Chapter 5 Geological Ore Reserves of the F3 Ore Body

5-1 Basic Data for the Ore Reserve Estimation

The basic data sets that were used for the ore reserve estimation include the hole collar coordination (23 vertical drill holes with the total length of 2,300m), the contents of RE_2O_3 (%), CaF_2 (%) and $BaSO_4$ (%) in drill core samples (calculated from the assay results for the 1m-long drill sections), the rock types (surface soil, syenite, minette, limestone, loose sand, clay, breccia and cave) and the topographic data.

5-2 Estimation Procedures

(1) Data Processing System and Software

- Hardware : Compaq, Professional Workstation AP550
- OS : Microsoft, NT Workstation 4.0+Service Pack4(English Version)
- Software: Mintec Inc., Mine Sight 2.7

(2) 3-Dimensional Block Model

Blocks having a dimension of 20m in N-S, 20m in E-W and 5m in height were set up for the extent of the ore reserve estimation.

(3) Composite Assay Run

The composite assay runs with an equal length of 5m that were bounded by block boundaries, were produced.

(4) Treatment of Extraordinary Assays

Logarithmic histograms and log-normal probability distributions of composite assays for RE_2O_3, CaF_2 and $BaSO_4$ were prepared in order to examine extraordinarily high assays for their suitability for grade estimation. Extraordinary assays exceeding the thresholds were converted to the respective thresholds and then were used for the variogram analysis and for the grade assignment to each block.

(5) 3-D Solid Models of the Ore Body and Lithological Units

The ore and lithological boundaries that were indicated on the cross-sections with the azimuth of 100° , were digitized and extrapolated to 25m each side of the relevant cross-sections, observing the longitudinal sections with the azimuth of 5° , in order to construct 3-dimensional solid models of the ore body(syenite), minette, limestone and unmineralized syenite.

(6) Variogram

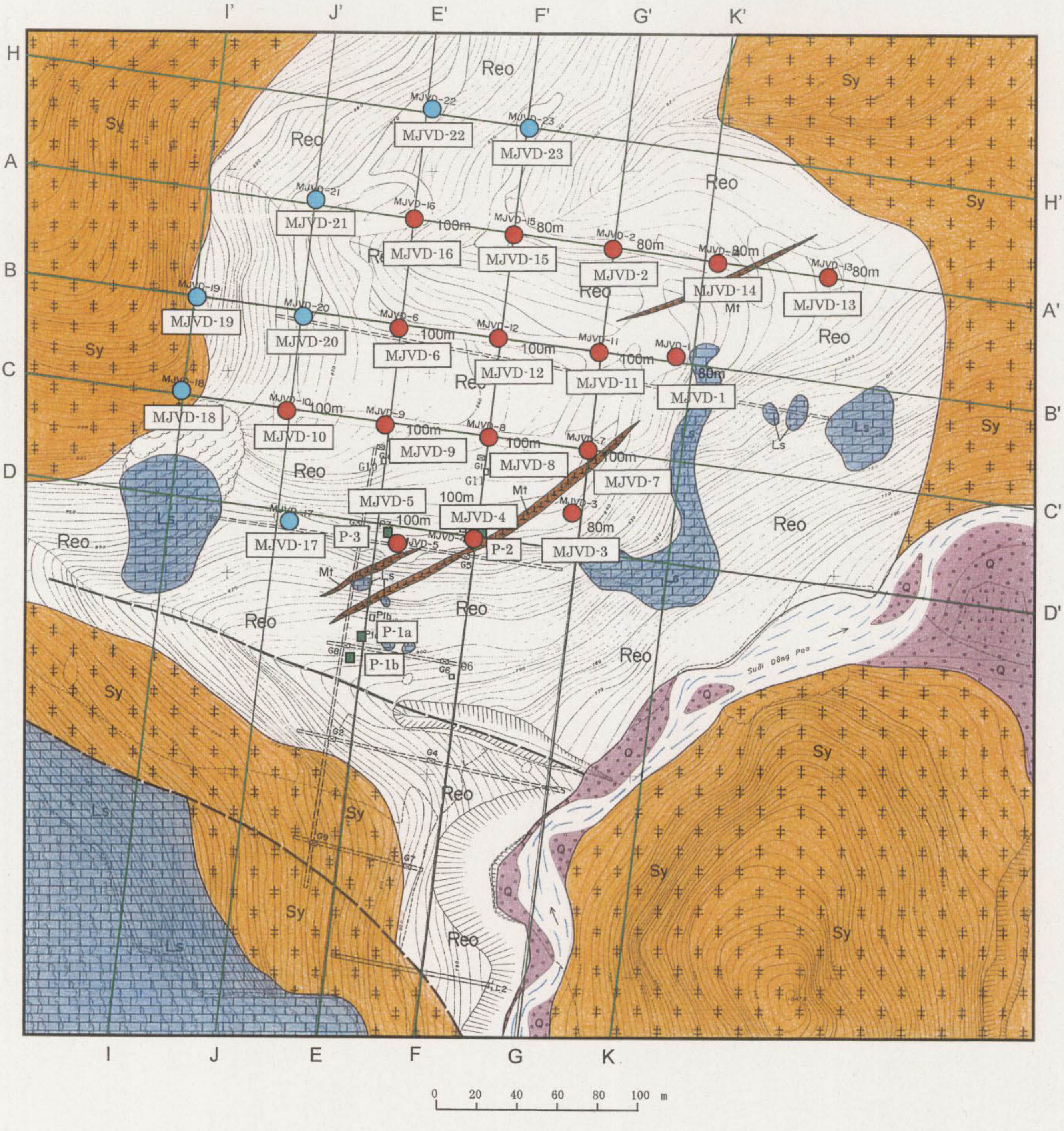

Figure Ⅱ-5-1 Plane map of cross section setting for Ore reserve calculation

Experimental variograms for the 3 compounds, RE_2O_3, CaF_2 and $BaSO_4$ were estimated using composite assay run pairs only for syenite. Distances between the composite pairs (lag distances) were taken at 5m, 10m, 15m, ・・・・, with an allowance of ±2.5m. All holes were drilled vertically and limited in the total number. Therefore, it was assumed that variances of the ore grades would be isotropic in any directions. With this assumption, the parameters based on the vertical holes were equally adopted to all directions.

(7) Assignment of Oxide Grades to Blocks

The ore grades of each block were estimated using the ordinary Kriging method based on the composite assay run data. The ambit enclosing composite assay run data was defined as a sphere with a radius of 40m centering the center of each block. The Kriged ore grades were assigned to the blocks that contained more than 1% of ores according to the 3-D solid model. The ore type of each block was determined level by level using a polygonal method according to the ore types included in the composite assay run data. The locations of cross and longitudinal sections that were used for the interpretation are shown in Figure II-5-1. The cross-sections and plans that demonstrate RE_2O_3 grades assigned to individual blocks are attached in Apx. 10 and Apx. 11 respectively.

(8) Specific Gravity

The results of the specific gravity measurement for 15 samples indicated that the specific gravities for the weakly weathered ores ranged between 2.5 and 2.9 (7 samples) and those for the weathered sandy ores, between 2.7 and 4.7 (8 samples). Because the number of the measured samples is small to verify an appropriate specific gravity, the specific gravity of 2.6, lower than the average of the 15 samples, is adopted to all types of ores and rocks.

5-3 Result of Ore Reserve Estimation

The geological ore reserves, assuming 100% mining extraction and 0% dilution, were estimated and collected by cut-off grades ranging from 0 to 15% as shown in Table II-5-1. The reserve-grade relationship is demonstrated in Figure II-5-8.

Table II-5-1 Geological Ore Reserves by Cut-off Grade

		INSITU ORE (BCMS)	INSITU ORE (TONNES)	Average Grade RE2O3 (%)	CaF2 (%)	BaSO4 (%)
CUTOFF=	0	11,517,458	29,945,392	1.84	3.37	16.84
	1	5,696,462	14,810,801	3.60	6.57	31.24
	2	4,229,725	10,997,284	4.32	7.84	34.32
	3	2,836,391	7,374,617	5.23	9.87	34.50
	4	1,833,175	4,766,256	6.19	12.06	34.01
	5	1,221,250	3,175,249	7.06	12.80	34.97
	6	789,018	2,051,446	7.93	13.59	35.40
	7	520,980	1,354,549	8.69	14.24	36.16
	8	294,291	765,156	9.63	12.74	39.72
	9	153,551	399,232	10.67	12.07	42.05
	10	75,671	196,744	11.88	12.20	44.74
	11	51,691	134,396	12.53	11.31	45.97
	12	28,600	74,361	13.29	11.32	45.52
	13	11,340	29,484	14.50	10.74	43.24
	14	6,200	16,120	15.66	9.64	38.85
	15	2,380	6,188	17.56	15.22	16.66

The ore reserves were collected by 4 ore types, namely black, mixed, low grade mixed and yellow, in order to estimate flotation recoveries according to the ore types. The reserves by the ore types are estimated and shown in Table III-5-2 of Part III.

5-4 The Geological Reserves to the south of the Drilled Extent

The geological reserves estimated as above is limited to the extent where the 23 drill holes were put down. Therefore, the reserves that are expected to the south of the southern limit of the drilled extent are excluded from the above reserves.

In the 1st Year Campaign, A preliminary ore reserve estimation for the 18 ore blocks of the southern part of the F3 Ore Body was made on the basis of the plans and cross-sections prepared according to the data acquire in the 1986 exploration. the estimation result is shown in Table I-4-2(Chapter 4 of Part 1 in this report). The 6 ore blocks, CI-13 through CI-18 in Table I-4-2, superimpose part of the current drilling grid where the holes, MJVD-3, -4, -5 and -17 were put down. The ore reserves excluding these 6 ore blocks are re-estimated and tabulated in Table II-5-3.

Table II-5-2 The Extent of the Ore Reserve Estimation by ore type

BENCH TOE	ZONE NAME	ZONE NO.	CUTOFF	INSITU ORE ORE	INSITU ORE ORE	INSITU GRADES		
						RE2O3	CAF2	BASO4
TOTALS	BLACK	1	0	2,958,339	7,691,680	2.35	3.44	24.54
			1	1,734,260	4,509,077	3.91	5.67	39.56
			2	1,520,225	3,952,585	4.24	6.07	41.17
			3	1,006,451	2,616,773	5.14	7.86	39.36
			4	617,431	1,605,321	6.21	9.89	39.29
			5	414,453	1,077,578	7.06	10.70	40.02
			6	268,370	697,761	7.94	11.28	40.60
			7	163,690	425,593	8.90	11.69	43.09
			8	103,560	269,256	9.72	10.52	44.04
			9	54,260	141,076	10.84	10.37	46.83
			10	34,400	89,440	11.62	11.47	48.36
			11	20,740	53,924	12.36	10.23	51.06
			12	9,500	24,700	13.09	6.92	54.63
			13	3,520	9,152	13.80	9.07	51.09
			19	380	988	20.00	15.84	28.73
	MIXED	2	0	7,122,345	18,518,100	1.58	2.84	14.48
			1	3,227,682	8,391,972	3.35	5.99	28.72
			2	2,133,700	5,547,620	4.29	7.69	32.65
			3	1,371,500	3,565,900	5.30	9.95	34.50
			4	914,604	2,377,971	6.22	12.06	33.62
			5	636,096	1,653,850	6.96	12.90	33.19
			6	396,557	1,031,049	7.85	13.54	33.59
			7	264,540	687,804	8.54	13.81	33.98
			8	155,540	404,404	9.30	13.71	37.08
			9	64,100	166,660	10.45	11.90	39.89
			10	23,040	59,904	12.27	11.12	41.91
			11	16,720	43,472	13.02	9.34	43.99
			12	9,820	25,532	14.17	11.41	40.73
			14	5,820	15,132	15.38	9.24	39.51
			17	2,000	5,200	17.09	15.10	14.37
	MIXED?	3	0	1,418,774	3,688,813	1.99	5.77	12.34
			1	716,520	1,862,952	3.87	11.26	22.31
			2	561,800	1,460,680	4.55	13.11	21.96
			3	444,440	1,155,544	5.10	14.12	23.27
			4	287,140	746,564	5.95	16.77	23.61
			5	158,700	412,621	7.25	17.98	28.32
			6	112,091	291,436	8.02	19.54	28.52
			7	82,751	215,152	8.55	20.87	28.71
			9	27,191	70,696	10.77	15.53	38.49
			10	14,231	37,000	11.80	15.29	41.47
			11	10,231	26,600	12.25	15.71	40.64
			12	7,280	18,929	12.50	16.28	40.38
			13	2,000	5,200	13.17	18.03	40.27
	YELLOW	4	1	18,000	46,800	7.18	10.75	36.75
			4	14,000	36,400	8.74	11.35	40.77
			6	12,000	31,200	9.46	11.64	42.73
			7	10,000	26,000	10.11	12.26	41.94
			9	8,000	20,800	10.81	13.24	38.97
			11	4,000	10,400	12.15	13.84	41.48
			12	2,000	5,200	12.78	13.75	44.44
TOTALS	SUMMARY		0	11,517,458	29,945,392	1.84	3.37	16.84
			1	5,696,462	14,810,801	3.60	6.57	31.24
			2	4,229,725	10,997,284	4.32	7.84	34.32
			3	2,836,391	7,374,617	5.23	9.87	34.50
			4	1,833,175	4,766,256	6.19	12.06	34.01
			5	1,221,250	3,175,249	7.06	12.80	34.97
			6	789,018	2,051,446	7.93	13.59	35.40
			7	520,980	1,354,549	8.69	14.24	36.16
			8	294,291	765,156	9.63	12.74	39.72
			9	153,551	399,232	10.67	12.07	42.05
			10	75,671	196,744	11.88	12.20	44.74
			11	51,691	134,396	12.53	11.31	45.97
			12	28,600	74,361	13.29	11.32	45.52
			13	11,340	29,484	14.50	10.74	43.24
			14	6,200	16,120	15.66	9.64	38.85
			15	2,380	6,188	17.56	15.22	16.66
			16	2,380	6,188	17.56	15.22	16.66
			17	2,380	6,188	17.56	15.22	16.66
			18	380	988	20.00	15.84	28.73
			19	380	988	20.00	15.84	28.73

Table II-5-3 Geological Reserves beyond the Southern Limit of the Drilled Extent

	Volume (m^3)	Gravity	Reserve (t)	TRE_2O_3 (%)	TRE_2O_3 (t)	Pit,Tunnel
CI-1	6,305	1.93	12,169	14.80	1,801	L2
CI-2	54,800	1.93	105,764	12.90	13,646	L2, G7
CI-3	19,850	1.93	38,311	12.73	4,876	G2,G4,G7
CI-4	21,735	1.93	41,949	12.73	5,340	G7
CI-5	2,770	1.93	5,346	12.73	681	G7
CI-6	504	1.93	973	12.70	124	G2
CI-7	2,585	1.93	4,989	15.20	758	G2,G8
CI-8	13,360	1.93	25,784	12.29	3,168	G2,G6,G8
CI-9	802	1.93	1,547	9.90	153	G6
CI-10	22,008	1.93	42,476	15.68	6,661	G3,G8
CI-11	35,656	1.93	68,816	14.29	9,832	G3,G5,G6G8
CI-12	23,419	1.93	45,199	12.87	5,816	G5,G6
		Ore reserve	393,322	Total	52,856	
				Ore grade	13.44	
Case of safety factor 10%		Ore reserve	→ 353,990	TRE_2O_3 (t)	→ 47,570	
Case of safety factor 20%		Ore reserve	→ 314,657	TRE_2O_3 (t)	→ 42,285	
				Ore grade	13.44	

The ore reserves of Ore Class I (C1+C2) are estimated at approximately 390,000 tons with 13.44% RE_2O_3. Taking a safety factor into consideration because of the irregular lens form of the F3 ore body, it is reasonable to expect an increase of the geological reserves of 310,000 to 350,000 tons with a high average grade in RE_2O_3. These reserves are located near surface at a relatively low elevation and easily accessible for an open pit mining.

Chapter 6 Flotation Test

6-1 Objectives and Background

Several flotation tests were conducted in the 1st Year Campaign but without any successful result to separate rare earth minerals from barite, fluorite and other gangues. The result was followed by a grinding-classifying test, taking advantage of difference in grindability between rare earth minerals and other gangues. After staged grinding, products with sizes below 2mm and above 500 μ m were recovered with the recovery rate of 32.5% and the concentration rate of 31.4%.

The ore samples, left over from the flotation tests in the 1st Year Campaign, were submitted for further flotation tests in the 2nd Year Campaign. It was indicated in the course of these tests that the flotation results employing the Mountain Pass process were unsatisfactory due to intensely weathered and altered nature of the Dong Pao ores. The test continued with developing a new process flow and reagent scheme, which led to much improved metallurgical results indicating a recovery rate of 50% for the concentrate with a grade of 50% RE_2O_3 (a recovery rate of 70% for the concentrate with a grade of 40% RE_2O_3). Locked cycle tests are still continuing to improve the metallurgical results.

6-2 Test Results

6-2-1 Work Index and True Specific Gravity

Work Index: 6.6 kWh/t, according to the Bond Test Standard

True Specific Gravity: 3.89

6-2-2 Concentration by Grinding-Classifying

The result is shown in Table II-6-1.

Table II-6-1 Analytical Result of Classified Products

	Mass	Assay			Distributions		
		REO	BaSO4	Ca2F	REO	BaSO4	Ca2F
Fine 1 (-2mm)	5.5	33.5	12.0	5.2	19.9	1.1	6.0
Fine 2 (-500um)	4.9	29.0	33.8	4.9	15.3	2.7	5.0
Fine 3 (-150um)	3.4	23.6	41.7	4.8	8.7	2.3	3.4
Fine 4 (-75um)	5.3	14.3	56.2	4.3	8.2	4.8	4.7
Coarse	80.9	5.5	68.2	4.8	48.0	89.2	80.9
Head	100.0	9.3	61.9	4.8	100.0	100.0	100.0
-2mm - +150um	10.4	31.4	22.3	5.1	35.2	3.7	11.0

The major rare earth oxides are CeO_2(46.1%), La_2O_3(36.0%) and Nd_2O_3(36.0%) with subordinate Pr_6O_{11}(4.0%), Y_2O_3(1.2%) and Sm_2O_3(1.1%) according to the analytical result.

ThO_2 and U_3O_8 are identified as oxides of radioactive elements and their contents in feed ore are 809 and 960 ppm respectively. While U_3O_8 can be easily removed by classifying, ThO_2 tends to concentrate in fine fractions.

6-2-3 Flotation Test

A series of flotation tests for the Dong Pao ore samples was carried out, employing the process flow that was being adopted at Mountain Pass. The result indicated that this process flow would be unsuitable to effectively separate rare earth minerals from barite, fluorite and other gangues contained in the Dong Pao ores. Therefore, a new approach for processing the Dong Pao ores had to be researched and developed. A series of flotation tests was conducted using the newly developed process flow and reagent conditions. The results are described below.

(1) Collective Flotation Test Results

The tests are still being carried out at the Laboratory of Lakefield Research, Canada Ltd. The test results to date are shown in Figure II-6-1 and Table II-6-2.

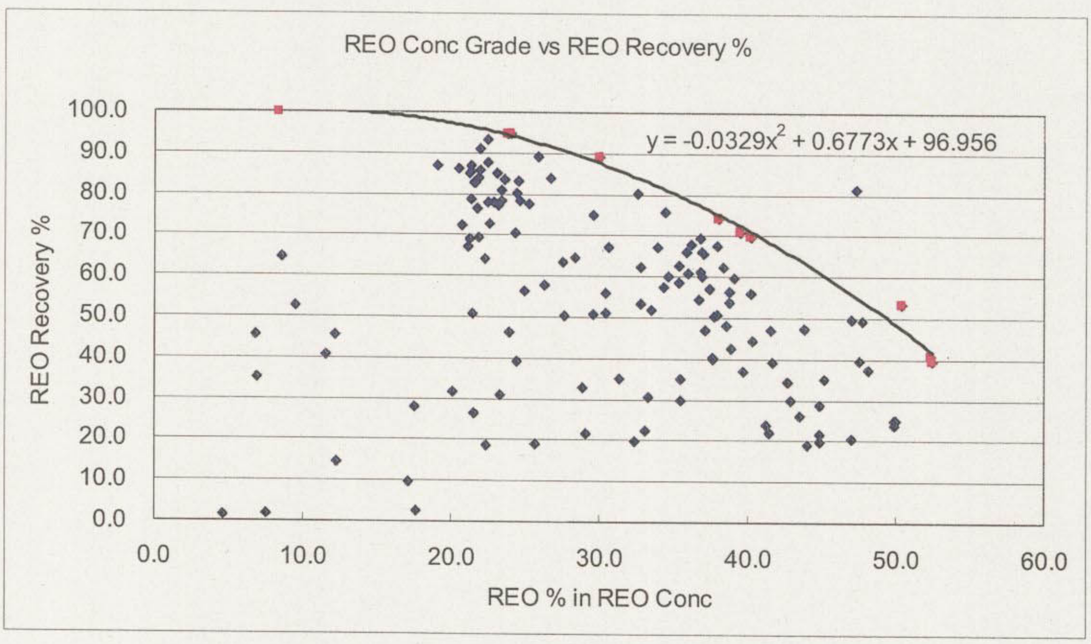

Figure II-6-1 REO Conc. Grade vs REO Recovery

Table II-6-2 Test Results for $BaSO_4$, CaF_2 and RE_2O_3

Test No.	Product	REO Concentrate								
		Wt	Assays %				% Distribution			
		%	$BaSO_4$	CaF_2	REO(total)	Others	$BaSO_4$	CaF_2	REO(total)	Others
	Head	100.00	63.3	5.1	8.4	24.7	100.0	100.0	100.0	100.0
Test 14	CaF2 Ro+1st&2nd Cl Tails	36.31	7.2	13.2	24	55.6	4.1	87.9	94.6	91.9
Test 18	CaF2 Ro+1st&2nd Cl Tails	38.40	7.82	13.5	23.8	54.9	4.8	92.9	94.6	95.4
70	CaF2 Tails + Slimes	29.81	7.46	6.16	30	56.4	3.6	34.6	89.3	73.5
69O	REO 1st Cl Conc	16.63	8.77	9.8	38	43.4	2.3	31.1	74.1	30.4
69N	REO 1st Cl Conc	15.19	9.03	9.76	39.5	41.7	2.2	28.9	71.0	26.6
69M	REO 1st Cl Conc	14.60	8.64	9.76	40.2	41.4	2.0	28.1	69.7	25.2
69O	REO Cl Conc	9.01	3.99	15	50.4	30.6	0.6	25.8	53.2	11.6
69M	REO Cl Conc	6.56	3.92	14.2	52.4	29.5	0.4	18.4	40.6	8.1
69N	REO Cl Conc	6.36	2.92	15.2	52.5	29.4	0.3	18.9	39.5	7.8

Test No.	Product	BaSO4 Concentrate								
		Wt	Assays %				% Distribution			
		%	$BaSO_4$	CaF_2	REO(total)	Others	$BaSO_4$	CaF_2	REO(total)	Others
	Head	100.00	63.3	5.1	8.4	24.7	100.0	100.0	100.0	100.0
Test 14	BaSO4 3rd Cl Conc	50.9	98.5	<0.5	0.6	0.9	79.0	4.7	3.3	2.1
Test 18	BaSO4 3rd Cl Conc	50.2	98.7	<0.5	0.7	0.6	78.9	4.5	3.9	1.3
70	BaSO4 Cleaner Conc	62.8	95.8	0.7	0.6	2.9	96.1	7.5	4.4	8.0
69O	BaSO4 Cl Conc	63.2	94.6	0.7	0.6	4.1	95.7	8.6	4.5	10.9
69N	BaSO4 Cl Conc	63.2	94.6	0.7	0.6	4.1	95.5	8.8	4.6	10.8
69M	BaSO4 Cl Conc	63.2	94.6	0.7	0.6	4.1	95.7	8.9	4.6	10.7

These results, obtained by the locked cycle tests of mainly $BaSO_4$ and CaF_2 as shown in the process flow, indicate that it is possible to produce bastnaesite concentrates containing 30%, 40% and 50% RE_2O_3 with the respective recovery of 90%, 70% and 50%. In addition, it is expected that very high grade barite concentrates will be produced, as by-product, with extremely high recoveries in the newly developed flotation process, which will significantly contribute to the mine economy. A series of tests are still going on and will further improve the metallurgical results.

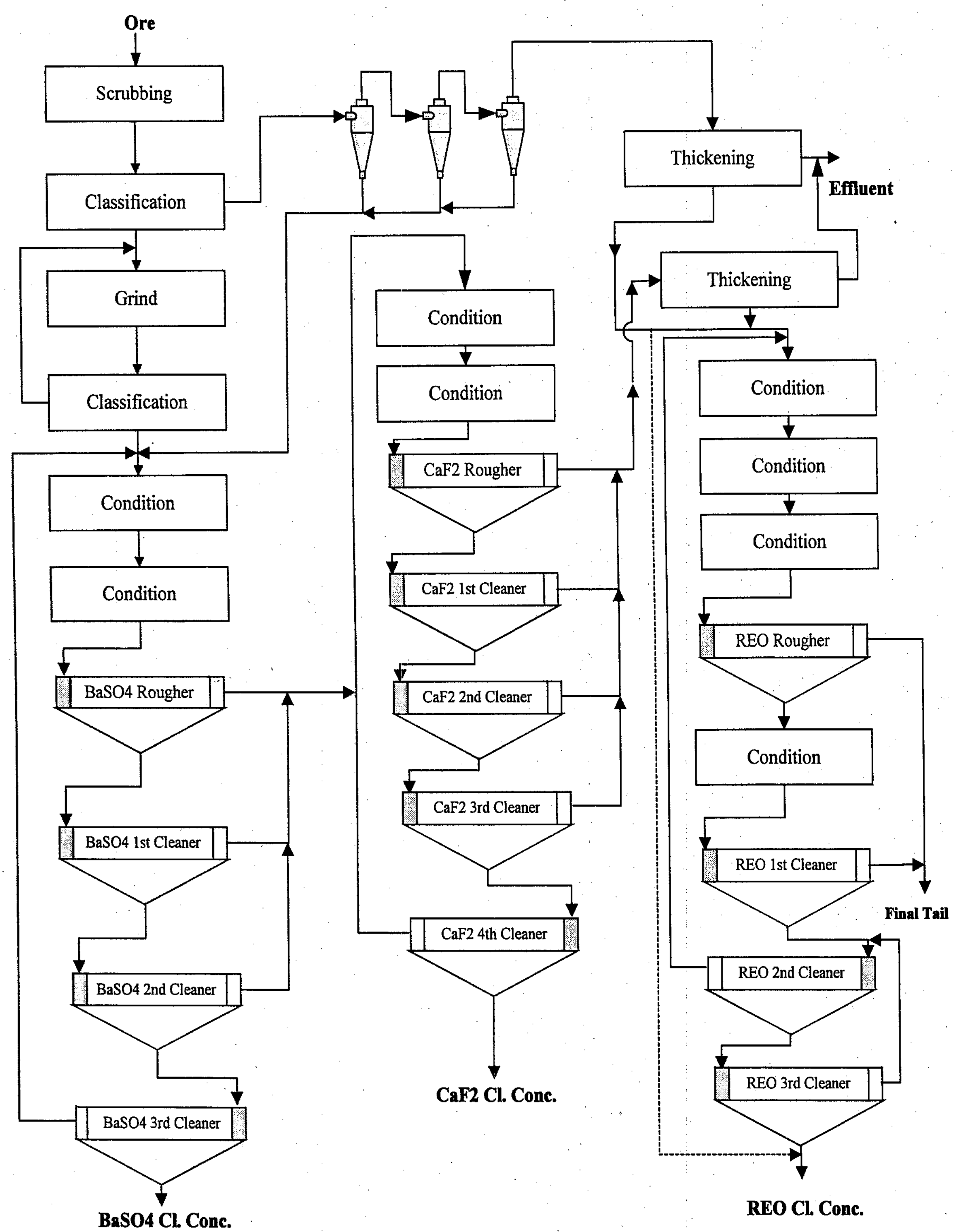

Figure II-6-2 Flotation Process Flow (Locked Cycle Test)

(2) Flotation Test Result by Ore Types

It was virtually impossible to mineralogically distinguish ore types only by visual observation on-site. Accordingly the ore samples collected from drill cores were principally classified into 3 categories by color based on visual observation, namely yellow, black and gray ore types. The gray ore type was further sub-classified into 2 types, the gray ore of upper level and that of lower level. The sampling locations and assay results are shown in Table II-6-3. Batch tests were conducted for the samples of these 4 types of ores in order to examine the difference in metallurgical characteristics by the ore types. The ore samples that had been submitted to the 1st Year flotation test were generally similar to those of the black ore type (F2) in composition.

Table II-6-3 Sampling Locations and Assay Results of 4 types of Ore Samples

Element			Assays				
			Sample F1 (Yellow)	Sample F2 (Black)	Sample F3 (Mixed)	Sample F4 (Mixed)	Test Composite
Cerium	Ce_2O_3	%	12.7	3.88	8.57	8	3.46
Lanthanum	La_2O_3	%	9.7	3.12	6.53	6.1	2.8
Total REO	REO	%	26.2	8.34	17.8	16.6	7.66
Barium	$BaSO_4$	%	36.7	67.9	24.3	20.7	65.3
Fluorspar	CaF_2	%	18.1	0.97	24.5	18.6	5.27
Silica	SiO_2	%	10.6	9.58	9.31	5.77	9.43
Alumina	Al_2O_3	%	0.52	1.77	1.12	0.97	1.17
Iron	Fe_2O_3	%	1.72	3.6	1.04	0.95	2.77
Magnesia	MgO	%	<0.05	0.25	0.05	0.06	0.08
Calcium	CaO	%	10.4	0.57	25.3	28.3	6.02
Cal Ca	CaO	%	0	0	7.7	14.9	2.2
Sodium	Na_2O	%	0.07	0.07	0.07	<0.05	<0.05
Potassium	K_2O	%	0.07	0.23	0.18	0.14	0.06
Titanium	TiO_2	%	0.06	0.18	0.09	0.1	0.10
Phosphorus	P_2O_5	%	0.19	0.63	0.06	0.13	0.48
Manganese	MnO	%	0.38	2.03	0.23	0.46	-
Chromium	Cr_2O_3	%	<0.01	<0.01	<0.01	<0.01	<0.01
Vanadium	V_2O_5	%	<0.01	0.01	0.01	<0.01	0.02
LOI		%	9.64	5.03	11.9	18.8	-
Total		%	104.3	100.6	98.4	98.2	94.6
(Back Calculation)							
REO			24.8	8.46	16.9	15.9	7.66
$BaSO_4$			36.5	69.2	25.8	22.7	65.3
CaF2			19.2	2.27	27.6	18.8	5.27
Others			19.5	20.07	29.7	42.6	21.77

Sample No.	Weight(kg)	Type of ore	Boring No.	From	To	Note
F1	20	Yellow ore	MJVD-6	69.00 70.00 74.00 76.40	69.40 71.55 74.90 78.00	Mainly yellow color bastnaesite rich ore
F2	20	Black ore	MJVD-12	70.00 82.00	71.00 84.60	Mainly black color ore with a little bit light yellow color ore
F3	20	Mixed ore	MJVD-10	50.00	57.00	Grey, purple, white, dark brown, light brown, brown mixed ore
F4	20	Mixed ore	MJVD-9	75.00 79.00	76.00 83.00	Grey, dark grey, dark brown, light brown mixed ore

(3) RE_2O_3 Grade-Recovery Curve by Ore Type

The RE_2O_3 grade-recovery curve by ore type is prepared according to the test results and is shown in Figure II-6-3.

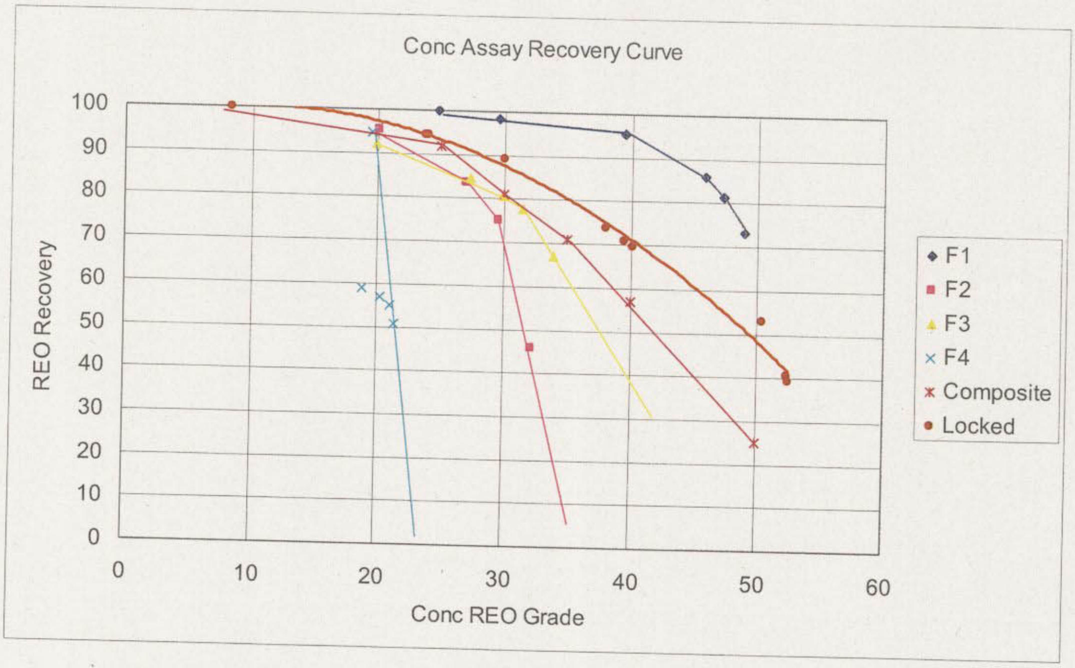

Figure II-6-3 RE_2O_3 Grade-Recovery Curve by Ore Type

- The recovery rate is the best for the F1 and declines in the order of those for the composite, the F3, the F2 and F4.
- Differences of 5 to 6%, 10 to 12% and 20 to 25% in the recovery rates between the best metallurgical results of the locked-cycle test and those of the batch test for the composite are observed at the concentrate grades of 30%, 40% and 50% RE_2O_3 respectively, according to the test results to date.
- The F2 test sample indicated significantly low recovery rates for the concentrate grade higher than RE_2O_3, which was possibly resulted from shortcutting the CaF_2 circuit because of the low CaF_2 content in the test sample.
- The F1 test sample contained 26.2% RE_2O_3 and indicated a high recovery rate even for the high grade concentrate. However, the sample had been collected at depth and would not be referred to ores in the currently designed pit.
- In contrast, it was very difficult for the F4 test sample to obtain sufficiently high grade concentrates with satisfactory recovery rates. The sample contained less RE_2O_3, CaF_2 and $BaSO_4$ than other test samples and indicated a significant ignition loss, suggesting high clay content.

Table II-6-4 Proportion of Tested Ore Types in the Designed Pit

F1	F2	F3	F4
0.2%	31.5%	66.7%	1.6%

(4) Relationship bwtween Feed RE_2O_3 Grade and Recovery Rate

The relationship between the feed RE2O3 grade and the recovery rate is obtained from the test results for the 4 ore types and shown in Figure II-6-4.

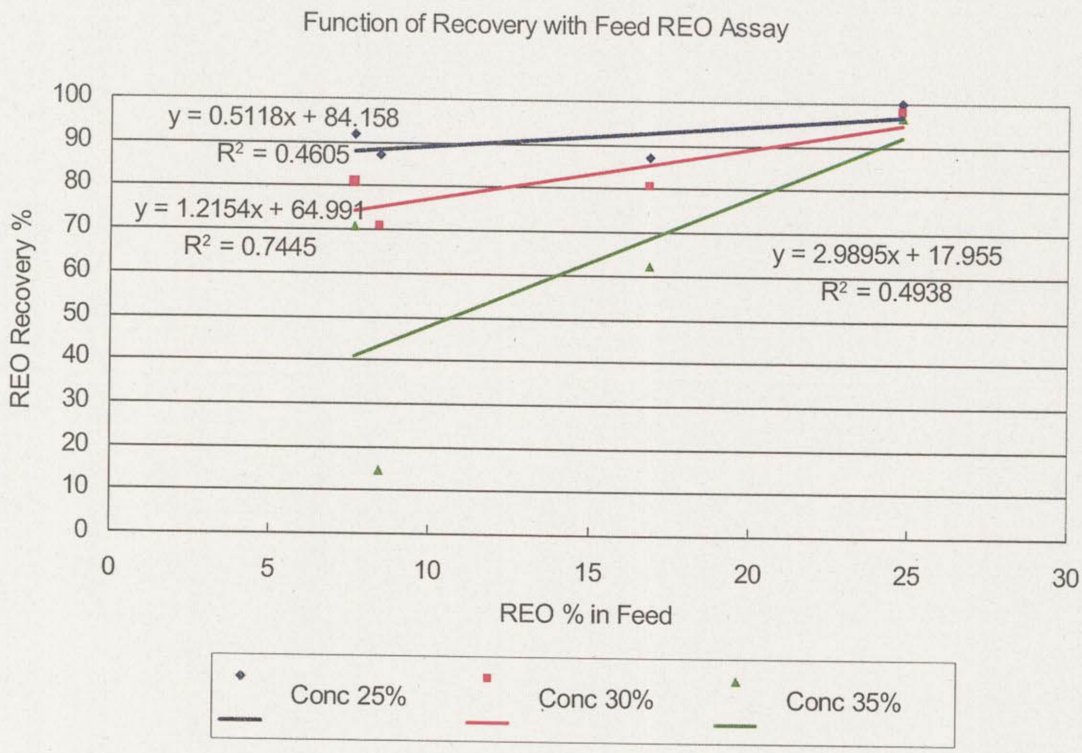

Figure II-6-4 Function of Recovery with Feed REO Assay

These parameters were set based on the test results only for the four types of ores, actually excluding the F4 test sample. It will be rquired to conduct further flotation tests for representative composite samples of drill cores and to make multivariate analysis for the test result, in order to establish meatallurgical parameters serving for a realistic mine development plan.

6-3 Design Parameters for Flotation Plant

(Feed)

Total Ore throughout Mine Life (ton) : 3 M t

REO : 6 %

CaF_2 : 8.7%

$BaSO_4$: 39.0%

(Metallurgical Parameters)

REO : Concentrate Grade 40%, Recovery 70%

CaF_2 : Concentrate Grade 44%, Recovery 55% (disposed to the tailing dam)

$BaSO_4$: Concentrate Grade 95%, Recovery 90%

(Grinding and Classifying (Desliminig))

Particle Size of Slime : −200 mesh

Grinding Size : −150 mesh (105 μ m)

Wi : 6.6 kWh/t

Chapter 7 Assessment of Economic Viability of the Dong Pao F3 Ore Body

7-1 Objectives

The study of the current Project is limited to the mining-flotation operation that produces rare earth concentrates as the final product. It is, however, extremely difficult to market bastnaesite concentrates in the present international rare earth marketplace. Therefore, it is necessary to study post-flotation metallurgical processes that produce marketable products, in order to properly assess the economic viability of the Dong Pao F3 Ore Body. The objectives of this assessment are to preliminarily examine the economic viability of the mining and the flotation process for the F3 Ore Body and to find a justification for extending the current study to the preliminary feasibility study including the post-flotation metallurgical and the product market researches. In this assessment, it is assumed that bastnaesite concentrate is the only valuable product of the flotation process, although fluorite and barite concentrates are also produced.

7-2 Preposition

The current Project is still premature to determine parameters for the economic assessment with acceptable certainty at this stage. The price of US$ 2.87/kg RE_2O_3 for the bastnaesite concentrate with the standard grade of 60% RE_2O_3, as quoted in USGS Commodity Summary (2001), is adopted to estimate the value of the concentrates produced from the Dong Pao ores. A conceptual cost for the post-flotation process is introduced to estimate values of concentrates lower than the standard grade of 60% RE_2O_3, by assuming that mischmetal is the final product placed in the market with the price at US$ 5/kg(quoted at US$ 5 to 7/kg in USGS Commodity Summary(2001)). These quoted prices are standards in the US domestic market and are not necessarily applied to actual trading in the world market. Since the rare earth market is oligopolistic, product prices tend to be determined on spot basis. Therefore, it is extremely difficult to forecast long term effective market prices.

In addition to the uncertainty in the market, the examination is still in a premature stage to determine the parameters necessary for estimation of the mining reserves, plan and design of the mine and the flotation plant, preparation of the production schedule and economic assessment of the entire exploitation scheme. It must be noted, therefore, that the results of this assessment are possible economic indications of the Dong Pao F3 Ore Body in the order of magnitude.

7-3 Parameters for the Economic Assessment

7-3-1 Mining Reserves

(1) Geological Ore Reserves

The total geologic reserves are estimated at approximately 30million tons containing 1.84% RE_2O_3, 3.37% CaF_2 and 16.84% $BaSO_4$. Looking at the reserves with the average grade of 8% RE_2O_3, a total of 2,051,446tons of ores are available at the cut-off grade of 6% RE_2O_3 averaging 7.93% RE_2O_3, 13.59% CaF_2 and 35.40% $BaSO_4$. These figures suggest that the waste to ore ratio (W/O) would become high in an open pit where a high average grade of RE_2O_3 is required for a profitable operation.

(2) Pit Design

An open pit operation is proposed to mine the F3 Ore Body. The pit design and the in-pit reserve estimation were made according to the geological reserves as above mentioned, taking account of operation and economic parameters. The Lerchs-Grossman method of Medsystem was employed for the design and reserve estimation.

Design Parameters

Overall Pit Slope : 34°
Bottom Level : 780m
Ramp Width : 15m
Ramp Grade : 10%
Berm Width : 2m
Bench Height : 5m
Slope Face Angle : 75°
Unit Block Dimension : 10mx10mx5m
Mining Cost for Ore : 5 $ /t
For Waste : 5 $ /t
Processing Cost : 13 $ /t
Recovery : Calculation according to Feed Grade(RE_2O_3)

(3) In-pit Reserves

The in-pit reserves are compared in the pits with the assumed price at US$ 1.00, 1.40, 1.80 and 2.18 /kg RE_2O_3 (pit identifications; P100, P140, P180 and P218) as shown in Table II-7-1.

Based on Table II-7-1, the in-pit reserve of P180 with the cut-off grade of 5% RE_2O_3 was selected for the economic assessment as follows, taking account of the total amount of the reserves, the average RE_2O_3 grade and the waste-to-ore ratio.

- Ores≥5% RE_2O_3 : 983,796 tons,
  6.96% RE_2O_3, 10.00% CaF_2, 39.27% $BaSO_4$
- Low Grade Ores<5% RE_2O_3 : 2,237,476 tons,
  2.12% RE_2O_3, 1.76% CaF_2, 33.61% $BaSO_4$
- Waste : 256,194 tons
- Overall Waste to Ore Ratio : (2,237,476+256,194)/983,796=2.535

Table II-7-1 Comparison of Ore and Waste in Designed Pit

Designed Pit	P100	P140	P180	P218
Price : US$/kg$RE_2O_3$	1.00	1.40	1.80	2.18
Bench : Top	1,015	1,015	1,020	1,075
Bottom	815	800	795	780
Ore(ton),Cut-off0	446,732	2,443,820	3,221,272	12,762,034
Av.RE_2O_3(%)	6.12	3.92	3.60	2.04
1	426,144	2,045,060	2,595,772	6,357,973
Av.RE_2O_3(%)	6.40	4.63	4.42	3.99
2	386,724	1,706,549	2,138,648	5,130728
Av.RE_2O_3(%)	6.90	5.23	5.02	4.58
3	329,940	1,376,556	1,691,968	3,680,396
Av.RE_2O_3(%)	7.69	5.93	5.72	5.40
4	314,870	1,133,051	1,328,883	2,441,735
Av.RE_2O_3(%)	7.88	6.46	6.31	6.39
5	291,373	854,212	983,796	1,764,992
Av.RE_2O_3(%)	8.17	7.10	6.96	7.12
6	235,918	521,138	564,038	1,105,254
Av.RE_2O_3(%)	8.80	8.18	8.11	8.11
7	200,617	380,225	400,401	748,229
Av.RE_2O_3(%)	9.21	8.84	8.80	8.91
8	157,172	252,904	263,304	482,016
Av.RE_2O_3(%)	9.70	9.50	9.46	9.70
9	100,128	122,644	122,644	258,624
Av.RE_2O_3(%)	10.34	10.57	10.57	10.73
10	56,448	68,564	68,564	142,144
Av.RE_2O_3(%)	10.99	11.43	11.43	11.78
Waste (ton)	186,455	1,837,326	2,493,670	11,576,857
W/O, Ore>=5	0.640	2.151	2.535	6.559
Waste (ton)	241,910	2,170,400	2,913,428	12,236,595
W/O, Ore>=6	1.025	4.165	5.165	11.071

7-3-2 Production Schedule

(1) Annual Operation Days

300 days/annum

(2) Mining Rate

- Pre-production Stripping : 329,319 tons,
- Annual Average Mining Rate

  Ores : 75,000 tons, 6.96% RE_2O_3, 10.00% CaF_2, 39.27% $BaSO_4$

  Waste : 165,000 tons

  Total Tonnage : 240,000 tons

  W/O Ratio(Average) : 2.2
- Mine Life : 13.1Year

(3) Average Annual Production Rate of Concentrates

The flotation test result of the 2nd Year Campaign indicated that concentrates with the grades of 30%, 40% and 50% RE_2O_3 were obtained at the recovery rates of 90%, 70% and 50% respectively. However, the test samples contained 8% or better RE_2O_3 and one batch test showed a possibility to lower a recovery rate with the lowered feed grade to obtain a concentrate with 35% RE_2O_3. Therefore, the recovery rate of 60% and the concentrate grade of 40% RE_2O_3 were set for the average feed grade of 6.96% RE_2O_3 as the realistic metallurgical parameters.

- Feed Amount(Annual Average): 75,000 tons, 6.96% RE_2O_3, 10.00% CaF_2, 39.27% $BaSO_4$
- Recovery Rate : 60% RE_2O_3, 60% CaF_2, 95% $BaSO_4$
- Concentrate Amount(Annual Average) : 7,830 tons RE_2O_3, 11,250 tons CaF_2, 29,453 tons $BaSO_4$
- Concentrate Grade : 40% RE_2O_3, 40% CaF_2, 95% $BaSO_4$

  Amount of Contained Mineral(Annual Averageaaa9 : 3,132 tons RE2O3, 4,500 tons CaF_2, 27,980 tons BaSO4

(4) Annual Production Schedule

An annual production schedule is prepared on the assumption to mine the ores from the upper to lower levels successively and is shown in Table II-7-2.

7-3-3 Development Plan

The dispositions of the mine and plant facilities are shown in Figure II-7-1. The construction period of 2 years is assumed. Karst morphology is extensively developed in the Project Area, forming numerous doline, polje and ponor. There fore, it is essential to conduct detailed geotechnical investigation for the planned sites of surface structures.

(1) Mining

Table II-7-2 Yearly production schedule

Year		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Mine	Ore(ton)			75,000	75,000	75,000	75,000	75,000	75,000	75,000	75,000	75,000	75,000	75,000	75,000	75,000	8,796
	RE_2O_3(%)			6.91	7.37	7.47	7.47	7.32	6.73	7.13	7.24	6.91	6.82	6.70	6.48	5.98	5.74
	CaF_2(%)			10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
	$BaSO_4$(%)			39.27	39.27	39.27	39.27	39.27	39.27	39.27	39.27	39.27	39.27	39.27	39.27	39.27	39.27
	Waste(ton)	164,660	164,659	200,000	200,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	170,000	150,000	4,351	0
	Total(ton)	164,660	164,659	275,000	275,000	255,000	255,000	255,000	255,000	255,000	255,000	255,000	255,000	245,000	225,000	79,351	8,796
Flotation	Feed(ton)			75,000	75,000	75,000	75,000	75,000	75,000	75,000	75,000	75,000	75,000	75,000	75,000	75,000	8,796
	RE_2O_3(%)			6.91	7.37	7.47	7.47	7.32	6.73	7.13	7.24	6.91	6.82	6.70	6.48	5.98	5.74
	CaF_2(%)			10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
	$BaSO_4$(%)			39.27	39.27	39.27	39.27	39.27	39.27	39.27	39.27	39.27	39.27	39.27	39.27	39.27	39.27
	Conc.(ton)																
	RE_2O_3			7774	8291	8404	8404	8235	7571	8021	8145	7774	7673	7538	7290	6728	757
	CaF_2			11250	11250	11250	11250	11250	11250	11250	11250	11250	11250	11250	11250	11250	1319.4
	$BaSO_4$			29453	29453	29453	29453	29453	29453	29453	29453	29453	29453	29453	29453	29453	3454
	RE_2O_3(%)			40	40	40	40	40	40	40	40	40	40	40	40	40	40
	CaF_2(%)			40	40	40	40	40	40	40	40	40	40	40	40	40	40
	$BaSO_4$(%)			95	95	95	95	95	95	95	95	95	95	95	95	95	95
	in Conc.																
	RE_2O_3(ton)			3110	3317	3362	3362	3294	3029	3209	3258	3110	3069	3015	2916	2691	303
	CaF_2(ton)			4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	528
	$BaSO_4$(ton)			27980	27980	27980	27980	27980	27980	27980	27980	27980	27980	27980	27980	27980	3281

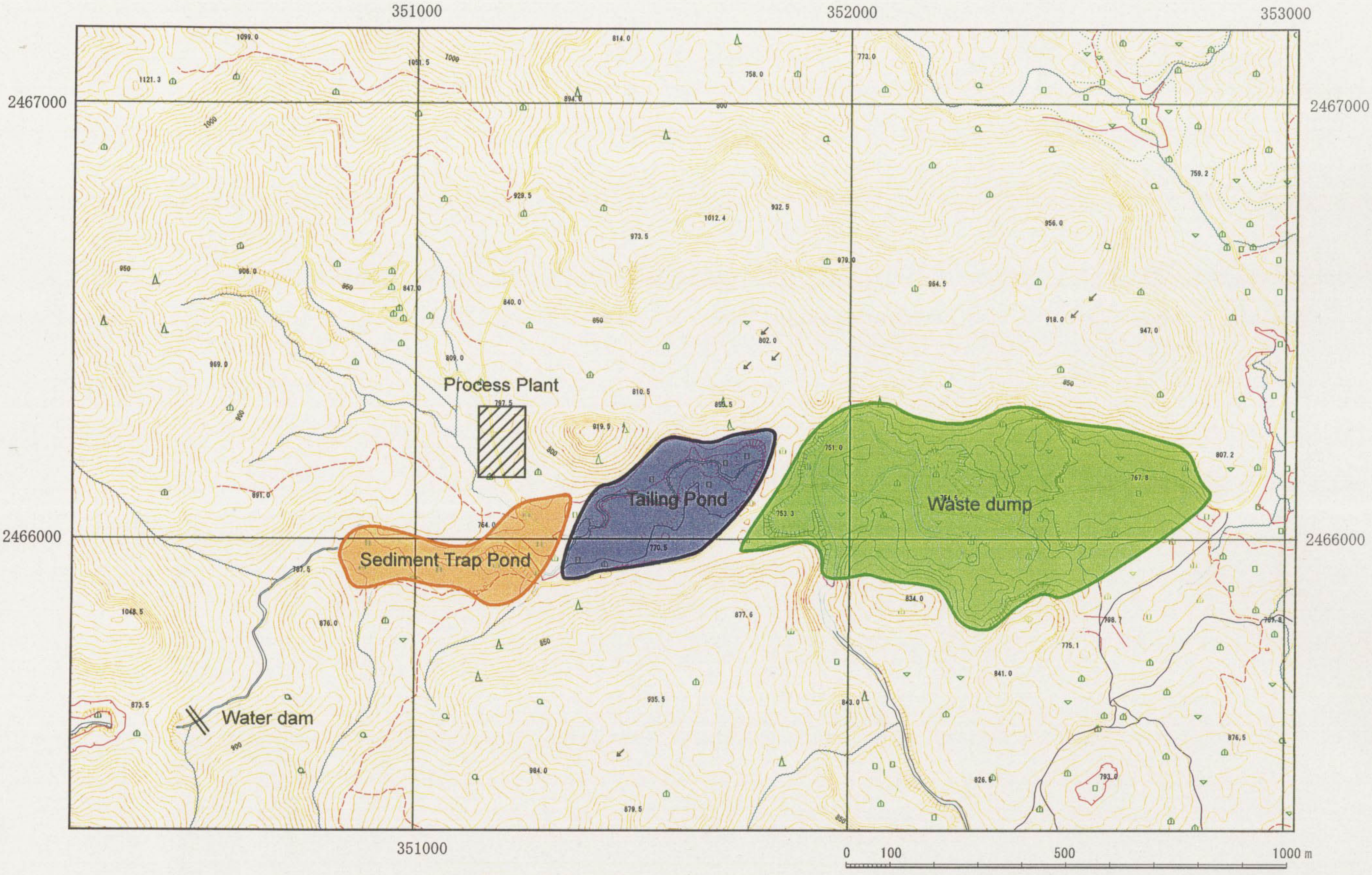

Figure Ⅱ-7-1 Mine facilities layout plan

The mine development plan includes preparatory excavation (removal of soil cover and waste), equipment selection and purchase, and construction of the waste disposal and of other mine facilities(mine office, repair shop and other buildings).

(2) Flotation

The development plan includes design and construction of the flotation plant, selection, purchase and installation of the plant facilities and equipment, and construction of the tailing dam and of other buildings and facilities.

(3) Infrastructures

The infrastructures that may become necessary for the exploitation are an independent power plant for emergency use, a water supply system, an access road from Old Dong Pao and a telephone line from Binh Lu to Dong Pao.

7-3-4 Operation Plan

(1) Mining

An open pit mining is to be employed. The operation will be carried out on 3-shift a day, 6-days a week and 300-days a year basis. The work force is assumed to comprise 61 in total number.

(2) Flotation

Ores are crushed and ground and then put into the reversed flotation circuit to sequentially produce barite, fluorite and bastnaesite concentrates. The bastnaesite concentrate is condensed in the thickener, dewatered by the pressure filter and then store in the concentrate storage. The operation will be carried out on 3-shift a day, 6-days a week and 300-days a year basis. The work force is assumed to comprise 36 in total number.

(3) Administration and General

The administration office is responsible for the overall operation management, the accounting and financing, the safety and sanitation, the product marketing and inventory control, the public relations and so forth. The work force is assumed to comprise 61 in total number.

7-3-5 Capital and Operating Costs

The capital and operating costs are estimated as follows.

(1) Capital Cost (in US $)

Mining:	5,927,221
Flotation:	5,294,000
Infrastructure:	3,155,000
Working Capital (3-month Operating Cost):	880,500
Capital Cost Total	15,256,721

(2) Operating Cost (Annual Average, in US $)

Mining:(75,000 tons Ore, 165,000 tons Waste, Total 240,000 tons @ US $ 7.00 / ton)

	1,680,000
Flotation:(75,000 tons Feed, @ US $ 20.29 / ton)	1,521,750
A & G:(@ US $ 4.27 / ton of Feed)	320,250
Operating Cost Total:	3,522,000

7-4 Profit-Loss Estimation

7-4-1 Annual Production and Profit-Loss Schedules

The profit-loss is estimated year by year in accordance with the production schedule as shown in Table II-7-2. Although the run-of-mine, equal to the flotation feed, is constant at 75,000 tons/year, the revenue changes year-by year as the run-of-mine grade, that is the flotation feed grade, changes. While the annual operating cost for the flotation is constant with the constant annual feed rate, the annual mining cost declines with the amount of waste reducing towards the bottom of the pit. The profit loss schedule is shown in Table II-7-3.

7-4-2 Assumptions

Revenue : Since the rare earth market is oligopolistic, product prices tend to be determined on spot basis between the buyer and the seller concerned. Therefore, it is extremely difficult to forecast long term effective market prices. The price of US$ 2.87/kg RE_2O_3 for the bastnaesite concentrate with the standard grade of 60% RE_2O_3, as quoted in USGS Commodity Summary (2001), is adopted in this economic assessment to estimate the value of the concentrate produced from the Dong Pao ores. A conceptual cost for the post-flotation process is estimated by comparing the value of the concentrate with the standard grade of 60% RE_2O_3 with that of mischmetal, the supposed final product, sold in the market at the price of US$ 5/kg(quoted at US$ 5 to 7/kg in USGS Commodity Summary(2001)). The surplus of the mischmetal value to the raw material, concentrate value is regarded as the post-flotation processing cost, including the operating cost, the depreciation for the capital cost, the taxes and levies and the profit margin. It is assumed that this surplus must be maintained with any bastnaesite concentrates, regardless of their grades in RE_2O_3. In case of the Dong Pao concentrate with the grade of 40% RE_2O_3, the price of RE_2O_3/kg contained must be discounted by US$ 0.70 to US$ 2.17/kg from US $ 2.87/kg for the standard 60% RE_2O_3 concentrate. This price of US$ 2.17/kg RE_2O_3 is applied to estimation of the revenue.

Meanwhile, no values are given to the fluorite and the barite concentrates.

Table II-7-3 Profit-Loss Estimation and Cash Flow Schedule

Year		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Production	ROM('000t)			75,000	75,000	75,000	75,000	75,000	75,000	75,000	75,000	75,000	75,000	75,000	75,000	75,000	8,796
	RE2O3(%)			6.91	7.37	7.47	7.47	7.32	6.73	7.13	7.24	6.91	6.82	6.70	6.48	5.98	5.74
	Waste('000t)			200,000	200,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	170,000	150,000	4,351	0
	Total('000t)			275,000	275,000	255,000	255,000	255,000	255,000	255,000	255,000	255,000	255,000	245,000	225,000	79,351	8,796
	Feed('000t)			75,000	75,000	75,000	75,000	75,000	75,000	75,000	75,000	75,000	75,000	75,000	75,000	75,000	8,796
	RE2O3(%)			6.91	7.37	7.47	7.47	7.32	6.73	7.13	7.24	6.91	6.82	6.70	6.48	5.98	5.74
	Conc.(t)			7,774	8,291	8,404	8,404	8,235	7,571	8,021	8,145	7,774	7,673	7,538	7,290	6,728	757
	RE2O3(%)			40	40	40	40	40	40	40	40	40	40	40	40	40	40
	RE2O3(t)			3,110	3,317	3,362	3,362	3,294	3,029	3,209	3,258	3,110	3,069	3,015	2,916	2,691	303
Operating	Mine			1,925	1,925	1,785	1,785	1,785	1,785	1,785	1,785	1,785	1,785	1,715	1,575	555	62
Cost	Mill			1,522	1,522	1,522	1,522	1,522	1,522	1,522	1,522	1,522	1,522	1,522	1,522	1,522	178
('US$'000)	A & G			320	320	320	320	320	320	320	320	320	320	320	320	320	38
	Total			3,767	3,767	3,627	3,627	3,627	3,627	3,627	3,627	3,627	3,627	3,557	3,417	2,397	278
Revenue	(US$'000)			6,748	7,197	7,294	7,294	7,148	6,572	6,962	7,070	6,748	6,660	6,543	6,328	5,839	657
Operating Profit	(US$'000)			2,981	3,430	3,667	3,667	3,521	2,945	3,335	3,443	3,121	3,033	2,986	2,911	3,442	380
Depreciation	(US$'000)			1,610	1,949	2,423	2,000	1,500	1,500	1,000	1,000	749					
Taxable Profit	(US$'000)			-0	0	2	700	1,347	1,042	2,171	2,443	2,372	3,033	2,986	2,911	3,442	380
Tax @40%/y	(US$'000)			0	0	0	280	539	417	868	977	949	1213	1194	1164	1377	152
Profit after Tax	(US$'000)			1,371	1,481	1,244	1,388	1,482	1,028	1,467	1,466	1,423	1,820	1,791	1,746	2,065	228
Construction Cost	(US$'000)	7,629	7,628														
Loan	(US$'000)	7,629	7,628														
Interest @ 8%/y	(US$'000)	610	1,269	1,371	1,481	1,242	968	674	403	165							
Repayment	(US$'000)				2,981	3,430	3,667	3,388	2,982	2,225							
Cum. Loan	(US$'000)	8,239	17,137	18,508	15,527	12,097	8,430	5,042	2,060	0							
Cash Flow	(US$'000)	-8,239	-8,897	2,981	3,430	3,667	3,388	2,982	2,528	2,467	2,466	2,172	1,820	1,791	1,746	2,065	228
Cum. Cash Flow	(US$'000)	-8,239	-17,136	-14,156	-10,726	-7,059	-3,671	-689	1,840	4,307	6,773	8,944	10,764	12,555	14,302	16,367	16,595
DCF @ 15.7%/y	(US$'000)			2,576	2,562	2,368	1,890	1,438	1,054	889	768	585	423	360	303	310	30
Cum. DCF	(US$'000)			2,576	5,138	7,506	9,397	10,835	11,889	12,778	13,546	14,130	14,554	14,914	15,217	15,528	15,557
DCF @ 16%/y	(US$'000)			2,569	2,549	2,350	1,871	1,420	1,038	873	752	571	412	350	294	300	29
Cum. DCF	(US$'000)			2,569	5,118	7,467	9,338	10,758	11,796	12,669	13,421	13,992	14,405	14,755	15,049	15,349	15,377

(2) Financing for and Depreciation of Capital Cost

- It is assumed that the capital cost will be allocated evenly for each year of the 2-year construction period.
- Financing:

  In reality, 20 to 30% of the capital cost will be raised on equity basis and the rest, on loan basis. In this estimation, however, it is simply assumed that 100% of the capital cost is raised by loan at the interest rate of 8%/annum.
- Depreciation:

  It is assumed to depreciate 90% of the capital cost in the initial 9-year operation. The amounts of the depreciation in the initial 3-year period are adjusted in the depreciation schedule to produce no taxable profit.
- Loan Repayment:

  It is assumed that the positive cash flow generated in each production year is entirely appropriated to the loan repayment until the loan is completely written off.

(3) Income Tax

The income tax rate is assumed at 40% of the profit after the depreciation and the interest on loan. At the present stage, investigation on the taxation system in Vietnam has been insufficient. Further investigation will be required for the income and other taxes, levies and royalties applied to a mining enterprise.

7-4-3 Result of the Estimation

(1) Payback Year : The loan to the capital cost of US $ 15,256,721 can be repaid within 7 years at the loan interest rate of 8%/annum.

(2) Discounted Cash Flow : The discount rate for the cash flow is estimated at approximately 16%/annum.

7-5 Environmental Impact by Exploitation

7-5-1 Law on Environment

Law on Environment of the Socialist Republic of Vietnam that has been obtained in the course of the Current Project, describes fundamental standards and regulations for environmental conservation in general. However, it contains no numerical codes or regulatory figures to control industrial and domestic activities with respect to the environmental conservation. It is considered reasonable to refer to the Japanese Environmental standards, regulations and codes.

7-5-2 Environmental Impact Assessment

Law of Environment prescribes that it is necessary to conduct an environmental impact study on the occasion of planning an exploitation of natural resources. An environmental base-line study was conducted for a conceptual environmental impact assessment.

There are two communities, New Dong Pao and Dong Pao, in the neighbour of the Project Site. It is assumed that New Dong Pao, the closest community to the planned mine site, will be relocated. The Japanese numerical standards and codes are referred to for assessment of allowable discharges and emissions.

The on-site investigation was carried out for atmosphere, water quality, noise and vibration, land uses, vegetation, public facilities and cultural assets, and radioactivity.

The stream water of the Project Area is weakly alkaline indicating pH 7.33 to 8.55 and is slightly higher than the upper limit of pH allowed in the Japanese environmental standards for the industrial and agricultural water (pH 6.0 to 8.5). The water quality survey indicated that the stream water contained 0.25 to 0.32 mg/l of As, 0.79 to 2.42 mg/l of F and 0.001 mg/l of Hg. These As, F and Hg contents exceed the limits prescribed at 0.01 mg/l As and 0.0005 mg/l Hg in the Environmental Standards for Protection of Human Health of Japan.

The Dong Pao ores contain a minor amount of U and Th that are radioactive. These elements tend to be concentrated in the products of the mineral processing and may be contaminated in discharges from the open pit and the plant. Special attention has to be paid on the storage of the rare earth concentrate and the effluent from the flotation plant.

A part of the land may become unavailable for cultivation and grazing when the exploitation starts. Investigation on faunas has not been conducted to-date and will be required in future.

No other serious environmental issue has been observed.

7-6 Discussion on the Economic Assessment

(1) In-pit Ore Reserves

The annual production of bastnaesite concentrate containing some 3000 tons RE_2O_3 appears to be appropriate based on the in-pit reserves of just short of 1million tons with an average grade of approximately 7% RE_2O_3 at the cut-off grade of 5% RE_2O_3. The ore reserve estimation is limited to the extent for which the drill holes have been put down to-date. According to the surface exploration result, the in-pit reserves will increase in some tonnage from the southern end of the drilling grid to the Dong Pao river. However, the increase will not be so substantial as to drastically change the production schedule. The cut-off grade at the operating cost break-even point is approximately 2.2% RE_2O_3, which substantially increases the in-pit reserves with the significantly reduced average grade. At the present stage, it is concerned that the reduced feed grade may adversely affect the flotation performances, specifically the recovery rates and the concentrate grade. Further detailed flotation tests will be required to verify the relationship between the feed grade and the flotation performances.

(2) Valuation of By-products

No values are given to either the barite or the fluorite concentrate in this assessment. It will significantly contribute to the project profit, if these concentrates are marketable. The largest demand for barite concentrate can be expected for drilling mud in oil drilling. The off-shore oil and gas exploration may be a promising market. Market research is necessary.

(3) Mineral Processing Technology for Beneficiation of Rare Earth Ores.

Rare earth ores are unique in their mineralogical characteristics from one occurrence to another and requires suitable flotation processes for their own mineralogical nature. A flotation process suitable for the Dong Pao ores has been developed in the course of the flotation test during the 2nd Year Campaign of the Current Project. This flotation process has made it possible to produce a bastnaesite concentrate acceptable in a post-flotation metallurgical processing plant.

(4) Post-flotation Metallurgical Process

No technological and economic assessment for any post-flotation metallurgical processes is included in this economic assessment. Since the bastnaesite concentrate is hardly marketable in the present market place, it is necessary to produce marketable products such as mischmetal or high grade rare earth oxides through post-flotation metallurgical processes. Mineralogical nature of concentrates also differs from on source to another and requires suitable post-flotation processes for their own nature. Therefore, it is essential to conduct a test for the post-flotation process using the products of the current flotation test, in order to appropriately assess the feasibility for the exploitation of the Dong Pao F3 Ore Body. Although mischmetal is assumed as the final product for marketing in this economic assessment, cerium oxide can be extracted in an early stage of an ordinary metallurgical process. It will increase the total value of the metallurgical products, if it is possible to extract and concentrate cerium oxide to a marketable degree.

(5) Treatment of Radioactive Elements

Contamination of radioactive elements into concentrates is inevitable due to mineralogical nature of the ores. This is one of the major reasons that make it difficult to market the bastnaesite concentrate. It is technologically impossible to eliminate radioactive elements in the flotation process and is one of the major subjects in the post-metallurgical process. Handling of substances containing radioactive elements is the important subject for the entire production line.

(6) Result of Economic Assessment

The results of the economic assessment with the 7-year payback period and the 16% discount rate are not particularly attractive for an investment target, however, warrant to proceed to the stage for a post-flotation metallurgical test and for an economic assessment on more realistic basis. It must be noted that this economic assessment contains a great deal of uncertainty in various areas and should be completely reviewed upon the completion of the post-flotation metallurgical test.

Chapter 8 Conclusions and Recommendations

8-1 Conclusions

(1) Project Outline

This Project is the Mineral Exploration in the Dong Pao Area in the Socialist Republic of Vietnam and was executed in the 2-Year period of the Japanese fiscal 2000 and 2001.

The 1st Year Campaign comprised the geological survey for the entire Project Area, the environmental baseline study, the drilling investigation on the F3 Ore Body and the flotation test on the F3 ore samples. The 2nd Year Campaign comprised the geological survey for the F7 Ore Body and its environ, the trench investigation for the western part of the F7 Ore Body, the follow-up environmental base-line study, the additional drilling investigation for the F3 Ore Body, the follow-up flotation test on the F3 ore samples and the on-site data collection for possible future exploitation. In addition, economic viability of the F3 Ore Body was preliminarily assessed on the basis of the data acquired during the 2-year project period.

(2) Geological Survey

The geology of the Dong Pao Area consists of the Triassic limestone, shale, sandstone and siltstone, the Palaeogene alkaline volcanics and tuffs, the Palaeogene syenite intrusion and minette dikes. The limestone distributes in the northwestern, western and southeastern parts, and the shale, sandstone and siltstone, in the eastern part of the Project Area. The syenite body intrudes these sedimentary rocks and occupies an extensive area. Most rare earth mineral occurrences are located in the periphery of the syenite body.

This area has been subjected to the regional diastrophism characterized by the structural trend in the NW-SE direction. Major faults striking in this direction are located in the northeastern corner and southern part of the Project Area. A number of lineaments are also developed and are regarded as conjugate shear fractures of the major NW-SE trending faults.

(3) Environmental Baseline Study

The environmental baseline study consisted of the soil survey, the hydrological investigation, the meteorological observation and the vegetation survey. The analytical result of the 1,606 soil samples collected in the course of the soil survey indicates that significant anomalies of RE_2O_3 are associated with the ore bodies such as F1, F3, F4, F7, F9, F10, F14 and F16. Anomalies of $BaSO_4$ and CaF_2 show fair agreements in their distributions with the RE_2O_3 anomalies.

Stream water is weakly alkaline, indicating pH in the range of 6.98 to 8.52 in general. The headwater of the Dong Pao river ranges from 7.70 to 7.90 in pH. Therefore, these pH values are considered as the natural background of the stream water in the region.

According to the result of the trace element analysis, the stream water is relatively high in As and F contents ranging from 0.25 to 0.32 mg/l and from 0.79 to 2.42 mg/l, which suggests that the terrain of the Project Area has been extensively affected by hydrothermal mineralization to a certain degree. The general nature of the stream water that is neutral to alkaline in pH and several hundreds μ S/cm in conductivity reflects influence of extensive limestone distribution in the terrain.

The tracer test result, using uranine as the tracer, has confirmed that water of the Dong Pao river flows underground and flows out at the headwater of the Nam Hon river. However, there is no evidence for this underground flow to mix with the hot spring water flowing out in the vicinity of the Nam Hon river.

The general area belongs to the semitropical-monsoon climatic region. An annual climatic cycle is observed in the meteorologic data recorded for the last 5 years at the Tam Duong weather observatory. The months from May to August are high in temperature (20 to 24 ℃) and in precipitation (200 to 800 mm/month), and those from September to April next year are low in temperature (13 to 18 ℃) and low in precipitation (0.3 to 200 mm/month). The automatic weather recorder, installed at the Project site for the period of approximately one year in 2001, recorded weekly precipitation exceeding 60 mm including the highest of 154 mm during the wet season. The maximum rainfall intensity was recorded at 32 mm/hour. The maximum instantaneous wind velocity was recorded at 8.0 m/second. The highest of daily maximum temperatures was recorded at 34.4℃, while the lowest of the daily minimum temperatures, at 6℃. The Tam Duong weather observatory recorded the highest daily precipitation at 97 mm for the last two years and the highest weekly precipitation at 384 mm for the last five years.

(4) Trench Investigation

The trench excavation in the western part of the F3 Ore Body exposed the 3 layers of significant mineralization, the uppermost, the intermediate along the road and the lowermost along the creek, all of which are gently inclined. The elevation difference of 55m from the bottom of the creek to the uppermost layer suggests that possible superior ore zones are concealed underground in this part of the F3 Ore Body.

(5) Drilling Investigation

A total of 23 drill holes with the aggregated length of 2,300 m were put down to explore the F3 Ore Body at depth. The geology observed in the recovered drill cores comprises syenite, limestone blocks or boulders and minette dikes intruding these rocks. Significant mineralization, containing 10 % or better RE_2O_3, was intersected by 8 holes out of the 23 holes. In addition, other 5 holes encountered moderate mineralization with the grade ranging from 5 to 10 % RE_2O_3.

(6) F3 Ore Body

The F3 Ore Body, forming an irregular lens, consists of the high grade zone equal to or better than 10 % RE_2O_3 in its center surrounded by the medium grade zone ranging from 5 to 10 % RE_2O_3. Low grade mineralization, surrounding these zones, extends beyond the limit of the drilling grid. Numerous limestone blocks and boulders bound the eastward and westward extensions of the F3 rare earth mineralization. The flat lying high grade zone deepens northward, with the surface elevation increasing, and also weakens in its intensity of mineralization. The lateral extent of the high grade zone is approximately 150 m wide in the east-west and 400 m wide in the north-south.

The ores are rich in light rare earth elements in proportion to medium to heavy rare earths according to the chondrite-normalized REE pattern, which indicates the main rare earth mineral to be bastnaesite. The ore minerals are bastnaesite, hydroxy-bastnesite, synchysite, barite, fluorite and minor monazite and pyrite. The gangues are quartz, calcite, K-feldspar and minor phlogopite, illite, kaolinite, halloysite, smectite and boehmite. Bastnaesite mainly occurs as fine-grained crystals interstitially filling spaces between crystals of barite, fluorite, calcite and other minerals. In part, it forms veinlets crosscutting barite, fluorite and calcite crystals.

(7) Mineralization Other Than the F3 Ore Body

The F1 and F4 ore bodies among others in the Dong Pao area principally consist of fluorite mineralization, with the former being currently mined and the latter having been closed down. In addition to the F3 Ore Body, there are other rare earth ore bodies such as F7, F9 and F10, which may become commercially viable resources.

(8) Genetic Model of Rare Earth Ore Deposits

The Triassic system was subjected to the Alpine Orogenic Movement and broken into a number of blocks by major faults and fracture systems trending mostly in the NW-SE direction. In the early Palaeogene, intrusion of alkaline magmas initiated along the NW-SE trending fault systems at depth. The high-pressure and high-temperature vapor enriched in volatile matters and rare earths were formed at depth and migrated through cooling-joints, formed in the peripheries of syenite bodies or through fractures mechanically formed in surrounding limestone by intruding forces of the magmas. The high pressure-temperature vapor was cooled down to hydrothermal solution , mixing with meteoric water as it ascended, and precipitated rare earth minerals under favorable conditions. The syenite body has been exposed on the surface as the limestone on the top was eroded out. It has been undetermined whether concentrations of rare earths, barite and fluorite were secondarily formed by weathering-oxidation or the present mode of occurrences exhibits the weathered and oxidized states of the primary concentrations.

(9) Geological Ore Reserves

Blocks having a dimension of 20m in N-S, 20m in E-W and 5m in height were set up for the extent of the geological ore reserve estimation, based on the drilling result (23 holes, 2300 m). The composite assay runs with an equal length of 5m that were bounded by block boundaries, were produced to estimate the composite grades by averaging the assay results of original assay runs with the weight of their core length. The specific gravity of 2.6 was adopted for all types of ores and lithological units.

The geological reserves were estimated and collected by changing the cut-off grades from 0 to 15 % RE_2O_3. The table below shows the geological reserves up to the cut-off grade of 11%.

Table : Geological Reserves

Cut off graid %	Insitu ore (BCMS)	Insitu ore (Tonnes)	Average Graid (%)		
			RE2O3	CaF2	BaSO4
0	11,936,707	31,035,436	1.78	3.26	16.32
1	5,732,723	14,905,079	3.59	6.54	31.24
2	4,258,782	11,072,833	4.32	7.81	34.40
3	2,856,637	7,427,256	5.22	9.82	34.45
4	1,839,669	4,783,140	6.20	11.99	34.00
5	1,218,034	3,166,887	7.09	12.90	34.88
6	812,062	2,111,360	7.89	13.87	35.17
7	534,170	1,388,843	8.65	14.39	36.39
8	306,991	798,176	9.49	13.26	39.13
9	158,271	411,504	10.48	12.54	41.15
10	76,111	197,888	11.67	12.91	44.23
11	46,811	121,708	12.44	11.27	45.75

The above reserves exclude the expected reserves to the south of the southern limit of the drilled extent.

(10) Flotation Test

The 1st year flotation test using a conventional process flow failed to effectively separate rare earth minerals possibly due to the intensely weathered nature of the test samples. In the 2nd year test, a new process flow and reagent scheme was developed. The new approach sequentially float barite, fluorite and rare earth minerals in the progressive order. The flotation results were dramatically improved and achieved the recovery rate of 50 % to produce the 50 % RE_2O_3 concentrate and that of 70 % to produce the 40 % RE_2O_3 concentrates. Since this newly developed flotation method are highly effective to treat intensely weathered and oxidized materials.

(11) Economic Viability Assessment for the F3 Ore Body

The economic viability of the F3 Ore Body was preliminarily assessed, although a great deal of uncertainty was included the data acquired to-date. The result indicates that it will be possible to produce some 3,000 tons of RE_2O_3 contained in concentrate annually for the period of approximately 13 years. The mine and flotation plant development will require some US $ 15 million of the initial investment. The discounted rate of return to the initial investment is estimated at approximately 16% per annum, which is not necessarily high but suggests a certain economic viability of the exploitation of the F3 Ore Body. A conceptual post-flotation processing cost was taken into account in this estimation, however, without any technical supports. Metallurgical testing for the post-flotation processes is currently being conducted. This estimation has to be comprehensively reviewed after the completion of the testing. A supplemental report will follow after reviewing this economic assessment incorporating the post-flotation metallurgical test result.

8-2 Recommendations

The following follow-up works will be recommended in order to acquire further information necessary for planning the development of the Dong Pao F3 Ore Body.

8-2-1 Additional Investigations for the F3 and F7 Ore Bodies

(1) Drilling Exploration for the F3 Ore Body

Since the F3 Ore Body laterally extend, forming a irregular lens of mineral concentrations, it is necessary to delineate lateral changes of ore grades more in detail. The present spacing of the drill holes at 50m is too wide to estimate the ore reserves with a satisfactory precision. It is recommended to conduct in-fill drilling with a spacing at 25 m.

The pit for the current study has been designed with the overall slope angle at 34° , which requires extensive excavation of the western steep slope. Because this slope consists mainly of limestone blocks and boulders, more competent than weathered syenite, it may be possible to make the overall slope angle steeper and to reduce the excavating amount of unnecessary waste. Since no drill hole has been put down on this slope, some drill holes are recommended to verify geotechnical nature of the ground as well as the state of mineralization if any (Figure II-8-2).

(2) Trench Investigation

The F3 Ore Body extends to the south of the southern limit of the drilled extent, where some 350.000 tons of expected reserves are estimated according to the past surface exploration results(ref. II-5-4). The terrain is too steep to set up a drilling machine and, therefore, has been left unexplored by drilling. It is recommended to conduct a detailed trench investigation for this part of the F3 Ore Body in order to delineate the ore grade distribution.

(3) Exploration on the F7 Ore Body

An extensive geochemical anomaly has been delineated over the F3 Ore Body, a part of which is revealed by trench excavation and is proved to contain 3 layers of high grade mineralization. This ore body appears to have an excellent potential for significant rare earth resources. If the resources increased in the order of magnitude, it would drastically change the entire aspect of the Dong Pao exploitation scheme. It is desirable to drill-explore this ore body.

(4) Follow-up Flotation Test

Variation of the tested samples has been limited in ore grades and types. Therefore, it has not been well established how the flotation performances (recovery rates and concentrate grades) are susceptible to the changes in feed grades and ore types. It will be necessary to conduct a more detailed flotation test in order to determine engineering and design parameters of the flotation process for the economic assessment.

8-2-2 Economic Assessment for the Exploitation of the F3 Ore Body

The economic viability of the F3 Ore Body is preliminarily assessed in this report. However, the assessment contains a great deal of uncertainty in assumption of various parameters. The geological and in-pit ore reserves have to be completely revised according to the result of the detailed exploration as above recommended. The production plan has to be altered accordingly. It is necessary to completely review all parameters for mining, flotation, post-flotation process, economics, marketing, environment and other related fields in order to prepare a comprehensive feasibility report.

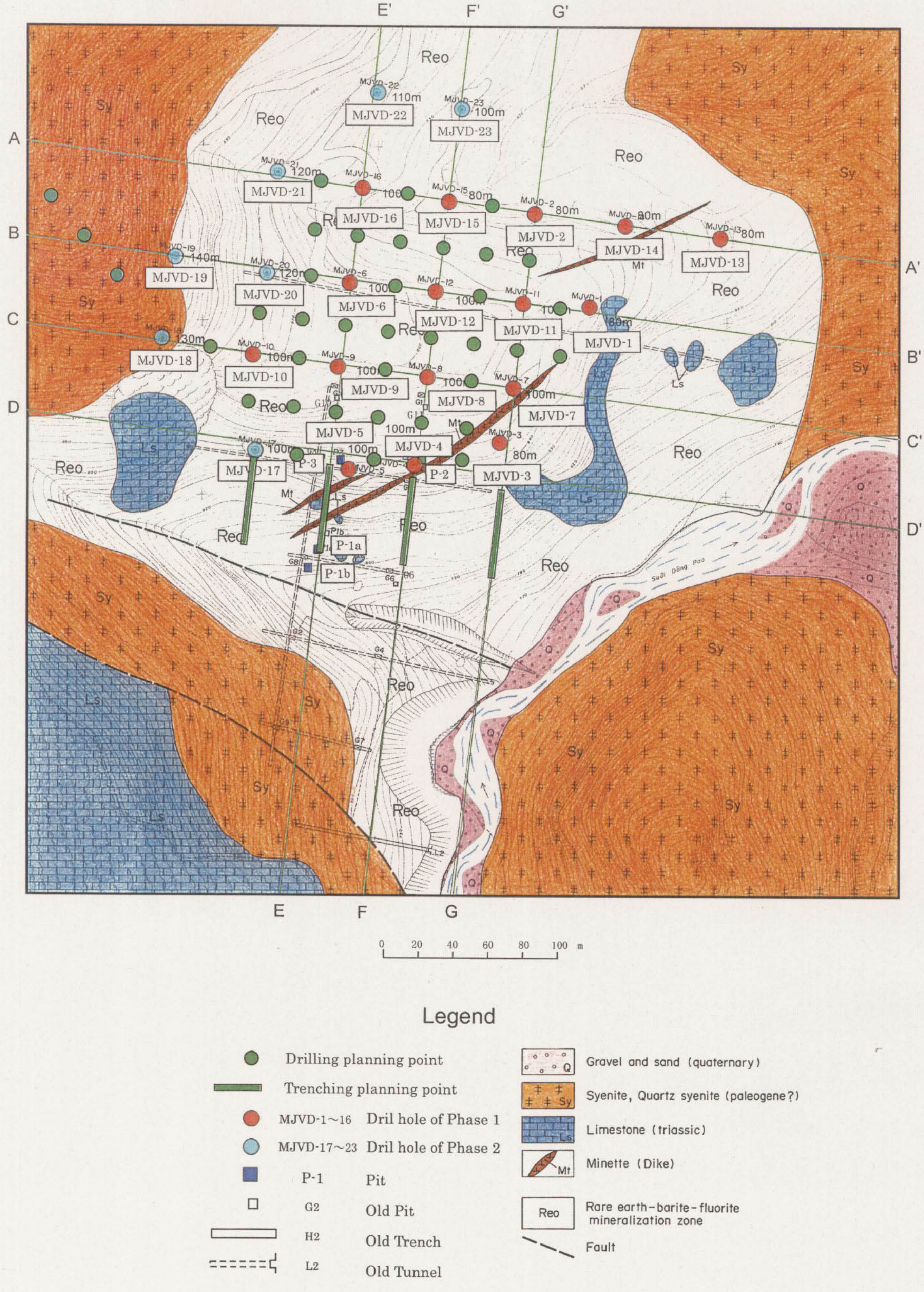

Figure Ⅱ-8-1 Additional drilling plan on F3 orebody