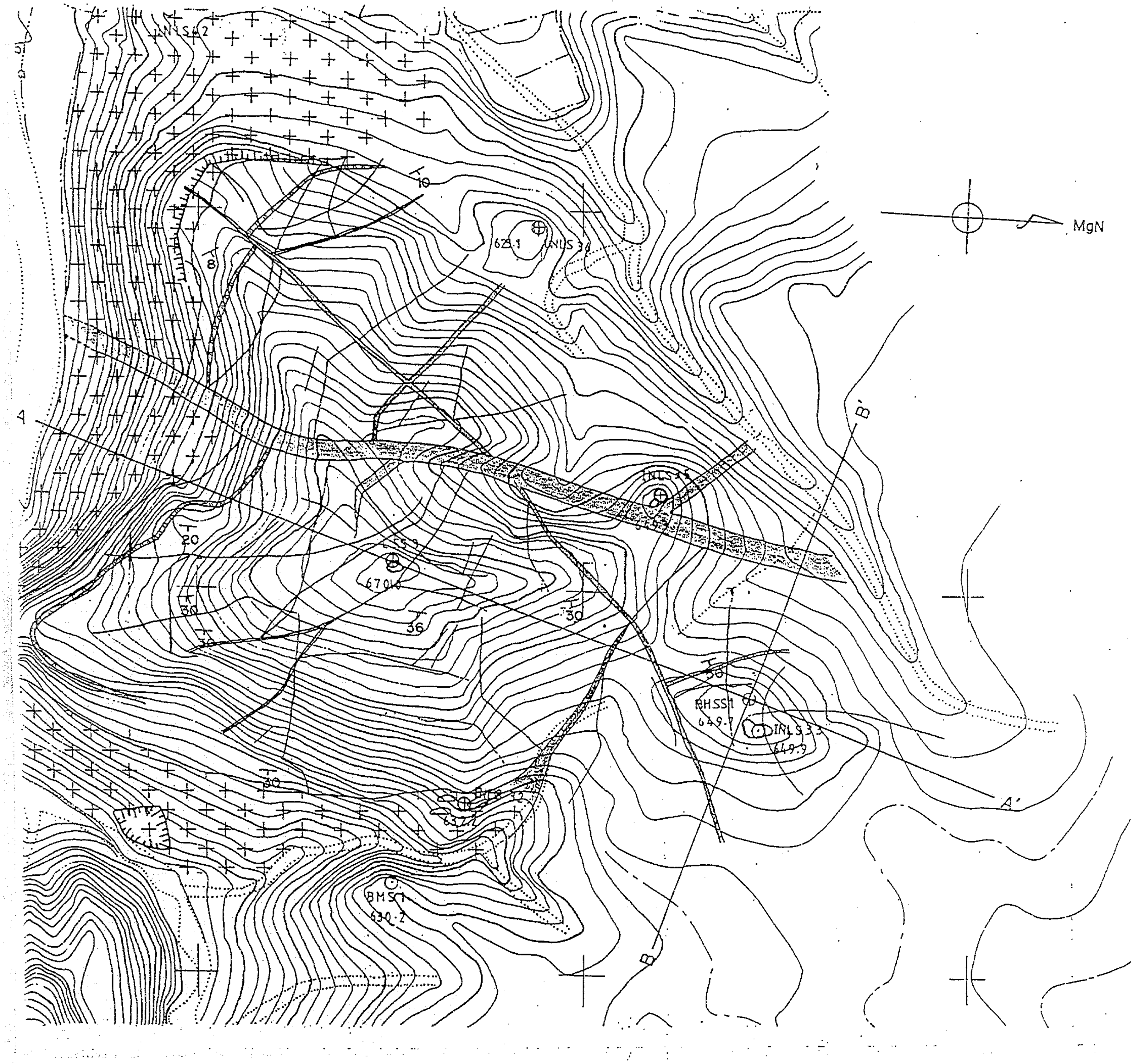
The sandstone deposits mainly consist of coarse sand. There are some thin tuff layers sandwiched in the sand stone.

2) Chemical Analysis of Drilling Core Samples

The results of the chemical analysis and sampling locations are shown in Table 6-8.

Figure 6-11

GEOLOGICAL MAP OF SANDSTONE AREA 1/2000

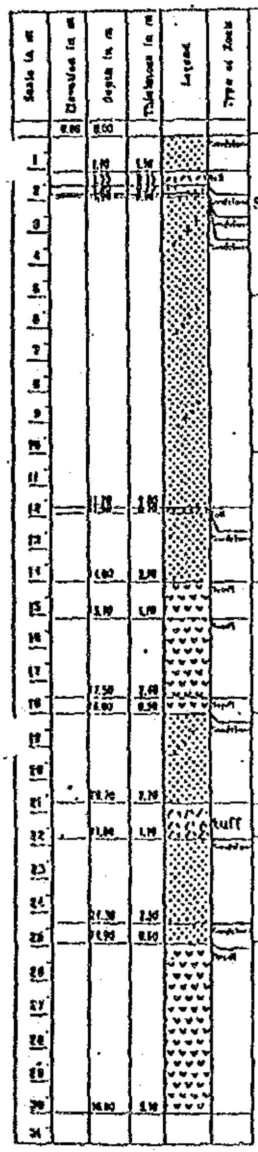


LEGEND

	SANDSTONE
	DYKE
+ + + + +	BASALT
	TUFF
30	DIP and STRIKE
BHSS 1 ⊕	BORE HOLE LOCATION

Table 6-8 Ss-1 Drilling Log and Chemical Composition of each Rock

Ss-1.



No.	SiO2	TiO2	Al2O3	Fe2O3	MnO	MgO	CaO	K2O	Na2O	Ig-loss	P2O5	Cl⁻	SO3	Total
Ss1- 1	91.60	0.25	2.41	1.39	0.02	0.34	0.75	0.94	0.19	1.20	0.09	0.01	0.62	99.8
〃 - 2	93.80	0.29	1.26	1.10	0.03	0.35	0.70	0.88	0.04	1.05	0.09	0.91	0.11	99.7
〃 - 3	90.15	0.32	2.50	1.17	0.04	0.34	1.25	1.15	0.07	1.75	0.15	0.01	0.81	99.7
〃 - 4	47.10	2.80	10.73	13.83	0.20	4.64	11.20	0.14	2.20	6.15	0.30	0.00	0.27	99.70
〃 - 5	93.00	0.25	1.61	0.87	0.04	0.32	1.30	0.57	0.05	1.35	0.07	0.00	0.47	99.77
〃 - 6	75.70	1.16	9.00	3.43	0.04	1.19	1.65	2.00	0.05	3.10	0.50	0.01	0.01	97.84
〃 - 7	88.55	0.40	1.64	5.80	0.03	0.34	1.15	0.44	0.02	1.20	0.07	0.00	0.17	99.8

3) Ore Grade

The quantity of SiO_2 in the Sandstone is approximately 90%.

It is assumed that the chemical composition is homogenous in the sandstone quarry except for in the tuffs and dykes (basalt).

Therefore, except for tuffs and dykes, the material existing in the sandstone quarry area is acceptable.

4) Calculation of Ore Reserve

The results of the calculations are shown on Table 6-9.

Table 6-9 Ore Reserve of Sandstone

Quantity to be quarried	Block A	Block B	Total	Block A	Block B	Total
(m)	(m3)			※ (×1000t)		
670～668	—	378	378	—	0.9	0.9
668～666	—	1,766	1,766	—	4.1	4.1
666～664	—	4,642	4,642	—	10.7	10.7
664～662	—	8,369	8,369	—	19.2	19.2
662～660	—	12,360	12,360	—	28.4	28.4
660～658	—	16,882	16,882	—	38.8	38.8
658～656	—	21,561	21,561	—	49.6	49.6
656～654	—	26,397	26,397	—	60.7	60.7
654～652	—	31,604	31,604	—	72.7	72.7
652～650	—	36,633	36,633	—	84.3	84.3
650～648	944	41,437	42,381	2.2	95.3	97.5
648～646	2,870	46,278	49,148	6.6	106.4	113.0
646～644	4,973	51,220	56,193	11.4	117.8	129.2
644～642	7,950	56,468	64,418	18.3	129.9	148.2
642～640	12,870	61,822	74,692	29.6	142.2	171.8
640～638	19,951	67,043	86,994	45.9	154.2	200.1
Total	49,558	484,860	534,418	114.0	1,115.2	1,229.2

※: Specific Gravity of Sandstone = 2.3 (t/m3).

6.1.4 The Design for Raw Material Proportioning

1) The Value of The Chemical Composition for Proportioning.

Limestone

Considering the amount of ore reserve, the siliceous limestone will be supplied for more than 10 years from the commencement of the quarry operation where 2 lines are operated.
Therefore high grade limestone shall not be considered herein.
The results of the chemical analysis except for LS-5-3 and LS-5-6 which are polluted by dikes, and the relation between CaO and other components are shown on Table 6-10.

Volcanic rock

Since it is presumed that SM in clinker will be increased by using high SiO_2 material in the volcanic rock quarry, Block C and D are not suitable as raw material when the siliceous limestone is used for CaO reserves.
The chemical composition of the bottom part of Vr-2 (depth 10.4-20m) is shown on Table 6-11.

Sandstone

The result of the chemical analysis except for SS-4 and SS-6 is shown on Table 6-12.

No.	Sample No.	CHEMICAL COMPOSITION OF RAW MATERIAL (%)													
		Si02	Ti02	Al203	Fe203	MnO.	MgO	CaO	K20	Na20	Ig-loss	P205	Cl^-	S03	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	〃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
11	〃 - 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
12	〃 - 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
13	〃 - 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
14	〃 - 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
15	〃 - 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
16	〃 - 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
17	〃 - 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
18	〃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
19	〃 - 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
20	〃 - 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
21	〃 - 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
22	〃 - 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
23	〃 - 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
24	〃 - 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
25	〃 - 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
26	〃 - 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
27	〃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
28	〃 - 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
29	〃 - 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
30	〃 - 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
31	〃 - 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
32	〃 - 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
33	〃 - 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
34	〃 - 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
35	〃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
36	〃 - 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
37	〃 - 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
38	〃 - 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
39	〃 - 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
40	〃 - 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		410.30	5.93	59.49	38.49	0.85	50.95	1,878.80	27.47	3.61	1,509.35	3.17	0.12	3.07	
Σx/n		10.26	0.15	1.49	0.96	0.02	1.27	46.97	0.69	0.09	37.73	0.08	0.00	0.08	99.79
σx(n-1)		3.0722	0.0937	0.5647	0.4675	0.0076	0.9327	2.2296	0.2937	0.1328	1.7656	0.0736	0.0046	0.1016	
a(CaO)		63.0095	0.9655	9.0870	4.8326	0.0119	6.9383		4.7684	0.2828	10.1201	0.0212	0.0112	0.1304	
b(〃)		-1.1231	-0.0174	-0.1618	-0.0824	0.0002	-0.1206		-0.0869	-0.0041	0.5879	0.0010	-0.0003	-0.0026	
r(〃)		-0.8151	-0.4149	-0.6388	-0.3932	0.0448	-0.2883		-0.6597	-0.0685	0.7424	0.0296	-0.1608	-0.0576	

Table 6-10 Chemical analysis data of silicious limestone

Table 6-11 Chemical Composition of bottom part of Vr-2

	Sample	CHEMICAL COMPOSITION OF RAW MATERIAL (%)													
No.	No.	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	K_2O	Na_2O	Ig-loss	P_2O_5	Cl^-	SO_3	Total
1	Vr2- 3	45.20	3.64	13.75	12.10	0.10	4.77	8.30	1.34	3.92	6.30	0.48	0.03	0.04	99.97
2	〃 - 4	43.20	3.53	13.35	13.10	0.16	4.44	8.05	1.51	4.19	7.95	0.40	0.02	0.01	99.91
3	〃 - 5	44.30	4.16	16.10	13.50	0.16	4.25	9.40	1.34	4.01	2.12	0.56	0.02	0.02	99.94
Σx		132.70	11.33	43.20	38.70	0.42	13.46	25.75	4.19	12.12	16.37	1.44	0.07	0.07	
$\Sigma x/n$		44.23	3.78	14.40	12.90	0.14	4.49	8.58	1.40	4.04	5.46	0.48	0.02	0.02	99.94
$\sigma x(n-1)$		1.0017	0.3365	1.4858	0.7211	0.0346	0.2631	0.7182	0.0981	0.1375	3.0051	0.0800	0.0058	0.0153	

Table 6-12　Chemical Composition of Ss-1

	Sample	CHEMICAL COMPOSITION OF RAW MATERIAL (%)													
No.	No.	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	K_2O	Na_2O	Ig-loss	P_2O_5	Cl^-	SO_3	Total
1	Ss1- 1	91.60	0.25	2.41	1.39	0.02	0.34	0.75	0.94	0.19	1.20	0.09	0.01	0.62	99.81
2	〃 - 2	93.80	0.29	1.26	1.10	0.03	0.35	0.70	0.88	0.04	1.05	0.09	0.01	0.11	99.71
3	〃 - 3	90.15	0.32	2.50	1.17	0.04	0.34	1.25	1.15	0.07	1.75	0.15	0.01	0.81	99.71
4	〃 - 5	93.00	0.25	1.61	0.82	0.04	0.32	1.30	0.57	0.05	1.35	0.02	0.00	0.42	99.75
5	〃 - 7	88.55	0.48	1.64	5.86	0.03	0.34	1.15	0.44	0.02	1.20	0.02	0.00	0.12	99.85
Σx		457.10	1.59	9.42	10.34	0.16	1.69	5.15	3.98	0.37	6.55	0.37	0.03	2.08	
$\Sigma x/n$		91.42	0.32	1.88	2.07	0.03	0.34	1.03	0.80	0.07	1.31	0.07	0.01	0.42	99.77
$\sigma x(n-1)$		2.1239	0.0952	0.5432	2.1295	0.0084	0.0110	0.2842	0.2876	0.0673	0.2679	0.0550	0.0055	0.3075	

2) Raw Material Proportioning

Since silicious limestone includes a great deal of SiO_2, lower SiO_2 volcanic rock is required to avoid increasing S.M. in clinker.

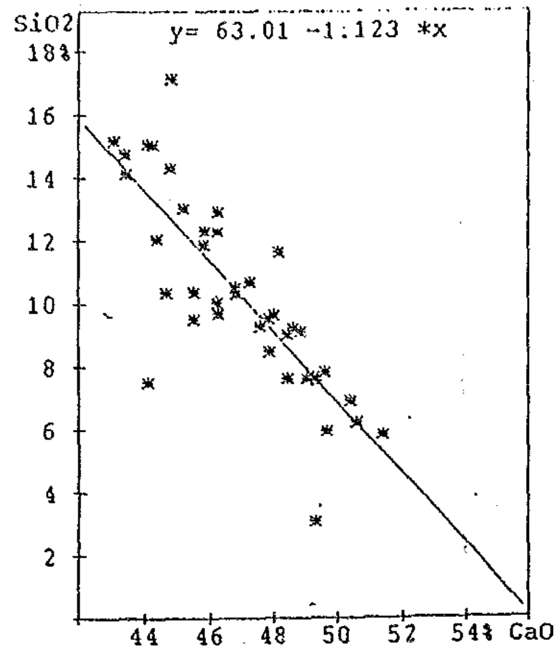
Table 6-13 indicates the proportion, theoretical consumption unit of raw materials, chemical composition, moduli and mineral phases of clinker produced by using silicious limestone, volcanic rock (SiO_2=44.23%) and sandstone where L.S.F is adjusted at 91.

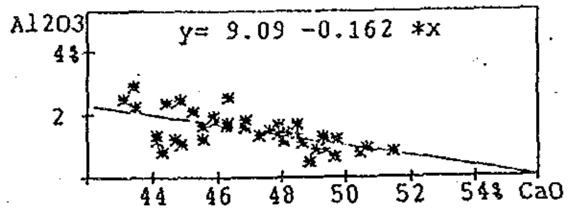
3) Conclusion of Raw Material Proportioning

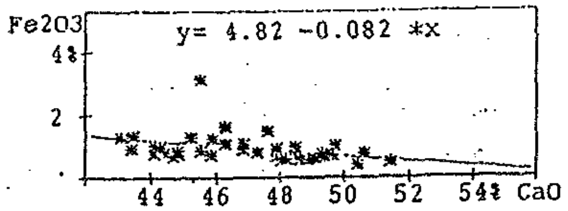
a) The target value of the CaO content of limestone to be transported to the mixed bed should be more than 46%.

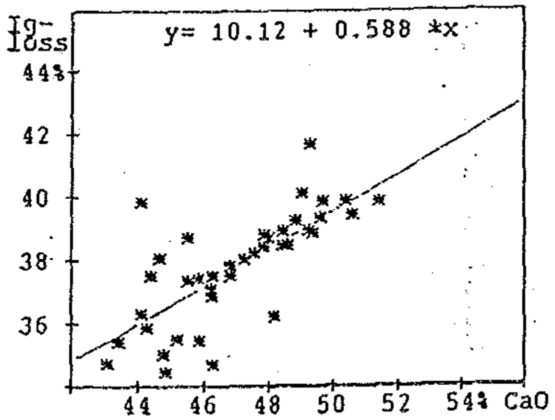
b) As long as silicious limestone is supplied as a CaO resource, lower SiO_2 volcanic rock is required.

c) It is difficult to adjust I.M. (Al_2O_3/Fe_2O_3) within the normal range without using the raw material that includs high alumina. However, it is reported that a high alumina resource with enough quantity was not found near Mafraq plant.









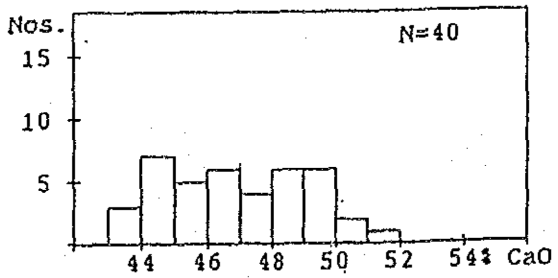


Table 6-13 Mixing Ratio of raw materials

	CHEMICAL COMPOSITION OF RAW MATERIAL (%)										
	SiO2	TiO2	Al2O3	Fe2O3	MnO	MgO	CaO	K2O	Na2O	Ig-loss	Total
Silicious LIME -STONE	14.72	0.22	2.13	1.29	0.02	1.75	43.00	1.03	0.11	35.40	99.67
	13.59	0.20	1.97	1.21	0.02	1.63	44.00	0.94	0.10	35.99	99.65
	12.47	0.18	1.81	1.12	0.02	1.51	45.00	0.86	0.10	36.58	99.65
	11.35	0.17	1.64	1.04	0.02	1.39	46.00	0.77	0.09	37.16	99.63
	10.22	0.15	1.48	0.96	0.02	1.27	47.00	0.68	0.09	37.75	99.62
	9.10	0.13	1.32	0.88	0.02	1.15	48.00	0.60	0.09	38.34	99.63
	7.98	0.11	1.16	0.80	0.02	1.03	49.00	0.51	0.08	38.93	99.62
	6.85	0.10	1.00	0.71	0.02	0.91	50.00	0.42	0.08	39.52	99.61
	5.73	0.08	0.84	0.63	0.02	0.79	51.00	0.34	0.07	40.10	99.60
VOLCANIC ROCK (n= 3)	44.23	3.78	14.40	12.90	0.14	4.49	8.58	1.40	4.04	5.46	99.42
SAND -STONE	91.42	0.32	1.88	2.07	0.03	0.34	1.03	0.80	0.07	1.31	99.27

Limestone : Chemical composition of silicious limestone which is estimated by using correlation between CaO and other components.

Volcanic rock and sandstone;
Volcanic rock : Average chemical composition of Vr2-3, Vr2-4 and Vr2-5.

Proportion, consumption unit (dry condition), chemical composition of clinker, clinker moduli, mineral phases are estimated when L.S.F. is adjusted at approx. 91.

CaO in	PROPORTION (%)			CONSUMPTION UNIT (t/cl't)				CHEMICAL COMPOSITION OF CLINKER (%)										CLINKER MODULI				MINERAL PHASES			
LIMESTONE	L.S.	V.R.	S.S.	L.S.	V.R.	S.S.	Total	SiO2	TiO2	Al2O3	Fe2O3	MnO	MgO	CaO	K2O	Na2O	Total	H.M.	L.S.F.	S.M.	I.M.	C3S	C2S	C3A	C4AF
43%	98.11	1.89	0.00	1.506	0.029	0.000	1.535	23.45	0.44	3.63	2.32	0.03	2.77	65.01	1.59	0.28	99.52	2.21	90.9	3.94	1.56	58.7	22.9	5.7	7.1
44	95.16	4.84	0.00	1.453	0.074	0.000	1.527	23.02	0.57	3.93	2.71	0.04	2.70	64.57	1.47	0.44	99.45	2.18	91.0	3.47	1.45	57.6	22.5	5.8	8.2
45	92.31	7.69	0.00	1.402	0.117	0.000	1.519	22.66	0.69	4.22	3.08	0.04	2.64	64.09	1.37	0.61	99.40	2.14	90.9	3.10	1.37	55.9	22.8	6.0	9.4
46	89.66	10.34	0.00	1.356	0.156	0.000	1.512	22.29	0.82	4.47	3.42	0.05	2.59	63.71	1.26	0.75	99.36	2.11	91.0	2.83	1.31	55.0	22.4	6.1	10.4
47	87.22	12.74	0.04	1.314	0.192	0.001	1.507	22.01	0.92	4.71	3.74	0.05	2.53	63.41	1.16	0.89	99.42	2.08	91.0	2.60	1.26	53.9	22.5	6.2	11.4
48	85.48	13.59	0.93	1.286	0.204	0.014	1.504	22.01	0.94	4.66	3.79	0.05	2.40	63.49	1.07	0.94	99.35	2.08	91.1	2.60	1.23	54.5	22.0	5.9	11.5
49	83.82	14.41	1.77	1.259	0.216	0.027	1.502	22.07	0.96	4.62	3.85	0.06	2.28	63.57	0.97	0.98	99.36	2.08	91.0	2.61	1.20	54.5	22.1	5.7	11.7
50	82.18	15.23	2.59	1.233	0.228	0.039	1.500	22.10	1.00	4.59	3.90	0.06	2.16	63.65	0.87	1.02	99.35	2.08	91.0	2.60	1.18	54.7	22.1	5.6	11.9
51	80.64	15.99	3.37	1.208	0.240	0.050	1.498	22.11	1.02	4.56	3.96	0.06	2.05	63.72	0.79	1.06	99.33	2.08	91.1	2.60	1.15	55.1	21.8	5.4	12.1

(※1)

(※1) L.S.F. = 100*CaO/(2.8*SiO2+1.2*Al2O3+0.65*Fe2O3)

6.1.5 Acquisition of Raw Materials

1) Annual Consumption Amount of Each Raw Material

Assuming that the CaO content of limestone supplied to the mix bed is 46%, the mixing ratio and consumption unit are shown on Table 6-14.

Table 6-14 The mixing ratio and consumption unit of raw materials

Raw material	Mixing ratio	Consumption unit	Annual consumption amount for 2 line operation
Limestone	89.66%	1.409	1,409,000 t
Volcanic rock	10.34%	0.163	163,000 t
Sandstone	0.00%	0.000	very small quantity
Total	100.00%	1.572	-

* Mixing ratio is estimated where L.S.F is adjusted at 91%. Theoretical total consumption unit is 1.512. Considering dust loss (0.03), by-pass loss (0.03), the actual total consumption unit without including moisture is estimated as 1.572.

2) Life of Each Raw Material Resource

Comparing the confirmed amount of ore reserves with the annual consumption amount, the life of each raw material resource is estimated.
The result is shown on Table 6-15.

Table 6-15 The life of each raw materials

Raw material	Confirmed amount of ore reserves	Annual consumption amount for 2 line	Life of each raw material
	approximately(t)	(t/Y)	(Y)
Limestone	47,000,000	1,409,000	33.4
Volcanic	1,900,000	163,000	11.7
Sandstone	1,200,000	very small quantity	-

3) Countermeasure for Acquisition of Raw Materials

Limestone

There is enough limestone for a 2 line operation if the mining area next to the south side of the trench is exploited.

The confirmed ore reserves of limestone (47 m.t) is estimated inside northern area of the trench.

It is desirable to exploit the working face to the south after the north side working floor reaches the high grade limestone level. And the limestone from the south side should be transported to the mix bed with high grade limestone included as a certain proportion because the CaO content of limestone located in the south side is rather low.

Volcanic rock

In case of an ore reserves shortage due to a 2 line operation, it is necessary to exploit the working face to the outside of the planning area for a 1 line operation.

There is enough volcanic rock along Maqbanah road. Therefore the working face to be exploited is toward the north next to the planning area.

The chemical composition of volcanic rock which are taken as samples during this investigation next to the planning aea is shown in Table 6-16.

Table 6-16 The chemical composition of volcanic rock

No.1	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	K_2O	Na_2O	Ig-loss	P_2O_5	Cl-	SO_3	Total
1	48.71	3.11	12.68	11.51	0.17	3.22	7.41	1.62	2.80	5.88	0.54	<0.01	0.02	97.68
2	45.23	3.17	12.91	13.52	0.18	3.53	9.23	1.53	2.66	6.32	0.55	0.01	0.01	98.85
3	43.02	3.08	12.52	16.22	0.17	3.84	10.89	1.41	2.72	4.38	0.53	0.01	0.03	98.82
4	44.21	3.28	13.37	15.93	0.18	4.08	9.12	1.36	2.69	4.16	0.57	<0.01	0.01	98.97
5	45.06	3.51	14.29	15.21	0.20	4.52	8.37	1.16	2.80	3.43	0.60	0.01	0.02	99.18
6	43.21	3.34	13.60	15.46	0.19	3.76	9.14	1.22	2.56	4.84	0.58	0.01	0.01	97.92
7	40.18	2.91	11.83	15.12	0.16	2.74	11.77	1.00	2.38	8.87	0.50	0.01	0.02	97.49
8	44.34	3.06	12.44	14.83	0.17	3.21	8.34	1.11	2.50	6.31	0.53	0.01	0.01	97.96
9	48.81	3.23	13.14	12.87	0.18	3.14	5.68	2.83	2.80	4.62	0.56	0.01	0.01	97.88
10	48.56	3.02	12.29	11.42	0.17	3.07	7.53	2.16	3.09	5.32	0.52	<0.01	0.01	97.17
av.	45.13	3.17	12.91	14.21	0.19	3.51	8.80	1.60	2.70	5.41	0.55	0.01	0.02	98.21

Sandstone

It is assumed that there is enough sandstone for a 2 line operation because of its small consumption unit.

Therefore, there is enough ore reserves for 2 line operation.

6.2 Water Supply

6.2.1 Problems with Water Sources

The valley bottom plain of Wadi Risyan and Wadi Ar Rub is the most developed agricultural area in this region. Squall rainfall and high evaporation rates are characteristic of Yemen, therefore, supply of irrigation water is necessary even during the rainy season. Many traditional, hand-dug wells are constructed in the alluvium of Wadis, so that the idea of vested water rights is especially strong.

The social problems related to political water rights are not touched upon in this chapter, which examines problems related to the natural environment.

The aquifer in this area is thin at 10m to 20m, with a shallow depth within 45m. Therefore, there is a strong relationship between the amount of shallow layer groundwater and rainfall. Vertical correlation is clearly shown by the few unit hours. Horizontally the distance from the origin of the Wadi is several tens of kilometers, however the distance is divided along the way, generally, making the unit of a few weeks to several months. Generally speaking, it is a short cycle, and in this way the strong correlation with rainfall shows a sensitive reaction to seasonal and yearly changes.

Weather characteristics of Kudeiha of Wadi Risyan and Zabid on the Tihamah coast are shown in Figure 6-17. Total precipitation is small at 200mm, furthermore, it is divided into the former rainy season (March to May) and the latter rainy season (July to October). Only 5 months receive precipitation over 10mm, and the days of rain per month can be divided into 5 days and 10 days. From these figures precipitation per day is 2mm to 4mm, with the largest being 8.5mm. This shows squall type rainfall.

In this way shallow layer groundwater is directly affected by rainfall.
Droughts in many locations throughout the world have been reported and abnormal global weather has been registered, presenting serious environmental problems.
From the perspective discussed above, the use of shallow layer groundwater, which is subject to weather, as a continuous water source presents significant problems.
The development of deep layer groundwater is essential as a method to resolve these problems. Deep layer groundwater potential can be examined through field investigation.

6.2.2 Field Investigation

The field investigation at this time was conducted for 3 days from March 17th. Interview investigation with the person in charge at YCC, IHI was conducted in the morning and outcrop investigation from a hydrological viewpoint was conducted in the afternoon.
At first, the investigation was conducted in a 6km radius of the plant site, but good results were not obtained. The range was then expanded to 10km, and as a result, a prospective area for deep layer groundwater.

6.2.3 Topography and Geology in the Vicinity of Mafraq

Yemen is located in the southwestern region of the Arabian peninsula and can be divided geographically into 4 areas. Figure 6-13 outlines Yemen's geographical classifications.

a. Tihamah Coastal Plain (western lowlands): Facing the Red Sea, the Tihamah Coastal plain extends north and south approximately 400km and is an newly accumulated area with a width of 30km to 50km on the trough of the Red Sea. The area consists of a desert plain created from marine and wind drifts and alluvial fans which can be seen in the mountains foothills.

b. Central Mountain Area (western midlands and highlands): A rugged mountain range extends north and south with an approximate height of 3,000m and its watershed ends 100km inland from the Red Sea. The western slope of mountain ridge, which faces the Red Sea, forms an extremely steep topography and shows erosional landforms of a mature period. The rivers that flow into the Red Sea further erode the mountain surface and penetrate the alluvial fans creating wadis.

c. Central Highland Area (central highlands): The relatively mild eastern slope of the mountain ridge consists of highlands which extend north and south. In regard to height, Taizu Basin in the south is approximately 1,500m and Sanah Basin is 2,250m.

d. Eastern Mountain Range - Desert (eastern highlands, eastern & midlands, eastern lowlands): East of the Central Highland area, elevation gradually diminishes and the topography merges into the Rubalkhali Desert. Wadis have developed in this mountainous area and water flow is generated only during the rainy season. Water is absorbed into the desert and rivers becomes dry river-beds.

The area of investigation is located in a valley bottom plain in the Central Mountain area. Wadis Rahaba's watershed is Habashi Mountain, 12km southwest of Taizz, and extends north joining Wadi Ar Rub. The wadi's direction shifts to the west at this point and drops in height. It is then jointed by Wadi Risyan located at the apex of an alluvial fan before reaching the Tihamah Coastal plain. Wadi Risyan is a large river originating in the Central Mountain area with a total length of over 100km.

A high terrace surface (580m-640m in height), and a low terrace surface with a height difference of 2m-5m from the river bottom, are seen at the basin of Wadi Ar Rubu. These areas are used as agricultural land. The majority of shallow wells are located in the low terrace. In terms of geology, a large rift valley was created on the Arabian peninsula during the Miocene epoch of the Tertiary period (approximately 25 million years ago), separating the area from the African continent and creating a peninsula. This is a stable area now called Arab Table Land.

The geology of Yemen is shown in the attached Figure 6-13.

The oldest layer has a base consisting of Precambrian gneiss, schist, and granite. This layer is covered by Wajid sandstone considered to be Palaeozoic Permian and is seen in the northern areas. The following layers consist of the Kohln formation of Lower Jura, and Amran formation of Upper Jura, both of the Mesozoic era. The Tawilah Group of the Chalk and Medi-zir formation of the tertiary period follow next, along with Trap formations widespread throughout the country, consisting of mainly volcanic and pyroclastic rock from volcanoes active from the Chalk to the Tertiary period.

Violent volcanic activity from the Tertiary period to present day has created a large layer of lava and volcanic tuff extending from the Central Mountain area to the Highlands. During the Quaternary period, several river terraces were developed on the valley bottom plains of the wadis, alluvium was deposited in fan shapes at the foot of mountains, and sand dunes formed by marine and wind drifts were formed along the coast. Diluvial to alluvial plains of river and lake drifts, and partiaa glacial drift were formed on the basin structure of the Highland area. As well, a sand desert created by wind drift is continued on the west side. These geological layers are shown in Figure 6-16. (T. Igarashi, 1972)

a. Precambrian:

Schist and granite are found mainly in the northern part of Yemen, and granite is found in the southern part of Maribu. There are not found in the Mafraq area.

b. Sedimentary rock

(1) Wajid Sandstone:
Found Farther north than Sadah, Wajid sandstone consists mainly of coarse grain sandstone from quartz grain which is a relatively good natural selection. It is not found in the Mafraq area.

(2) Kohln Formation:
This formation is found in the mountain areas northwest of Sanaa. A conglomerate layer lies underneath sandstone and shale layers.

(3) Amran Formation:
This calcareous rock is widely found in the northern half of Yemen. This formation is accompanied by shale and sandstone, and the layer thickness is believed to be over 300m. It is found in Mafraq as a cement material.

(4) Tawilah Group:
This groups consists of white to red-brown continental sandstone which is found near Sanaa and a narrow conglomerate. The layer thickness is believed to be over 200m and contains an aquifer which is an important source of water for the capital area. It is also found in southern area of Mafraq.

c. Volcanic rock:

Trap formations cover one-quarter of Yemen. These consist of lava flow such as basalt, andesite, and trachyte, as well as, volcanic pyroclastic rock such as tuff and grannel tuff. Trap formations exhibit a very thick layer with a maximum depth of over 1,200m. Following trap volcano activity is the present volcanic activity, which even though smaller, covers the entire nation forming craterous, coned shaped mountains. The majority of volcanoes are dead, however, some are dormant and solfatara is seen. During investigation situations which further intrude on the old Yemen Volcanics are often seen.

d. Alluvial Layer of the Quaternary Period:

Double layer river terraces are seen along Wadis Ar Rub in Mafraq and consist of alluvial deposits such as pebbles, rock, conglomerate, sand, silt, and clay. However, accumulation environment is assumed to have changed seasonally and yearly, therefore the selection is poor.

6.2.4 Climate Conditions

Yemen is located on the southwestern edge of the Arabian peninsula at north latitudes between 13 and 17 degrees and has to a tropical climate. However, the coastal area and East Inland area (western lowlands) adjacent to the Saudi Arabian border show a desert climate, with a little precipitation during the winter. The higher elevations of the Central Mountain area have an alpine climate. Moist air is brought to the mountain area by winds blowing onshore during the summer from the Red Sea. This causes rainfall on the western side of the mountain ridge. The Taiz region has the largest amount of precipitation in Yemen.

A precipitation map is shown in Figure 6-15. The climate of Tihamah Coastal plain and Kudeiha which is the drainage basin of Wadi Riysan is shown in Figure 6-17 as the climate characteristics chart. From this chart it is noted that rainy seasons occur in the spring and summer and that the majority of rainfall changes into squall rainfall from the afternoon. The annual precipitation varies. The coastal plain to Central Mountain area varies is 50mm to 300mm, with approximately 200m in the Mafraq area.

The average monthly maximum temperature in the coastal area reaches 35 to 43 degrees centigrade and 25 to 35 degrees in the Central Mountain area. Evapotranspiration reaches 2,500mm in the coastal plain.

6.2.5 Hydrological Discussion

When considering the possibility of deep layer groundwater development in the Mafraq area, the following 3 features are targeted. (Shallow layer groundwater is not targeted.)

a) Tawilah Sandstone

The characteristics of this layer are a general development of small and large cracks which form good conditioned aquifers with porous rock surface unique to land stratification. Except for partial confined water, the groundwater contained in Tawilah sandstone is unconfined groundwater. A shale layer which forms an impermeable layer is found beneath the sandstone layer and hydrologically intersects with the lower aquifer. This is the most prospective aquifer in Yemen and is a major water source for the Sanaa capital area. Pumping discharge per well in Sanaa is generally abundant at $500m^3$ to $2,000m^3$ per day.

6.2.6 Field Investigation Results

From a hydrological viewpoint, field investigations were conducted in regard to 3 types of layers which have high potentiality for deep layer groundwater development in the Mafraq area.
Even though trap series were wide ranging at the plant site, good results were not attained from previous test drilling investigation and a successful example was not found in this area. Many faults exist in the Amran formation and along the border of the trap series. However, basalt dick is often seen with the present volcanic activity and it is assumed that available interstices in the fracture zones are limited.

Because of this, field investigation was conducted with the objective of confirming Twilah sandstone which is found on the plant's south side on the geological chart (Figure 6-18).

Looking at the test boring point (No.1 well) to the right, which was test drilled approximately 3.5 km north from the plant, along the Taizs-Hodeidah road where it joins Wadi Habbaybah (tributary of Wadi Ar Rub) originating from Habashi Mountain, follow Wadi Rahaba to the east.
This wadi possesses a low terrace and many hand dug wells approximately 10m in depth are scattered on this terrace.
On both banks predominant Yemen Volcanics are seen, however, Tawilah sandstone believed to be the base rock of this area appears fragmented, as if it were pushed up by the basalt. Driving 5.5km along the river bed of the wadi, east from the test well, the Tawilah sandstone area begins.
A further 3km ahead from this border and arriving at the entrance of Al Harfa village, there is a deep well for irrigation. This was drilled with a rotary rig by

a local well drilling company. Its details were unknown, however an outline from information received through interviews is as follows.

[Deep well for irrigation]
Construction : 1985
Depth : approximately 70m
Diameter : 200m
Pump : Vertical Turbine Pump "Caprani-Italy"
: Discharge pipe diameter = 80mm
Pumping situation : Pumpage is abundant (assumption 400 to 700 liters per minute with a 3" discharge pipe, two years ago). Presently, the pumpage remains unchanged, but it now sucks air after 3 to 4 hours. A water level drawdown is assumed from this observation.

6.2.7 Suggestions for Deep Layer Groundwater Development

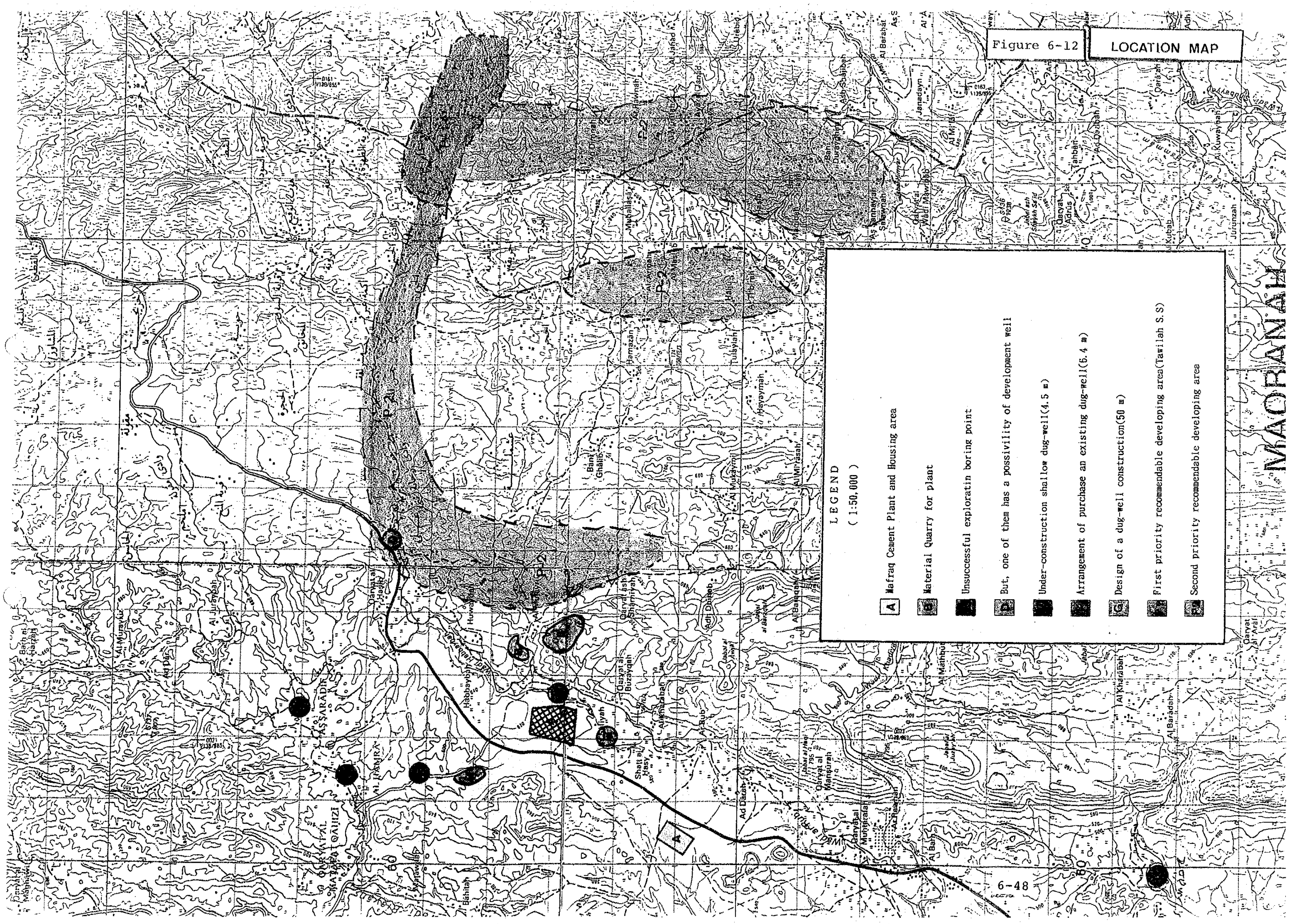
Securing a stable water source for plant operation is necessary for the original operation plan as well as its expansion. Shallow layer groundwater which is important for agriculture is annually and seasonally unstable, therefore deep layer groundwater development is a topic of emergency.
From the investigation results, the development target should be moved forward in terms of the following priorities.

First Priority: Twilah sandstone is found in the western Habashi mountains.(Figure 6-12) This excellent aquifer outcrop is widely distributed along Wadi Rahaba. The sandstone quarry at the plant site

DEEP LAYER GROUNDWATER DEVELOPMENT FLOW CHART

Preliminary Investigation	Field Reconnaissance, deciphering Aerial Photograph, Collection and Analysis of Existing Data and Information: - Hydrological, Meteorological Investigation - Investigation on Land Utilization Condition - Investigation on River, Waterway and Water Right
Preliminary Study	- Study and Determination on Scope of Investigation - Study and Determination on Investigation Method - Legal Study on Water Right - Pointing-out of Problems
Hydrogeological Investigation	- Investigation on Identification of Fault and Cracks by means of Radiation and Electr magnetic Prospectings - Ascertainment of Behavior and Depth of Aquifer Electrical Prospecting - Investigation on Existing Well (Utilization condition depth and variation of water level)
Test Boring Investigation	- Geological Boring Investigation (ø150x100m/200m) - Pumping Test (stagial test-estimation of yield) - Investigation on Influence of Existing Well
Integrated Investigation	Analysis and Study on Data resulted from Each Investigation
Well Design	Specification and Number of well, and Methods of Pumping
Construction of Deep Well	Facilities and Conduction

Figure 6-12 **LOCATION MAP**



LEGEND

(1:50,000)

- A Mafraq Cement Plant and Housing area
- B Material Quarry for plant
- ■ Unsuccessful exploratin boring point
- D But, one of them has a possivility of development well
- ■ Under-construction shallow dug-well(4.5 m)
- ■ Arrangement of purchase an existing dug-well(6.4 m)
- G Design of a dug-well construction(50 m)
- P1 First priority recommendable developing area(Tawilah S.S)
- P2 Second priority recommendable developing area

Figure 6-13

Classification graphic of landform in Yemen

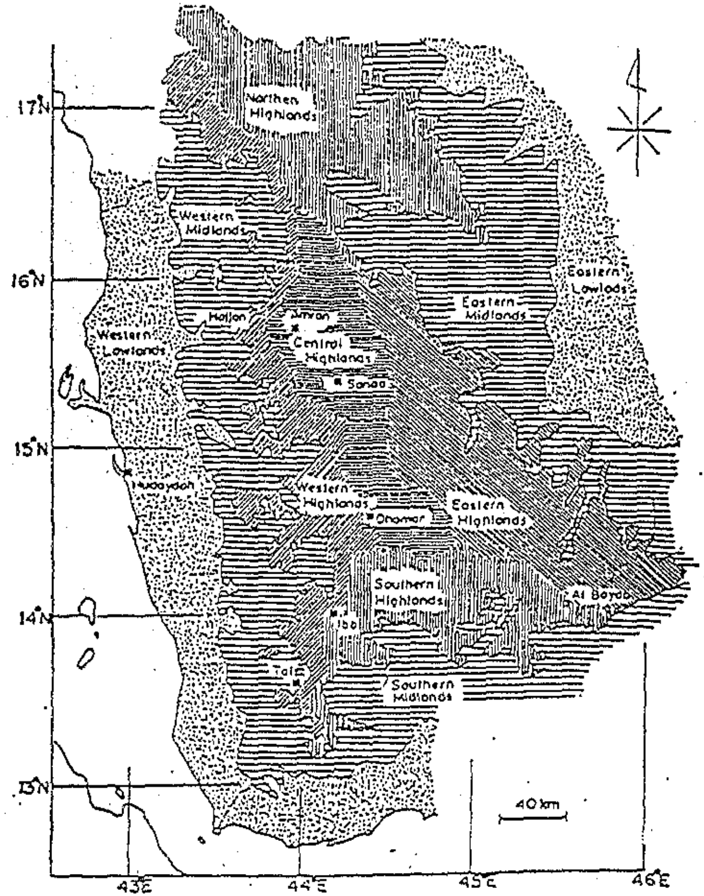
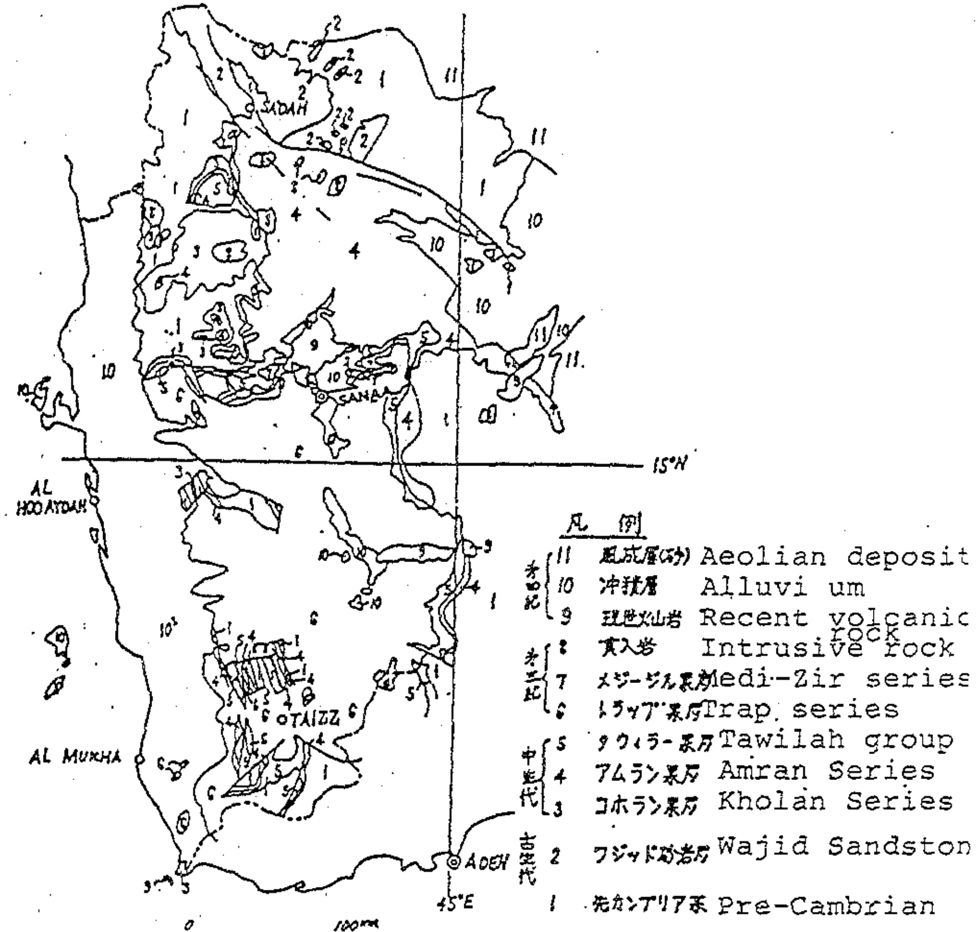


Figure 6-14

Geological map in Yemen



GEOLOGIC MAP OF THE ARABIAN PENINSULA
U.S.G.S (1963)による。

By Dr. Taguchi & Shindo "Water resource"

Figure 6-15

Annual mean precipitation of the Yemen

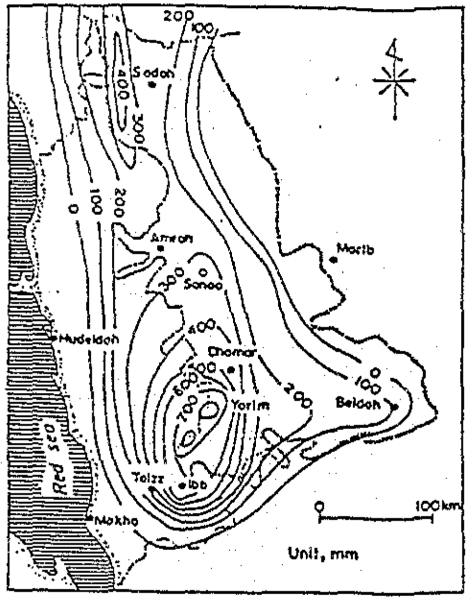
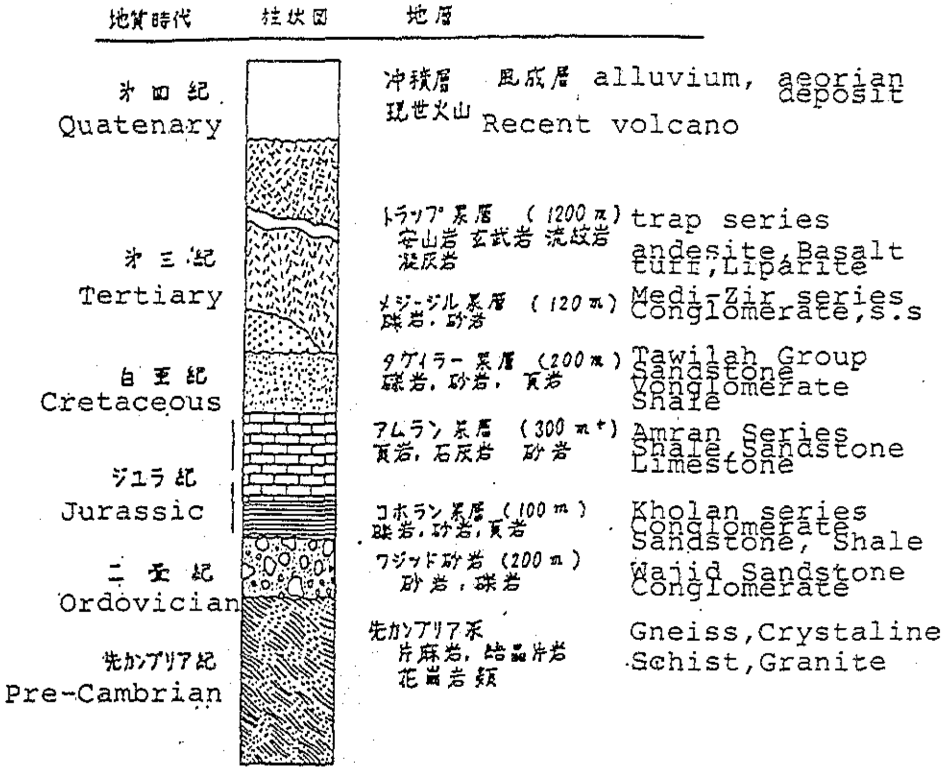


Figure 6-16

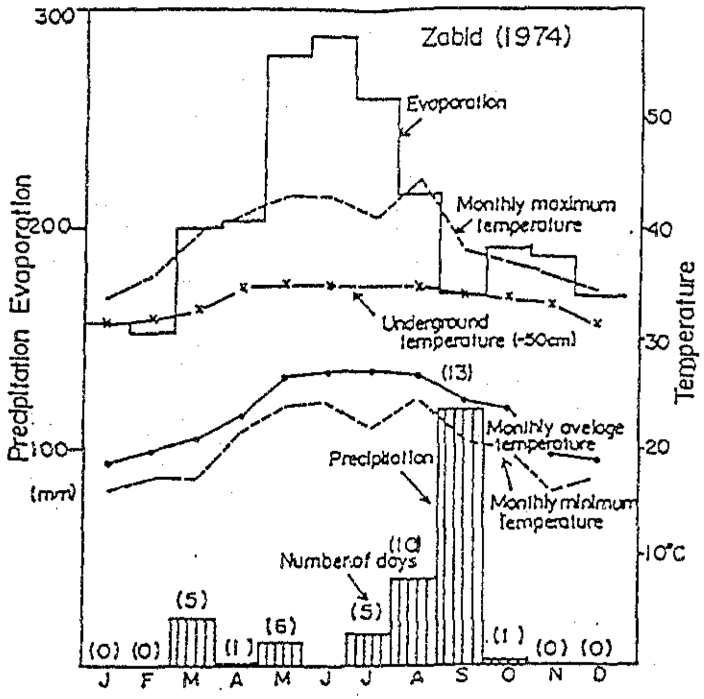
Stratigraphic sequence of the Yemen



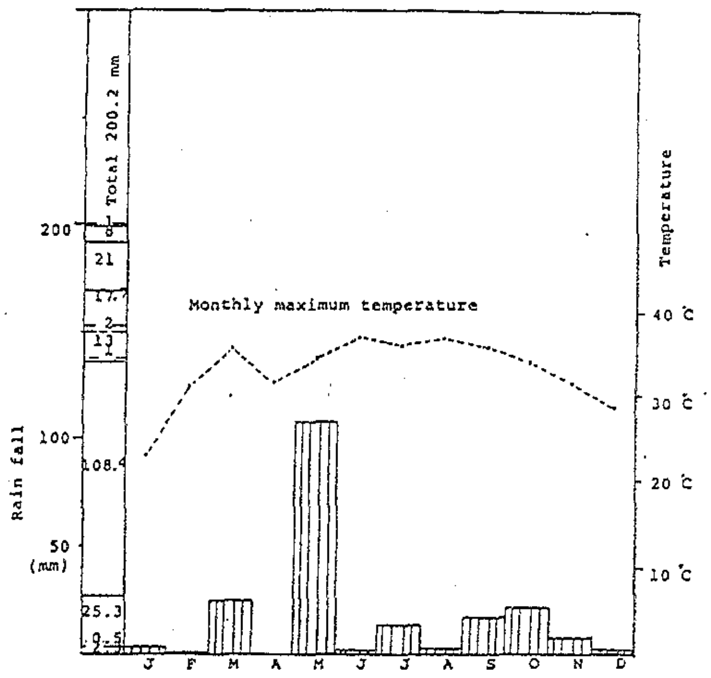
T. IGARASHI 1972

From "Water resource in Yemen" Taguchi,Shindo.

Figure 6-17 Hydro-meteorological condition of the Tihamah and wadi Risyan

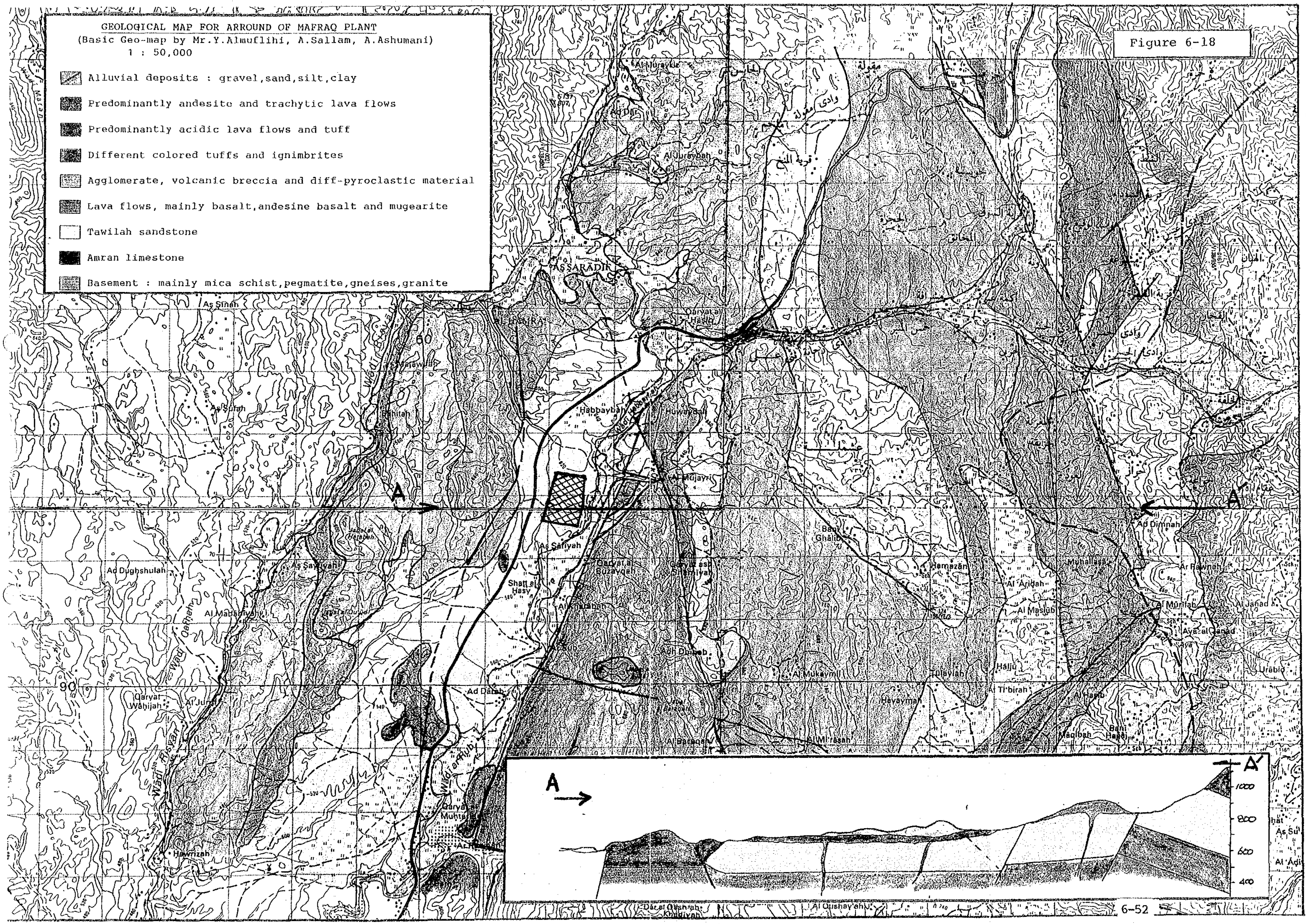


From "Water resource in Yemen"
by Taguchi, Shindo, 1981



KUDEIHA Year - 1982 (Tihama Development Authority)
Location Wadi Risyan Catchment Area

Figure 6-18



GEOLOGICAL MAP FOR ARROUND OF MAFRAQ PLANT
(Basic Geo-map by Mr.Y.Almuflihi, A.Sallam, A.Ashumani)
1 : 50,000

- ▨ Alluvial deposits : gravel,sand,silt,clay
- ▨ Predominantly andesite and trachytic lava flows
- ▨ Predominantly acidic lava flows and tuff
- ▨ Different colored tuffs and ignimbrites
- ▨ Agglomerate, volcanic breccia and diff-pyroclastic material
- ▨ Lava flows, mainly basalt,andesine basalt and mugearite
- ☐ Tawilah sandstone
- ■ Amran limestone
- ▨ Basement : mainly mica schist,pegmatite,gneises,granite

6.3 Electric Power Supply

6.3.1 Supplied Electric Power by P.E.C. (Public Electric Corporation)

Actual and expected electric power generation and load consumption by P.E.C in Yemen are shown in Table 6-17 "Power Consumption List". But in recent years, load consumption by general users are expected to increase more. Then, P.E.C. can supply the electric power 25 MVA maximum for MAFRAQ CEMENT PLANT including extension.

6.3.2 Load Consumption

Expected load consumption of existing Mafraq cement plant under construction is as follows:

Maximum demand: 18.9 MVA
Average : 17.5 MVA

(Data by I.H.I.)

Production capacity and facility of expansion plant is the same as existing. And, electric load consumption of expansion plant is expected also as same average 17.5 MVA as existing. Then, total load consumption of whole plant is 35 MVA. Capacity of Max. 25 MVA that is planned to supply to Mafrac cement plant by P.E.C. is a shortage to required power.

6.3.3 Electric Power Generation Facility

Existing plant will be covered by 25 MVA purchasing power. But, purchasing power can not cover the expansion. Therefore, generator facility for expansion is necessary.

For expansion, 4 - Diesel Generator Sets (6,250 kVA x 4, including the 1 set of stand-by) will be considered. Amran cement plant is providing the 4 (four) - Diesel Generator Sets (5,400 kW x 4, 1 set is stand-by).

6.3.4 Electric Power Supply System

Generally, parallel running with 3 - generator sets generate the required power for expansion plant. Generated 6,600V electric power will be distributed to each substation/electric room from main generator panel. And it is considered that this 6,600V line is connected to existing main 6,600V switchgear with 2 lines. Because, it is able to send and receive the electric power between existing and expansion switchgear at emergency.

6.3.5 Specification for Electric Power

Specification of generated power is as follows:

Source : 6,600V, 3 Phase, 50 Hz
Generator capacity : 18,750 kVA (6,250 kVA x 3) at normal operation
25,000 kVA (6,250 kVa x 4) 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 380V 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

6.3.6 Quality of Electric Power

Quality of electric power is very important for a cement plant especially for rotary kiln, because rotary kiln has large scale heat capacity and requires long run with steady condition for reducing operation and maintenance cost. Frequent stoppage of the kiln attacks refractory bricks of kiln.

According to the actual operation data by Amran cement plant, quality of purchasing power is not so high quality that Amran cement plant was recorded the several shut downs by voltage fluctuation of purchasing power.

Mafraq existing plant is designed to operate by using purchasing power. If quality of purchasing power is not improved to high quality, according to the data by Amran cement plant, power generation facility shall be considered.

Table 6-17 Power Consumption List

Year	Power Generation Capability (MW)	Load Consumption (MW)
1983	236	54
1984	225	80
1985	255	95
1986	385	106
1987	377	128
1988	372	
1989	372	145
1990	372	179
1991	372	195
1992	372	211
1993	382	221
1994	412	231
1995	442	253
1996		278
1997		283

(By P.E.C.)

Note: Data after 1991 is expected data.

6.4 Fuel Oil Supply

For the expansion project, same as existing plant, two kinds of fuels, heavy fuel oil and diesel oil shall be used.

Both fuels shall be also supplied to the plant by truck tank lorry from Mareb oil refinery and storaged to the storage tanks in the plant site.

As there is uncertainty of supplying fuel from Mareb oil refinery due to transportation stoppage by road in spite of its enough refinery capability, storage capacity in the plant shall be kept sufficiently.

6.4.1 Heavy Fuel Oil

Consumption

	Existing	Expansion
Clinker burning :	6.20	6.20
Hot gas generator:	1.24	1.24
Total :	7.44 tons/hour	7.44 tons/hour

= 14.88 tons/hour x 24 hours

= 357.12 tons/day

Storage Capacity : 2500 m^3 x 3 sets

= 7500 m^3

Specification of Heavy 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

6.4.2 Diesel Oil

Consumption

		Existing	Expansion
Steam boiler plant	:	0.15	0.15
Emergency power generating set	:	(0.25)	(0.25)
Diesel power plant	:	-	3.32
Total	:	0.15	3.47

= 3.62 tons/hour x 24 hours
= 86.88 tons/day

Storage Capacity : 500 m^3 x 1 set + 2500 m^3 x 1 set
= 3000 m^3

Specification of 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

7

7

CONTENTS

7.1 Basic Concept of the Expansion Project

7.1.1 Plant Capacity

Production capacity of the expansion plant shall be the same capacity as that of existing plant.

	Daily Production	Annual Production
Clinker Production	1,700 T/D	500,000 T/D

7.1.2 Scope of the Project

Scope of work of the expansion project shall be full turn key basis plant equipment supply and construction.

The equipment shall include not only production line from quarry to cement delivery through raw and cement grinding and clinker burning, but also related auxiliary facilities of utilities supply and supporting facilities such as offices and stores.

7.1.3 Basic Concept

Following basic concepts are applied for the engineering and construction of the expansion project.

1) Process of the expansion plant shall be latest energy saving and high efficiency process and be considered of application of common equipment between existing and expansion plant.

2) Plant shall be installed adjacent to the existing plant.

3) Maximum use of the existing facilities shall be considered.

4) Design base shall be applied the same of existing plant.

5) Expansion shall be considered not only to the plant facilities but also to the peripheral parts such as utilities supply necessary for the plant operation.

6) Water supply to the plant shall be included in the scope of the expansion project.

7) Electric power shall be supplied from the new diesel generating plant which is included as the scope of expansion project.

8) Quality and reserve of limestone quarry shall be studied through the report "Geological investigation works".

9) Additional housings for employees and their family use of expansion plant shall be considered.

10) Expansion of stores for storage of spare parts and consumables of expansion plant shall be considered.

11) Environmental assessment shall be applied the same level of existing plant.

7.1.4 Basic Calculation Sheet

Specifications and capacities of the main equipment shall be calculated by the following paper. Calculation results are shown in Figure 7.1 Engineering Flow sheet.

1) Production Capacity

(1) Clinker Production : 1,700 T/D

(2) Cement Production :
1700 T/D x (1.03 + 1.05) x 300 D/Y = 550,000 T/Y
1.03 : Gypsum Ratio
1.05 : Additive Ratio
300 : Annual Operation Days

2) Basic Factor for the Calculation

(1) Mixing Ratio of Each Materials

(a) Raw Meal : Limestone : 89.66%
Volcanic Rock: 10.34%
Sandstone : 0 %

Total : 100.0 %

(b) Raw Meal/Clinker :
L.O.I. : 1.512 kg/kg-cl
Dust Loss : 0.03
By-Pass Loss : 0.03

Total : 1.572 kg/kg-cl

(c) Clinker/Cement :

Clinker : 1.0 kg/kg-cl
Gypsum : 0.03
Additive : 0.05

Total : 1.08 kg/kg-cl

(2) Raw Material Characteristics

(a) Characteristics

	Moisture Content (%)	Bulk Density (t/m^3)	Repose Angle (Deg.C)
Limestone :	Max. 2.5	1.5	35
Volcanic Rock:	3.5	1.5	35
Sandstone :	1.8	1.5	35
Gypsum :	5.0	1.5	35

(b) Chemical analysis

	Limestone	Volcanic Rock	Sandstone
SiO_2 :	11.35	44.23	91.42
SiO_2 :	0.17	3.78	0.32
Al_2O_3 :	1.64	14.40	1.88
Fe_2O_3 :	1.04	12.90	2.07
MnO :	0.02	0.14	0.03
MgO :	1.39	4.49	0.34
CaO :	46.0	8.58	1.03
K_2O :	0.77	1.40	0.80
Na_2O :	0.09	4.04	0.07
Ig-loss :	37.16	5.46	1.31
Total :	99.63%	99.42%	99.27%

(3) Fuels

Banker C Heavy Oil

Calorific Value (Gross)	: 11,300 Kcal/kg (9,800 Kcal/kg-net)
Specific Gravity	: 0.93
Sulphur Content	: Max. 2.5%
Viscosity	: Min. 68 cSt

Fuel Consumption

Without By-pass : 790 kcal/kg-cl
20% By-pass : 830 kcal/kg-cl

3) Operating Hours of Each Modules

(1) <u>Quarries</u>
Limestone Quarry : 6 H/D x 5.5 D/W = 33 H/W
Volcanic Rock Quarry : 6 H/D x 5.5 D/W = 33 H/W

(2) <u>Raw Material Crushing</u>
Limestone Crushing : 7 H/D x 6 D/W = 42 H/W
Volcanic Rock Crushing : 8 H/D x 6 D/W = 48 H/W

(3) <u>Raw Materials Storage</u>
Limestone Stacking : 7 H/D x 6 D/W = 42 H/W
Limestone Reclaiming : 24 H/D x 6 D/W = 144 H/W

(4) <u>Raw Material Grinding</u>
Raw Grinding Mill : 24 H/D x 6 D/W = 144 H/W

(5) <u>Raw Meal Storage and Homogenizing</u>
Raw Meal Storage : 24 H/D x 6 D/W = 144 H/W
Raw Meal Homogenizing : 24 H/D x 7 D/W = 168 H/W

(6) Raw Meal Feeding

Raw Meal Feeding : 24 H/D x 7 D/W = 168 H/W

(7) Clinker Burning

Preheating, Kiln, and Clinker Cooler : 24 H/D x 7 D/W = 168 H/W

(8) Clinker Storage

Clinker Storage : 24 H/D x 7 D/W = 168 H/W
Clinker Extracting : 24 H/D x 6 D/W = 144 H/W
Gypsum/Additive Crushing : 24 H/D x 6 D/W = 144 H/W

(9) Cement Grinding

Cement Grinding Mill : 24 H/D x 6 D/W = 144 H/W

(10) Cement Storage

Cement Storage : 24 H/D x 6 D/W =144 H/W
Cement Discharge
- Packing : 16 H/D x 6 D/W = 96 H/W
- Bulk : 8 H/D x 6 D/W = 48 H/W

(11) Cement Packing

Packing Machine : 16 H/D x 6 D/W = 96 H/W

(12) Cement Dispatch

Bag Loading : 16 H/D x 6 D/W = 96 H/W
Bulk Loading : 8 H/D x 6 D/W = 48 H/W

(13) Utilities Supply

Water Supply :
Compressed Air Supply : Continuous operation
Fuel Oil Supply : during
Steam Supply : plant operation
Fire Fighting :