Chapter 6 Flotation Test

6-1 Objective and Prehistory of Flotation Test

The flotation test in the 1st Year Campaign was contracted to Oretest Pty., Ltd., Australia. Several flotation processes were tested, with changing reagent and flotation conditions, in order to identify a process to effectively concentrate rare earth minerals from the complex rare earth-barite-fluorite ore of the Dong Pao F3 Ore Body. The test result, however, indicated that it would be extremely difficult to separate rare earth minerals from barite and fluorite with ordinary flotation processes. The test failed to identify any effective reagents and flotation conditions for separation and concentration of rare earth minerals. This test was followed by a grinding-classifying test at the Laboratory of Oretest, 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 sent to the Laboratory of Lakefield Research in Ontario, Canada, for further flotation tests. This Laboratory has been in close contact in the metallurgical field with the Mountain Pass Mine, where bastnaesite ores, similar to those of Dong Pao, are being mined and processed. It was indicated in the course of this test 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 50% RE_2O_3). Locked cycle tests are still continuing to improve the metallurgical results and to produce samples for the test of post-flotation metallurgical processes(as of mid-March 2002).

The ores of the F3 Ore Body have been visually classified into 4 categories, namely yellow, black, upper gray and lower gray ores in order to examine their metallurgical differences. These 4 types of ores were tested by the newly developed process flow and the reagent scheme.

6-1-1 Additional Test at the Lakefield Oretest Laboratory

- Basic Design Parameters for a Flotation Plant (Work Index, True Specific Gravity)
- Concentration of Rare Earth Minerals by Grinding and Classifying

6-1-2 Flotation Test at the Lakefield Research Laboratory

- Flotation Test employing the Mountain Pass Process

- Development of Concentration Conditions for Rare Earth Minerals by Reversed Flotation
- Development of Flotation Conditions for Different Types of Ores

6-2 Test Result

6-2-1 Work Index

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

$$(Wi)_B = 44.5/ ((Pi)^{0.23} * (Gpb)^{0.82} * (10/(P_{80})^{0.5} - 10/(F_{80})^{0.5})) * 1.102$$

6-2-2 True Specific Gravity

True Specific Gravity: 3.89

6-2-3 Concentration by Grinding-Classifying

Table III-6-1 Concentration of Rare Earth Minerals by Grinding-Classifying

	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

Table III-6-2 Analytical Result of Classified Product

		Product						
		Fine 1 (-2mm)	Fine 2 (-500um)	Fine 3 (-150um)	Fine 4 (-75um)	Coarse	Head	-2mm - +150um
Wt	%	5.5	4.9	3.4	5.3	80.9	100.0	10.4
REO	%	33.5	29.0	23.6	14.3	5.5	9.3	31.4
CeO2	%	14.80	12.70	10.50	6.49	2.65	4.28	13.81
Dy2O3	%	0.016	0.013	0.010	0.006	0.001	0.003	0.015
Er2O3	%	0.010	0.012	0.012	0.012	0.012	0.012	0.011
Eu2O3	%	0.100	0.080	0.060	0.030	0.000	0.013	0.091
Gd2O3	%	0.190	0.150	0.120	0.080	0.030	0.050	0.171
Ho2O3	%	0.016	0.013	0.011	0.001	0.003	0.004	0.015
La2O3	%	12.30	10.90	8.77	5.21	1.93	3.35	11.64
Lu2O3	%	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nd2O3	%	3.88	3.27	2.60	1.50	0.54	0.98	3.59
Pr6O11	%	1.39	1.19	0.99	0.58	0.21	0.37	1.30
Sm2O3	%	0.430	0.350	0.280	0.170	0.050	0.100	0.392
Tb4O7	%	0.000	0.000	0.000	0.002	0.000	0.000	0.000
Tm2O3	%	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Y2O3	%	0.381	0.308	0.252	0.158	0.073	0.112	0.347
Yb2O3	%	0.012	0.010	0.012	0.016	0.020	0.019	0.011
BaSO4	%	12.0	33.8	41.7	56.2	68.2	61.9	22.3
CaF2	%	5.2	4.9	4.8	4.3	4.8	4.8	5.1
Fe2O3	%	5.0	3.4	3.2	3.1	2.4	2.7	4.2
MgO	%	0.3	0.2	0.1	0.1	0.0	0.0	0.3
MnO	%	6.3	3.9	3.1	1.5	0.5	1.1	5.2
ThO2	ppm	1,300	1,140	1,060	880	740	809	1,225
U3O8	ppm	400	700	800	960	1,020	960	541
SiO2	%	9.6	6.4	6.7	7.9	10.3	9.8	8.1
Total		71.93	81.60	83.22	87.35	91.72	89.61	76.48

- 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%).
- 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.

6-2-4 Flotation Test

6-2-4-1 Test employing the Mountain Pass Process

The sample was ground to 150 mesh to produce slurry with pulp density of 45%. Phased conditioning was given to the slurry under heated condition, added with the following reagents;

Na_2CO_3	4000 g/t
Lignin Sulphonate	4000 g/t
Na_2SiF_6	1000 g/t
Collector MRK	200 g/t

The phased conditioning continued for 20 minutes under the temperature of 80℃. The collector MRK used in this test is a reagent of fatty acids. The conditioned slurry underwent bastnaesite flotation for 8 minutes with 3-stage cleaning. The test result is shown in the following table. This test failed to differentiate barite, fluorite and bastnaesite and virtually produced bulk concentrates.

Table III-6-3 Result of the Flotation Test Employing the Mountain Pass Process

Product	Weight %	Assays %			% Distribution		
		$BaSO_4$	CaF_2	REO	$BaSO_4$	CaF_2	REO
REO 3rd Cleaner Conc	33.63	38.6	6.5	6.76	21.2	49.1	45.4
REO 1st Cleaner Conc	62.06	54.2	5.82	5.96	54.9	81.1	73.9
REO Rougher Conc	87.8	58.6	5.03	5.58	84.2	99.4	98
REO Rougher Tail	12.11	80	0.21	0.81	15.8	0.6	2
Head (Calculated)	100	58.9	5.03	5	100	100	100

The same test was repeated for the ore sample containing 55.9% $BaSO_4$, 2.06% CaF_2 and 12.9% RE_2O_3, with increased amounts of depressants, Na_2SiF_6 and lignin sulphonate. The amounts of the reagents added were as follows;

Na_2CO_3	4000 g/t
Lignin Sulphonate	5000 g/t
Na_2SiF_6	1500 g/t
Collector MRK	200 g/t

The result is shown in the table below. Although the bastnaesite grades in the concentrates were improved, the metallurgical results were very unsatisfactory as a whole.

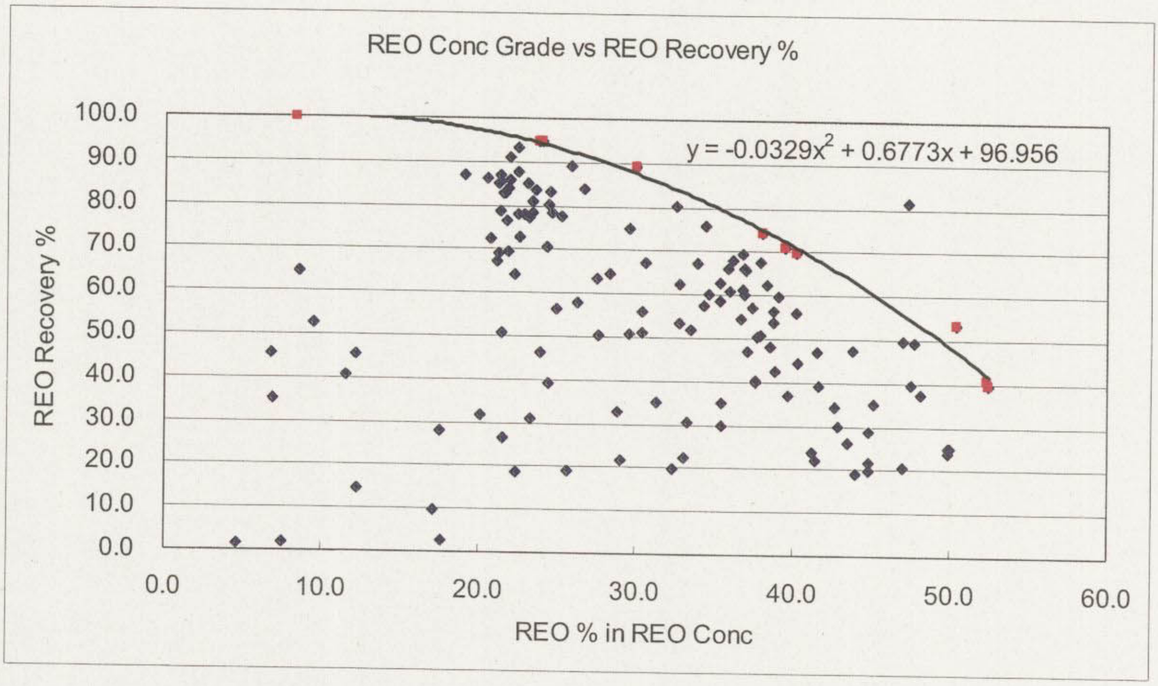
Table III-6-4 Result of the Repeated Test with the Increased Amounts of Depressant

Product	Weight %	Assays %			% Distribution		
		$BaSO_4$	CaF_2	REO	$BaSO_4$	CaF_2	REO
REO 3rd Cleaner Conc	14.65	34.2	5.16	28.9	9	36.7	32.9
REO 1st Cleaner Conc	54.32	60.2	3.12	14.7	58.5	82.4	62.1
REO Rougher Conc	81.54	58.1	2.43	13.8	84.7	96.2	87.5
REO Rougher Tail	18.46	46.3	0.42	8.73	15.3	3.8	12.5
Head (Calculated)	100	55.9	2.96	12.9	100	100	100

The above tests adopted treatment procedures that have been applied to ordinary ores. The results indicated that the conventional flotation processes were ineffective for separating bastnaesite from intensely weathered and altered ores.

6-2-4-2 Collective Flotation Test Results

A series of the tests is still continuing at the Laboratory of Lakefield Research. The collective results to date are demonstrated in the figure below.



FigureⅢ-6-1 REO Conc. Grade vs REO Recovery

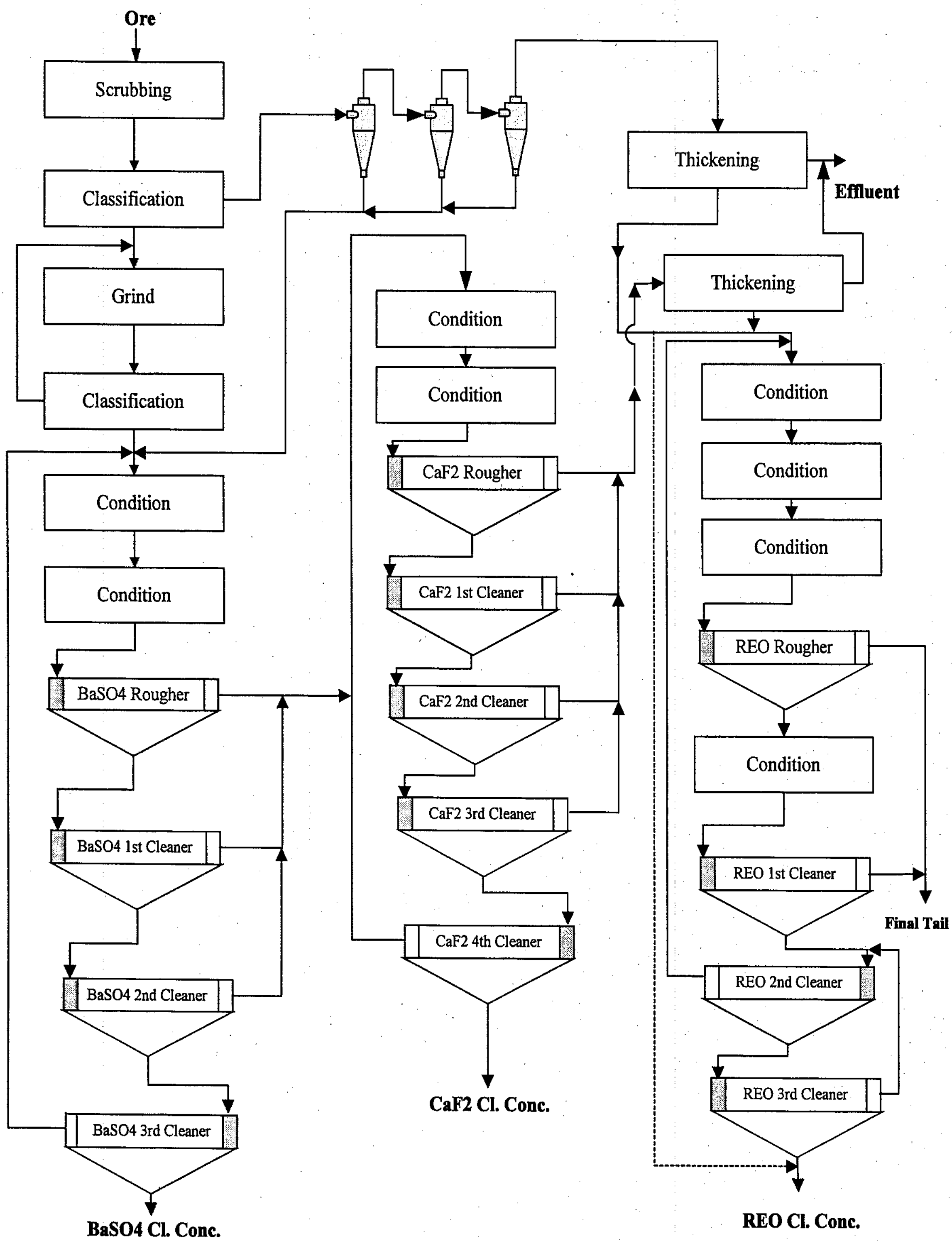
TableⅢ-6-5 Test Results for $BaSO_4$, CaF_2 and RE_2O_3

Test No.	Product	Wt %	Assays % BaSO4	Assays % CaF2	Assays % REO(total)	Assays % Others	% Distribution BaSO4	% Distribution CaF2	% Distribution REO(total)	% Distribution Others
REO Concentrate										
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	Wt %	Assays % BaSO4	Assays % CaF2	Assays % REO(total)	Assays % Others	% Distribution BaSO4	% Distribution CaF2	% Distribution REO(total)	% Distribution Others
BaSO4 Concentrate										
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.

6-2-4-3 Flotation Process Flow (Locked Cycle Test)



FigureⅢ-6-2 Floatation process flow (Locked Cycle Test)

6-2-4-4 Reagent Schedule

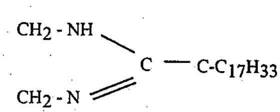
	$BaSO_4$ Circuit	NaF_2 Circuit	REO Circuit
Na_2SiO_3	2500 g/t	2000 g/t	–
$BaCl_2$	500 g/t	–	–
SR82 (collector)	600 g/t	–	–
$Al_2(SO_4)_3$	–	0 g/t	–
NaF	–	400 g/t	–
$Na_2S_2O_4$	–	400 g/t	–
AKF2 (collector)	–	350 g/t	–
Na_2CO_3	–	–	4000 g/t
Citric Acid	–	–	1000 g/t
Quebracho/Lignin Sulphonate	–	–	1000 g/t
Fuel Oil	–	–	200 g/t
MM6 ($BaSO_4$ Depressant)	–	–	1900 g/t
AGW (collector)	–	–	700 g/t

SR82: SR 82 is a compound composed of the following reagents. Although it is possible to purchase these reagents in the market, they individually contaminate bastnaesite into barite froth or, conversely, reduce the froth rate of barite. The following combination of the reagents will be able to float barite with minimal impurity contamination and with appreciably high recovery rates.

Petroleum sulphonate	*30–40%*	*by weight*
Sulphosuccinate	*30–40%*	*by weight*
Sulphosuccinamate	*20–40%*	*by weight*

In practice, these reagent should be mixed in concentration rates of 5 to 20% under higher than atmospheric temperature before added to slurry.

AKF2: A new fluorite collector, AKF2, is produced by reaction of ethyl-tetra amine and oleic acid indicated by the following chemical formula.



This new compound will become a very effective fluorite collector by reacting with alkyl-ethyl-phosphate. The combining ratio is 70% amine oleic acid and 30% alkyl-ethyl-phosphate. The ratio can be changed according to the nature or kind of ores. This collector is advantageous compared to conventional fluorite collector in improving separation of fluorite and bastnaesite.

AGW: This new collector is a compound of aminated tall oil fatty acid and sarcosine (CH_3NHCH_2COOH) and used with amine series collectors. The composition is as follows;

a) tall oil fatty acid (aminated)	*60–70% by weight*
b) sarcosine–type of collector	*20–30% by weight*
c) secondary amine	*10% by weight*

Primary amine is generally used to aminate tall oil fatty acid.

6-2-5 Grade-Recovery and Economic Aspect

The concentrate grade and metal recovery relationship is considered as the ultimate metallurgical test result. The result is assessed on the basis of the balance between the value of recovered proportion of metals in the concentrates and the marketability of the concentrates with a specific grade. The assessment is generally made from the following point of view.

- Metal Recovery Preference: where metal prices are appreciably high and mining and flotation costs are expensive.
- Concentrate Grade Preference: where product freights and treatment and refining charges are high.

The price of bastnaesite concentrates has been unchanged for the last five years, as shown below, according to the USGS Commodity Summary 2001.

Table III-6-6 The price of bastnaesite concentrates

Year	2000	1999	1998	1997	1996
Bastnaesite Conc. (US$/kg RE_2O_3)	2.87	2.87	2.87	2.87	2.87
Monazite (US$/ton)	730	730	730	730	480
Mischmetal (US$/kg)	5–7	5–7	6–8	8–12	7–11

Monazite ores are directly smelted with the grade of 30% that is the lower marketable limit. In case of bastnaesite concentrates, if the concentrates containing 30% RE_2O_3 is bought at the price of US$ 2.87/kg RE_2O_3 and treated in a smelting-refining plant to produce mischmetal, the smelting-refining margin will be considerably reduced to a degree that creates losses. Therefore, the concept of TC/RC that is prevailing in the copper concentrate market is introduced to estimate a conceptual TC/RC for bastnaesite concentrates. It is assumed that the profit margin of the smelting-refining plant is secured by buying bastnaesite concentrates of 50% RE_2O_3 at the price of US$ 2.87/kg RE_2O_3 and by selling the produced mischmetal at the price of US$ 5/kg. The difference between the values of the rare earths contained in the concentrates and of the sold mischmetal was estimated and regarded as the combined RC/kg RE. Whole of the combined RC was converted to TC that was taken into account for estimation of appropriate prices of RE_2O_3/kg contained in bastnaesite concentrates with different grades.

Table III-6-7 The collective flotation test results

REO Conc	REO $/kg		RE	Comb RC	Conc Ton	Cov to TC
%	$/REO-kg	$/RE-kg	$/RE-kg	$/RE-kg	t/RE-kg	$/t
50	2.87	3.198	5	1.802	2.23	808.59
45	2.69	2.998	5	2.002	2.48	808.59
40	2.47	2.748	5	2.253	2.79	808.59
35	2.18	2.426	5	2.574	3.18	808.59
30	1.79	1.997	5	3.003	3.71	808.59
25	1.25	1.396	5	3.604	4.46	808.59

Using this concept, the optimum metallurgical results that were obtained from the grade-recovery curve as afore-presented are compared in the table below.

Table III-6-8 Estimation of appropriate prices of RE_2O_3/kg contained in bastnaesite concentrates

Product		Assay REO(%)	Distribution REO(%)	Metal $/REO-kg	REO Value $/t-Ore
Head		8.4	100.0	(5.19)	(433.8)
Test 14	CaF2 Ro+1st&2nd Cl Tails	24.0	94.6	1.12	88.4
Test 18	CaF2 Ro+1st&2nd Cl Tails	23.8	94.6	1.09	86.1
70	CaF2 Tails + Slimes	30.0	89.3	1.79	133.7
69O	REO 1st Cl Conc	38.0	74.1	2.36	146.0
69N	REO 1st Cl Conc	39.5	71.0	2.44	144.7
69M	REO 1st Cl Conc	40.2	69.7	2.48	144.1
69O	REO Cl Conc	50.4	53.2	2.88	128.1
69M	REO Cl Conc	52.4	40.6	2.94	99.8
69N	REO Cl Conc	52.5	39.5	2.95	97.2

According to the above table, the ore value is expected to become an appreciable level for the concentrates with grades of about 40% RE_2O_3 at recovery rates of around 70%. At this stage, however, the flotation test is still continuing and expected to output better recovery rates, particularly for the higher grade concentrates.

Meanwhile, a trial estimation for reagents used in a post-flotation metallurgical process was made in order to test the viability of the above TC/RC concept, although no test for any post-flotation metallurgical processes had been carried out to date. The result of the trial estimation is as follows.

Main minerals in the bastnaesite concentrate and reactions in the hydrometallurgical process

(RE)FPO_4 — $2(RE)FPO_4 + 3H_2SO_4 \rightarrow (RE)2(SO_4)_3 + 2HF + 2H_3PO_4$

$2HF + CaCO_3 \rightarrow CaF_2 + H_2O + CO_2$

$2H_3PO_4 + 2CaCO_3 \rightarrow 2CaPO_4 + 3H_2O + 2CO_2$

CaF_2	$CaF_2 + H_2SO_4$ -> $CaSO_4 + 2HF$
$BaSO_4$	$2HF + CaCO_3$ -> $CaF2 + H_2O + CO_2$
Others	$CaO + H_2SO_4$ -> $CaSO_4 + H_2O$

Required Reagent amount (tons) for individual mineral (ton)

	H_2SO_4	$CaCO_3$
T-TRE2O3	0.942	0.962
CaF_2	1.256	1.282
$BaSO_4$	0.000	0.000
Others	1.750	0.000

Price of REO and Reagent / ton

H_2SO_4	100
$CaCO_3$	13

Reagent Cost for Each Mineral (20% over for equivalent)

	$/t
T-TRE2O3	128.1
CaF_2	170.8
$BaSO_4$	0.0
Others	210.0

Table III-6-9 The result of the trial estimation of TC/RC concept

Test No.	Product	Assays %				Reagent $/Conc-t	Cov to TC $/Conc-t	Ratio of Reagent C
		$BaSO_4$	CaF_2	REO(total)	Others			
Head		63.3	5.1	8.4	24.7	71.34	808.59	8.8%
Test 14	CaF2 Ro+1st&2nd Cl Tails	7.2	13.2	24	55.6	170.04	808.59	21.0%
Test 18	CaF2 Ro+1st&2nd Cl Tails	7.82	13.5	23.8	54.9	168.78	808.59	20.9%
70	CaF2 Tails + Slimes	7.46	6.16	30	56.4	167.34	808.59	20.7%
69O	REO 1st Cl Conc	8.77	9.8	38	43.4	156.61	808.59	19.4%
69N	REO 1st Cl Conc	9.03	9.76	39.5	41.7	154.85	808.59	19.2%
69M	REO 1st Cl Conc	8.64	9.76	40.2	41.4	155.09	808.59	19.2%
69O	REO Cl Conc	3.99	15	50.4	30.6	154.45	808.59	19.1%
69M	REO Cl Conc	3.92	14.2	52.4	29.5	153.27	808.59	19.0%
69N	REO Cl Conc	2.92	15.2	52.5	29.4	154.90	808.59	19.2%

The above estimation indicates that the proportion of the reagent costs is stable at around 20% of the TC estimated according to the TC/RC concept, which suggests the basis for the concept to be sound and appropriate.

6-2-6 Flotation Test Results by Ore Types

6-2-6-1 Test Samples

Table III-6-10 Sampling Locations and Assay Results of 4 types of Ore Samples

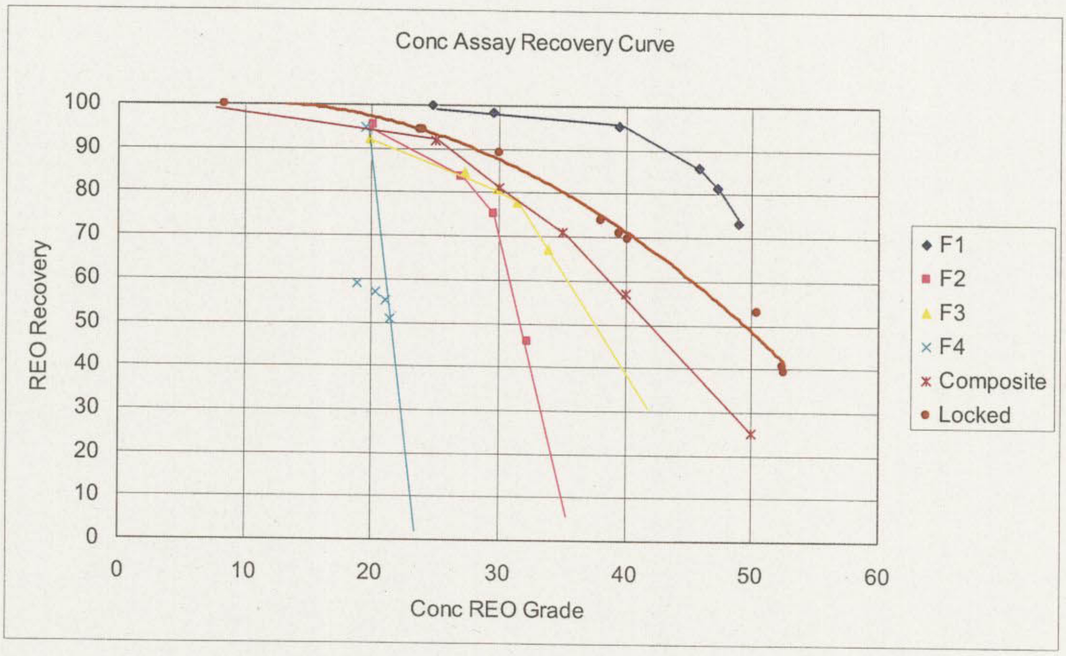
Element			Assays				
			Sample F1 (Yellow)	Sample F2 (Black)	Sample F3 (Mixed)	Sample F4 (Mixed)	Test Composite
Cerium	Ce_2O_3	%	12.7	3.88	8.57	8	3.46
Lanthanum	La_2O_3	%	9.7	3.12	6.53	6.1	2.8
Total REO	REO	%	26.2	8.34	17.8	16.6	7.66
Barium	$BaSO_4$	%	36.7	67.9	24.3	20.7	65.3
Fluorspar	CaF_2	%	18.1	0.97	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

- Batch tests were conducted for the sample of each type of ores in order to examine the metallurgical characteristics by ore types.
- The ores 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 two types, the gray ore of upper level and that of lower level. It was virtually impossible to mineralogically distinguish ore types only by visual observation on-site.
- The ore samples that had been submitted to the 1st Year flotation test were generally

those of the black ore type (F2).

6-2-6-2 RE_2O_3 Grade-Recovery Curve by Ore Type



FigureⅢ-6-3 RE_2O_3 Grade-Recovery Curve by Ore Type

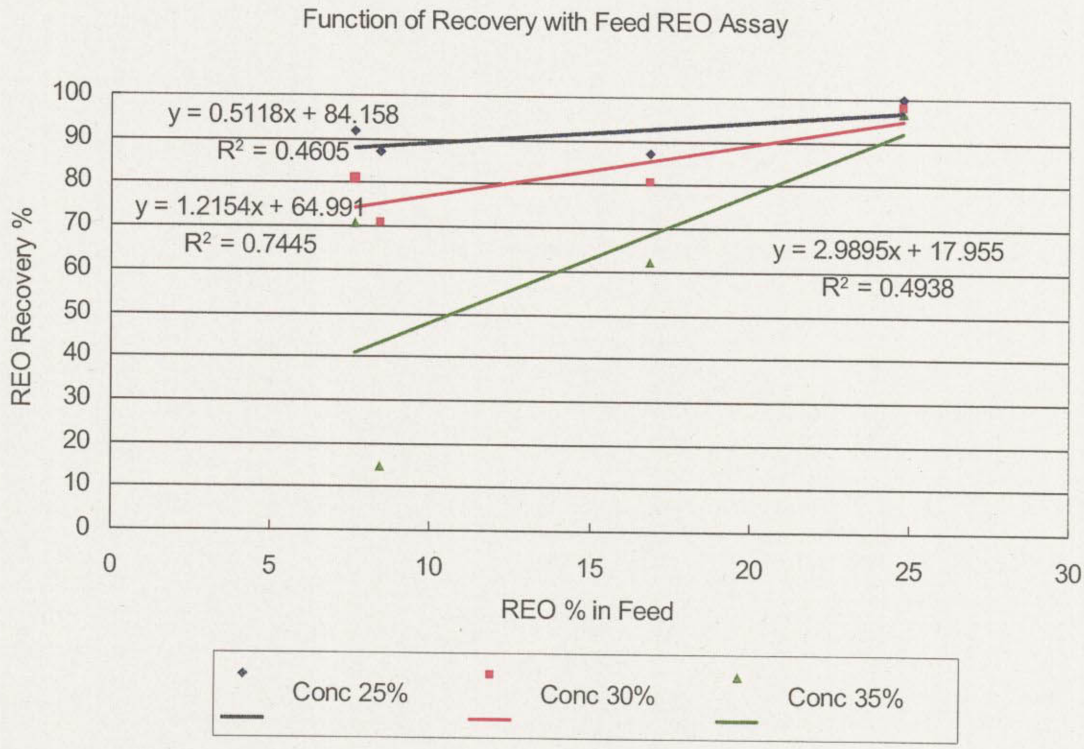
- The recovery rate is the best for the F1 and declines in the order of those for the composite, the F3, the F2 and F4.
- Differences of 5 to 6%, 10 to 12% and 20 to 25% in the recovery rates between the best metallurgical results of the locked-cycle test and those of the batch test for the composite 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. Such high clay content would adversely affect RE_2O_3 concentration in the flotation process. This sample, however, was collected at the depth of 75m of the hole MJVD-7, located at an elevation of 792.5m that would be

higher than the bottom of the currently designed pit. It is hoped that occurrence of this type ore would be minimal in the currently designed pit.

Table III-6-11 Proportion of Tested Ore Types in the Designed Pit

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

6-2-6-3 Relationship between Feed RE_2O_3 and Recovery Rate



FigureⅢ-6-4 Function of Recovery with Feed REO Assay

- The relationship between the feed grade and the recovery rate for various concentrate grades was estimated based on the RE_2O_3-Recovery Curve by Ore Types.
- This relationship was used for the pit design to estimate the mining reserves economically amenable.
- This relationship was derived only on the batch test basis. It will significantly improve when the locked cycle test results are taken into account and provide parameters with sufficient allowances.
- The concentrate grade of 40% is economically most desireable according to the economic examination as aforementioned. Therefore, the ore reserves in the designed pit was estimated assuming the metal price at US$ 2.18/kg RE_2O_3 for the concentrates

with the grade of 35% RE_2O_3, based on the TC/RC concept.

・ 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 required 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 metallurgical parameters serving for a realistic mine development plan.

・ The mining reserves estimated on the basis of the above conditions are shown in the following table.

6-3 Design Parameters for Flotation Plant

(Feed)

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

T-TRE_2O_3 : 6 %

CaF_2 : 8.7%

$BaSO_4$: 39.0%

(Metallurgical Parameters)

T-TRE_2O_3 : Concentrate Grade 40%, Recovery 70%

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

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

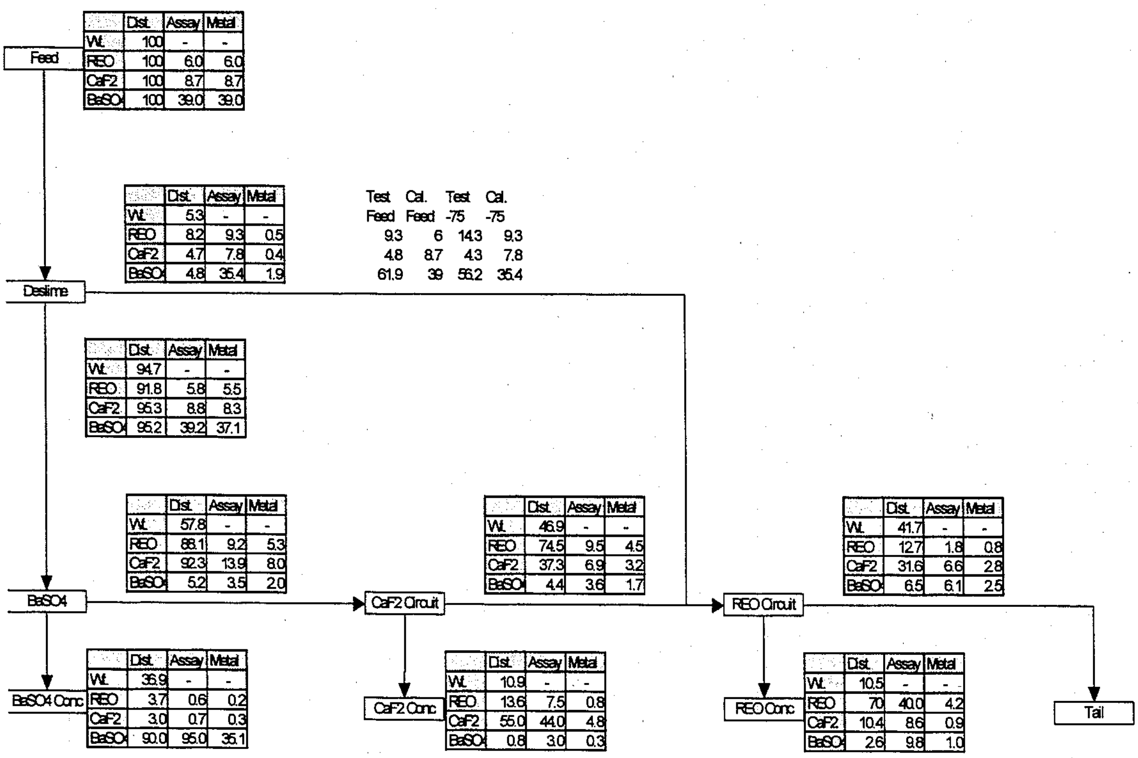
(Grinding and Classifying (Desliminig))

Particle Size of Slime : −200 mesh

Grading : −150 mesh (105 μm)

Wi : 6.6 k Wh/t

(Mass Balance)



(Retention Time)

Table III-6-12 Retention time of $BaSO_4$, CaF_2 and REO flotation circuit

BaSO4 Flotation Circuit

Stage	Time, minutes		
	Grind	Cond	Froth
Condition 1	-	5	-
Condition 2	-	5	-
Ba Rougher	-	-	3
Ba 1st Cleaner	-	1	2
	-	1	1
Ba 2nd Cleaner	-	1	1.5
	-	1	1
Ba 3rd Cleaner	-	1	1.5
	-	1	1

CaF2 Flotation Circuit

Stage	Time, minutes		
	Grind	Cond	Froth
Condition 1	-	5	-
Condition 2	-	5	-
Condition 3	-	5	-
CaF_2 Ro 1	-	1	6
CaF_2 Ro 2	-	2	3
CaF_2 1st Cl	-	3	4
	-	3	2
CaF_2 2nd Cl	-	3	4
CaF_2 3rd Cl	-	3	3

REO Flotation Circuit

Stage	Time, minutes			Temp °C
	Grind	Cond	Froth	
Condition 1	-	20	-	80
Condition 2	-	20	-	90
REO Rougher	-	-	10	-
Reheat Ro Conc	-	10	-	90
REO 1st Cleaner	-	-	5	-
REO 2nd Cleaner	-	1	3	-
	-	1	-	-
REO 3rd Cleaner	-	1	3	-

(Other Notes)

- Cyclone underflow should be recycled to grinding, although it differs from the flow sheet based on the test result.
- It is necessary to make the thickner with a sufficient diameter, because concentrates tend to be slow in precipitation.

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 geological ore reserves are shown in Table III-5-4 of Chapter 5. The syenite in the drilled extent is more or less mineralized with the main rare earth mineral, bastnaesite and other gangues such as fluorite and barite.. 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% RE2O3, 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). The pit size becomes larger with the increased RE_2O_3 prices. The lowered cut-off grade will increase the in-pit reserves with the lowered average grade. Meanwhile, the flotation test result (Chapter 5) indicated that a concentrate with the grade of 40% RE_2O_3 would be obtained with the recovery rate of 60%. Because the flotation test samples contained RE_2O_3 of 8% or better, it is concerned that the lowered feed grade may adversely affect the flotation performances such as the concentrate grade and the recovery rate.

Based on Table III-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 $\geq$ 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

TableIII-7-1 Comparison of Ore and Waste in Designed Pits

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 RE_2O_3, 4,500 tons CaF_2, 27,980 tons $BaSO_4$

(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 TableIII-7-2.

7-3-3 **Development Plan**

The dispositions of the mine and plant facilities are shown in FigureIII-7-1. The construction period of 2 years is assumed.

(1) Mining

- Mining Preparation (Pre-production Stripping)
  Waste Removal to reach Bench 860m and lower Levels : 329,319 tons
- Selection and Purchase of Heavy Equipment

The requirement for major heavy and ancillary equipment are planned as shown in Tables III-7-3 (1), (2), in accordance with the construction period of 2 years and the annual average production as indicated in 7-3-2(1).

Table III-7-2 Yearly Prodiction 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

Table III-7-3(1) Major Heavy Equipment and Price(in US $)

Item	No.	Unit Price CIF Hai Phon	Handling (1%)	Transport-ation(1.5%)	Unit Price On Site	Total Amount
Dump Track CAT725	4	260,000	2,600	3,900	266,500	1,066,000
Front-end Loader CAT950G	2	130,000	1,300	1,950	133,250	266,500
Excavator CAT325C	1	120,000	1,200	1,800	123,000	123,000
Dozer D7	1	205,000	2,050	3,075	210,125	210,125
Crawler Drill CDH-	1	333,000	3,330	4, 995	341,325	341,325
15T-Truck	2	113,000	1,130	1,695	115,825	231,650
Total						2,238,600

TableIII-7-3(2) Ancillary Equipment and Price

Item	Type	No.	Unit Price(A$)	Amount(A$)
Passenger Vehicles	Station Wagons, Pick-ups	4	25,000	100,000
Trucks	Explosive Carrier	1	55,000	55,000
	Flat-top with Crane	1	65,000	65,000
	1-ton Flat-top	1	22,000	22,000
Crane Mobile	25-ton, Rough-Terrain	1	450,000	450,000
Fork-lift	11.5-ton	1	140,000	140,000
Water Truck	Cat725	1	260,000	260,000
Light Vehicles		3	21,000	63,000
Ambulance		1	55,000	55,000
Buses		2	60,000	120,000
Total in A$ in US$ @0.635*A$				1,330,000 844,550

- Construction of Waste Dump

The waste dump is planned to be constructed in the flat yard, having an extensive area about 1,000m long in the east-west and 300m wide in the north-south, located approximately 1,500m to the east of the F3 Ore Body.

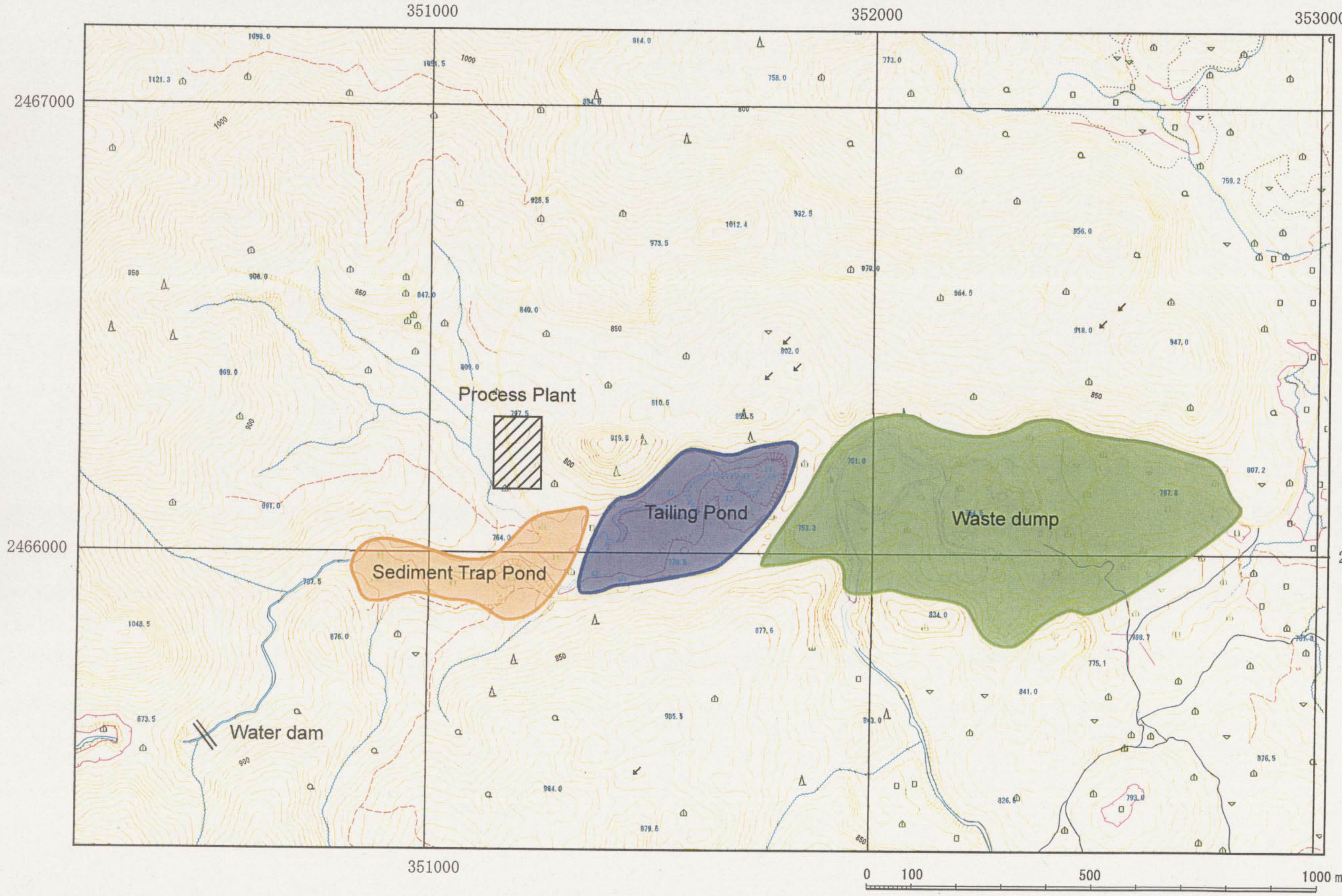
- Construction of Mine Office, Repair Shop and Other Ancillary Buildings

The major buildings such as the mine office and the repair shop are planned to be constructed on the gentle slope to the west of the Tower Karst, together with the flotation plant. In addition, the powder magazine, the warehouse, the living quarters and other ancillary buildings are to be constructed as necessary. The construction site must avoid the part where the F14 Ore Body is expected.

(2) Flotation

- Plant and Facilities

The flotation plânt is planned to be constructed on the gentle slope to the west of



FigureⅢ-7-1 Comparison of Ore and Waste in Designed Pit the Tower Karst, avoiding the F14 Ore Body, as above mentioned. The crushing/grinding, flotation and other attached facilities are planned to be installed based on the annual feed rate of 75,000 tons(250 tons/day)as shown in TableIII-7-4.

Table III-7-4 Major Flotation Plant Facilities and Costs

Section	Facilities	Description	Nos.	Cost
Crushing	Grizzly	500mm grid	1	
	Hopper	$50m^3$	1	
	Jaw Crusher	620x380mm, 30Kw	1	
	Vibrating Screen	30mm, 10mm, 7.5Kw	1	
	Cone Crusher	625mm dia., 37Kw	1	199,000
Grinding	Ball Mill	2400x2400mm, 190Kw	1	
	Spiral Classifier	1600x7900mm, 7.5Kw	1	
	Conditioners	7.5Kw	7	540,000
Flotation	Flotation Cells	Unit Cell : $1m^3$, 7.5Kw	34	
	Cyclone	150mm ϕ,	4	646,000
Thickening	Thickener	9m ϕ, 2.2Kw	2	193,000
Dewatering	Pressure Filter	15Kw	1	150,000
Laboratory	AA Spectrometer		1	50,000
Others	Boiler		1	20,000
Tailings Pond		$780,000m^3$, HDPE Sheets	1	875,000
Plant Building			1	856,000
Total				3,529,000
Installation etc				1,765,000
Grand Total				5,294,000

* Tailings Dam

The flat yard extending from the north of the present exploration camp to the south of the F7 Ore Body is suitable for the tailings dam. This yard provides an area of approximately $70,000m^2$, elongating in the east-west direction bounded by hills to the north and south. The tailings dam will require a volume of approximately $780,000m^3$. Fluorite and barite concentrates are recovered in the course of the rare earth flotation but are uncertain for their marketing at the present stage. Provided that tailings can be deposited to the height of about 12m, this yard will have a sufficient volume allowing disposal of fluorite and barite concentrates. It is observed that surface water infiltrated to underground outflow in the downstream because karst is extensively developed in the Project Area. The bottom of the tailings dam should be overlaid by a HDPE (High Density Polyester) sheet covered by a clay liner, in order to prevent leakage of tailings and infiltration of tailing water.

- Other Ancillary Facilities

An analytical laboratory will be attached to the flotation plant for the grade control at the various stages of the operation. The laboratory is equipped with atomic absorption spectrometers and other equipment and instruments for sample preparation. A concentrate storage is to be constructed independently from the flotation plant. The storage should be designated for the radioactive material control area, because the concentrates contain a significant amount of radioactive minerals.

(3) Infrastructures

- Power Supply

The national power grid provides electricity to Binh Lu from Lao Cai with the 35kV transmission line. There is a plan to construct a power grid supplying electricity from Binh Lu, via Dong Pao, to Bang Hong, which is expected to complete in 2004. However, it is desirable to install a diesel generator with the capacity of 600kW for emergency purpose, in order to secure power supply in quantity and quality. The cost for installing the diesel generator is estimated at US$ 1,155,000, including the freight, the custom clearance charges and the installation cost.

- Water Supply

The flotation plant will require approximately 1,000m^3/day of water supply. The upstream of Dong Pao river is expected to maintain a flow rate of 9−23m^3 without being dried up even in the dry season. A sufficient amount of water can be supplied to the flotation plant by piping from an in-take installed at the bank of the Dong Pao river. The analytical result of stream water in the current Project indicated higher contents of Pb, Hg and As than those allowed in the Japanese Environmental Standards. It is necessary to carry out further investigations on water quality, particularly for drinking water.

- Transportation

The railway and the roads are only transportation means available for bulky cargos and mine products. The railway reaches Lao Cai, some 50km northeast of the Project site, from which all goods have to be transported by trucks. The route for some 400km from Hanoi, via Lao Cai, to Sapa is connected by the national highways and other trunk roads with pavement, and will be able to serve for bulk transportation without any problems. No pavement is, however, maintained for the 50km-long mountainous road between Sapa and Binh Lu. The only access to Dong Pao at the present is a detour, branching off at the point shortly before Tam Duong, and is passable by 4-wheel drives or light trucks. A trunk road between Binh Lu and Dong Pao is now under construction and will improve the road transportation in great deal when completed. The roads from Sapa onwards are often submerged under water during the rainy season, and may create some problems in maintenance and management. However, there will be no serious problem in transporting bulk cargos in and out of the Project site. For the use of the immediate future, it will be necessary to construct an access road for about 2km between

Old Dong Pao and the Project site.

- Communication

The telephone net works reach only to Binh Lu at the present time. No tele-communication is available at Dong Pao. There is no plan to construct a telephone line between Binh Lu and Dong Pao. Accordingly, it is necessary to construct a telephone line for about 12km in this section. For emergency use, it is possible to utilize a satellite communication, Immalsat, upon a separate contract.

7-3-4 Operation Plan

(1) Mining

Mining Method : Open Pit Mining. Ores and wastes are drilled using a crawler drill and then blasted. It is anticipated that the amounts of explosives required will be relatively small because generally loose nature of the ground. The blasted ores and wastes are loaded to dump trucks using wheel loaders or an excavator and then hauled to the flotation plant(ores) or the waste dump(wastes). The grade control of ore blocks will be constantly practiced on blasting block basis in order to minimize fluctuation of run-of-mine grades. Ores may be stockpiled in the vicinity of the primary crusher to maintain the crusher feed grade at a desirable level by blending the ores from the pit and the stockpile.

- Mode of Operation : 3 shifts a day, 6 days a week, 300 days a year operations.
- Workforce

Expatriates : Mine Management, Mine Operation, Mine Engineering, Total=3

Locals : Mine Manager 1, Superintendents 2, Engineers 4, Operators 30, Clerks 4, Assistants 20, Total=61

(2) Flotation

- Flotation Process :

Ores are crushed and ground and then put into the reverse flotation circuit to produce barite, fluorite and bastnaesite concentrates as shown in Figures II-7-2(1) and (2). The bastnaesite concentrate is condensed in the thickener and dewatered by the pressure filter and stored in the concentrate storage.

- Mode of Operation : 3 shifts a day, 6 days a week, 300 days a year operations
- Workforce

Expatriates(Advisory) : Process Operation, Metallurgical Engineering, Environmental Control, Total=3

Locals : Mill Superintendent 1, Engineers 3, Operators 15, Clerks 2, Assistants 15, Total=36

(3) Administration & General

- Operation Management, Financing and Accounting, Safety and Sanitation, Product Marketing and Inventory Control, Public Relations and Others
- Workforce

  Expatriate : Marketing 1

  Locals : Superintendents(Personnel, Accounting, Marketing, Public Relations, Safety & Sanitation, etc.) 4, Clerks 9, Assistants 9, Total=22

7-3-5 Capital and Operating Costs

The capital and operating costs are estimated as follows, based on the production schedule (7-3-2), development plan (7-3-3) and operation plan (7-3-4).

(1) Capital Cost (in US $)

- Mining

Pre-production Stripping : 329,319 tons, @ US $ 7 /t, US $	2,305,233
Equipment :	3,083,150
Engineering & Others :	538,383
Total :	5,927,221

- Flotation

Crushing/Grinding :	739,000
Flotation & Accessory Facilities :	989,000
Tailings Pond :	875,000
Buildings, Installation & Engineering :	926,000
Construction & Installation :	1,765,000
Total :	5,294,000

- Infrastructures

Diesel Generators :	1,155,000
Access Roads, Telephone Line & Others	2,000,000
Total :	3,155,000

- Working Capital(3 Months Operating Cost) :

  US $ 880,500

- Capital Cost Total :

  US $ 15,256,721

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

- Mining

Unit Cost/Ton of Ore & Waste

Salary and Wage :		
Materials(Explosives, Fuel & Lubrication, Others) :		
Others		
Total Unit Cost :	US $	7.00

Mining Cost(Annual Average) :

Ore 75,000 tons, Waste 165,000 tons, Total 240,000 tons, @ US $ 7.00/ton, US $ 1,680,000

- Flotation

Unit Cost/Ton of Feed

Crushing/Grinding :		1.29
Flotation :		7.12
Electricity :		7.20
Miscellaneous :		4.68
Total Unit Cost :	US $	20.29

Flotation Cost(Annual Average):

Feed 75,000 tons, @ US $ 20.29 /ton, US $ 1,521,750

- A & G @ US $ 4.27/Ton of Feed, US $ 320,250

- Operating Cost Total

Unit Cost/Ton of Feed

Mining		22.40
Flotation		20.29
A & G		4.27
Total Unit Cost/Ton of Feed	US $	46.96

Total Operating Cost(Annual Average):

Feed 75,000 tons, @ US $ 46.96 US $ 3,522,000

7-4 Profit-Loss Estimation

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

The profit-loss is estimated year by year in accordance with the production schedule as shown in TableIII-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 TableIII-7-5.

7-4-2 Assumptions

(1) 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.

(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

Table Ⅲ-7-5 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

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. The environmental standards, regulations and codes are more or less similar in most of the countries in the world. It is, therefore, considered reasonable to refer to the Japanese Environmental standards, regulations and codes for the environmental impact assessment regarding to the exploitation of the Dong Pao F3 Ore Body.

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. Although an environmental base-line study has been made to some extent in the Current Project, more detailed study is necessary for the satisfactory environmental impact assessment. However, the base-line study to-date has revealed some environmental elements that have to be taken into account for exploitation of the Dong Pao F3 Ore Body.

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.

(1) Atmosphere

The site, being a typical pastoral district in a mountainous region, has no industry that adversely affects the atmosphere. Smoke from grass fire may pollute air but to a minimal extent. It is considered that SO_x and NO_x gases emitted from the planned mining and processing will be small in amount, taking account of the production scale, well diluted and cause no serious air pollution.

(2) Water Quality

The stream water of the Project Area, with extensive development of limestone and karst morphology, is weakly alkaline indicating pH 7.33 to 8.55 according to the water quality survey conducted in the course of the Current Project. The highest pH 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 F in the Environmental Standards for Protection of Human Health of Japan. The high contents of these elements in water may suggest that the rocks in the Project Area are affected by the hydrothermal activity that introduced the rare earth, fluorite and barite mineralization.

The planned mining and processing operations will produce waste waters such as supernatant of the tailings dam, infiltration from the tailings dam and mine water discharged from the open pit. With extensive development of karst morphology, a number of polijes are observed in the planned tailings dam site. Therefore, it is necessary to take preventive measures against water infiltrating from the tailings dam to underground. The supernatant water of the tailings dam is recycled to the flotation plant for reuse. These measures will be able to minimize discharges from the tailings dam and the plant. The mine water is introduced to a settling pond and is discharged to the Dong Pao river after sedimentation of suspended solids. The community of Dong Pao is located approximately 3km away from the Project Site and obtains the domestic water from sources in upstream of other drainage basins than the Dong Pao river. Therefore, the domestic water will not be adversely affected by discharges from the Project Site. Some communities are located along the downstream of the Dong Pao river and utilize the river water for their domestic uses. However, influence of the discharges from the Project Site will be minimal.

(3) Noises and Vibrations

Noises and vibrations will be caused by blasting in the mining operation and crushing, screening and grinding in the flotation plant. The rocks in the upper benches of the open pit are intensely weathered and require a insignificant amount of explosives in the earlier stage of the mining operation. The distance of 3km from the closest community, Dong Pao, will be sufficient to prevent these noises and vibration to reach.

(4) Land Uses

The land around the Project Site are utilized mainly for rice fields and partly for tea plantations. Houses and cattle are also grazed. A part of the land may become unavailable for cultivation and grazing when the exploitation starts.

(5) Vegetations and Faunas

The vegetation survey was conducted in the 1st Year Campaign covering an area of approximately 11 km^2. The survey identified some plants of rare species. However, the Project Site including the F3 Ore Body comprises largely cultivated lands. No specific plant limited in the Project Site has been identified. No ecological study of faunas has been carried out to-date. However, no wild animal has been identified other grazed cattle, houses, pigs, cats, hens and ducks. Tiny creatures such as insects are observed. It remains unidentified if they include any rare species. Investigation on faunas will be required.

(6) Public Facilities and Cultural Assets

There is neither public facility nor cultural asset in and around the Project Area.

(7) Radioactivity

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 my be contaminated in discharges from the open pit and the plant. As aforementioned, the bastnaesite concentrate is stored in an independent storage that is designated as the radioactive material control area. No effluent of the plant water is discharged by recycling. The mine water is discharged after sedimentation of suspended solids in the settling pond. All these measures will serve for minimizing adverse influences of radioactive materials. Although it is essential to closely monitor levels of radioactivity in all areas of the operations, particularly for the bastnaesite concentrate, influences of radioactive materials in dusts and effluents discharged from the operations will be kept in minimal levels.

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

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 hydrological investigation and the meteorological observation.

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. 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 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

According to the 7 drill holes with the aggregated length of 820m, it were observed that 10.09% T-RE_2O_3 average at 27m section of MJVD-17 and 5.08% T-RE_2O_3 average at 24m section of MJVD-23. Rare Earth mineralization was weak in the western to north western part of F3 ore body, cause of massive limestone block which was appeared in 5 holes. 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 of 2-year. In addition, other 5 holes encountered moderate mineralization with the grade ranging from 5 to 10 % RE_2O_3.

(6) 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.

(7) 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 floats 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. Besides, flotation results of Barite and Fluorite were the recovery rate of 90% to produce the 95% $BaSO_4$ and the recovery rate of 55% to produce the 44% CaF_2 respectively. Since this newly developed flotation method are highly effective to treat intensely weathered and oxidized materials.

The ores of the F3 Ore Body have been visually classified into 4 categories, namely yellow, black, upper gray and lower gray ores in order to examine their metallurgical differences. These 4 types of ores were tested by the newly developed process flow and the reagent scheme. The recovery rate is the best for the yellow and declines in the order of those for the composite, upper gray, black and lower gray.

(8) 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 III-8-1).

(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.

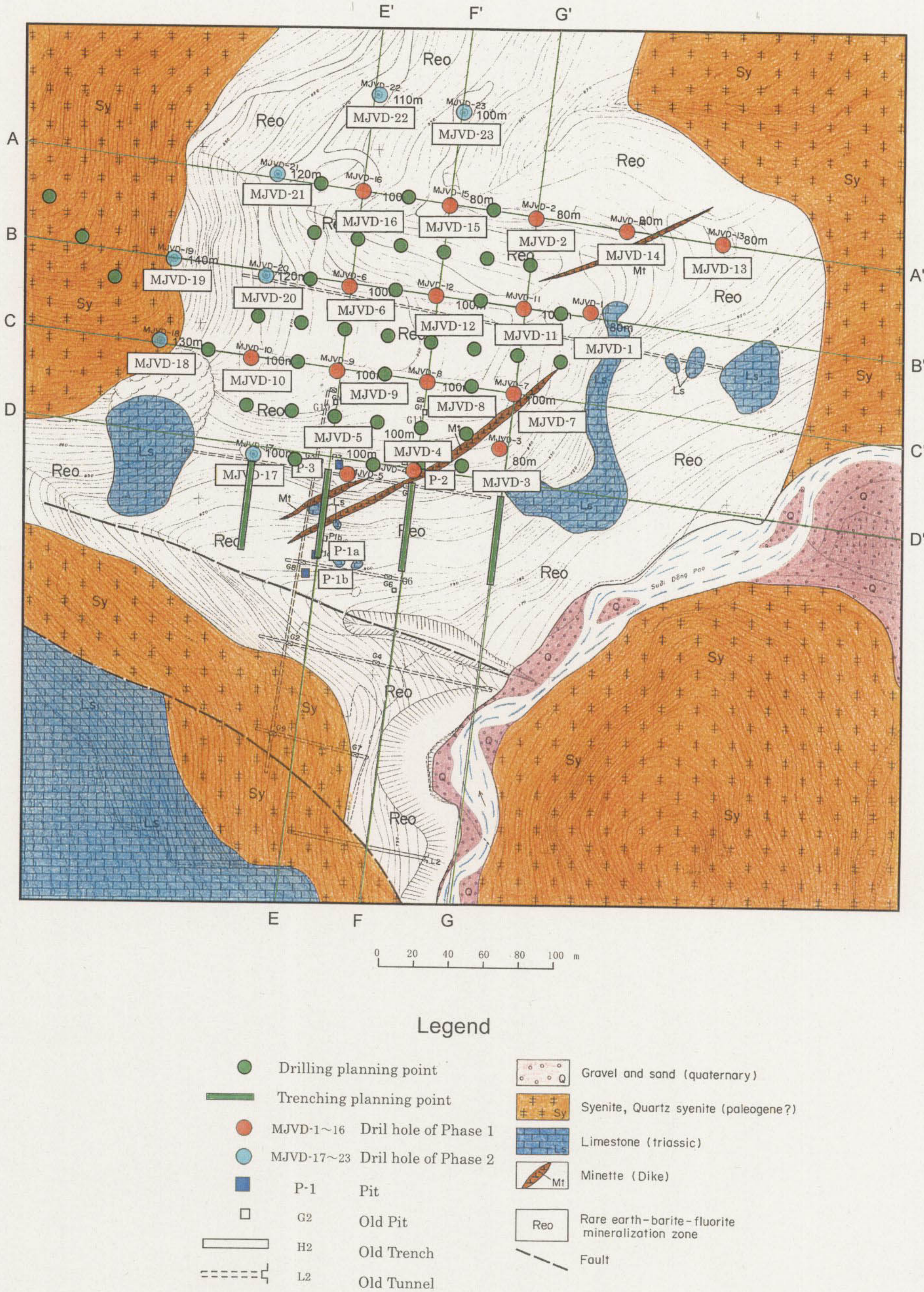


Figure Ⅲ-8-1 Additional drilling plan on F3 orebody