Chapter 4 Geological and Mineralogical Examination of F3 Ore Body

4-1 Geology and Geological Structures

The geology- mineralization map of F3 ore body and its vicinity is presented in Figure II-4-1. The geology of F3 ore body and its vicinity principally comprises the Palaeogene syenite intruding the Triassic limestone, both of which are intruded by a number of minette dikes.

The limestone forms steep cliffs in the southwestern part of the Project Area, and is light gray and massive in its appearance. The syenite extensively distributes in the general area and is generally soft on outcrops due to intense weathering. Weathered outcrops of unmineralized syenite show brownish color, while those of mineralized syenite are gray to black gray in appearance. A number of limestone blocks of various sizes are included within syenite intrusive bodies. Relatively large limestone blocks are found within those in the eastern and western parts of the area. Larger blocks appear to be light gray to gray and fine grained. In contrast, smaller blocks that are often found in mineralized zones in syenite bodies are white to gray, micro-crystalline, and mineralized.

Minette dikes are clearly identified in drill cores. However, no outcrop of minette dikes has been located. These dikes, intruding the syenite, are composed of brown colored soft rocks that have been subjected to intense weathering. The rocks characteristically contain green biotite phenocrysts(2-5 mm).

Alluvial sand-gravel deposits distributes along Dong Pao river to its southwest side.

The regional structures trend in the general direction of northwest-southeast. The Project Area is situated in one of the major structural zones of this trend. A fault system running in the NNW-SSE direction bounds the syenite and the limestone in the southwestern part of this area. Most minette dikes intrude in the NW-SE direction, according to the interpretation of the drill hole geological cross-sections.

4-2 Ore Deposit

Seven geology-mineralization cross-sections, A-A' through G-G', are drawn based on the result of drill core observation as shown in Figures II-4-2 (1/7) through (7/7). Fluctuations of T-RE_2O_3, CaF_2 and $BaSO_4$ contents according to the drill core assay results along the E-W cross-sections are graphically illustrated (bar graphs for T-RE_2O_3, line graphs for CaF_2 and $BaSO_4$) in Figures II-4-3 (1/4) through (4/4).

It is difficult to clearly define the outline of F3 ore body with a scarce number of outcrops due to extensive weathering. However, it is interpreted according to the results of the exploration in the past and the current project that the ore body is approximately

500 m long in the north-south direction and 300 m wide in the east-west direction. It is, however, possible that the ore body would extend further to the north and the west, judging from the mineralization observed in the drill cores. In the course of the current project, 16 holes, at an interval of 50m in principle, were drilled to F3 ore body at elevations of 826 to 875 m in its central part in order to verify its mode of occurrence, size and grade to the elevation at approximately 750 m (water level of Dong Pao stream).

(1) Rare Earth Mineralization

The 7 holes, MJVD-5, 6, 7, 9, 10, 12 and 15, out of the total 16 holes, have intersected rare earth mineralization with the grades better than 10 % T-RE_2O_3. Further, the mineralization of moderate grades ranging from 5 to 10 % T-RE_2O_3 has been encountered in the 5 holes, MJVD-2, 3, 4, 8 and 16. Other 4 holes have revealed only low grade mineralization.

The high grade zone thins out to the east but tends to become dominant westwards as seen in the E-W geology-mineralization cross-sections (A-A' through D-D'). Along the N-S cross-section E-E', the southern high grade zone is located near surface while the northern high grade zone is relatively deep-seated. It appears that there are two separate high grade zones, the upper and the lower (MJVD-9). However, the upper and the lower zones in the hole MJVD-9 join together in a single high grade zone in the hole MJVD-10 as seen in the E-W cross-section C-C'. Zones of moderate grade (10 % > T-RE_2O_3 ≧ 5%) are developed surrounding the high grade zone (T-RE_2O_3 ≧ 10%), forming irregular lenses with sizable dimensions within the extensive low grade mineralization(T-RE_2O_3 <5%).

The high grade zone (T-RE_2O_3 ≧ 10%) is projected on the plan as shown in Figure II-4-4 (1), based on the geology-mineralization cross-sections. The outline of the southern high grade zone to the south of the E-W cross-section is interpreted taking account of the past exploration data to the depth of 30 m from the surface. The plan indicates that the horizontal extent of the high grade zone is approximately 300 m long in the north-south and more than 100 m wide in the east-west. However, its northern and western limits have not been established in the course of the current exploration, which suggests a potential of the zone to further expand either to the north, west or both directions. The states of the mineralization of the high grade zone for F3 ore body is summarized in Table II-4-1.

Table II-4-1 Summary of the States of the High Grade Rare Earth Zones

Section No.	Boring No.	Depth (m)	Width (m)	Content T-RE_2O_3(%)
A-A'	MJVD-15	63.00~77.00	14.00	10.90
B-B'	MJVD-6	63.00~87.00	24.00	14.20
	MJVD-12	46.00~91.00	45.00	10.82
C-C'	MJVD-10	44.00~96.00	52.00	10.44
	MJVD-9	64.00~88.00	24.00	10.59
	MJVD-7	39.00~55.00	16.00	11.72
D-D'	MJVD-5	0.00~25.00	25.00	11.00

(2) Fluorite Mineralization

Significant fluorite mineralization occurs in the holes MJVD-5, 6, 7, 9, 10, 12 and 15. Its horizontal distribution is shown in Figure II-4-4 (2). The horizontal distribution of the high grade fluorite mineralization largely coincides with that of the high grade zone of the rare earth mineralization. In the cross-sections, however, these two types of mineralization are not necessarily correlated to each other, although fluorite is, in some cases, concentrated in the close proximity to the high grade rare earth zone. It is, therefore, implied that these mineralization types have been formed in different stages.

Fluorite occurs as disseminations in syenite, while fluorite veinlets, as well as disseminations, are commonly observed in association with limestone.

The states of the fluorite mineralization is summarized in Table II-4-2.

Table II-4-2 Summary of Fluorite Mineralization Zones

Section No.	Boring No.	Depth (m)	Width (m)	Content CaF2(%)
A-A'	MJVD-15	58.00 ~ 80.00	22.00	14.99
B-B'	MJVD-6	69.00~100.00	31.00	27.42
C-C'	MJVD-10	47.00~ 65.00	18.00	18.85
	Ditto	90.00~100.00	10.00	34.63
	MJVD-9	29.00~100.00	71.00	19.81
D-D'	MJVD-5	18.00~ 32.00	14.00	11.37
	Ditto	55.00~ 78.00	23.00	12.94

(3) Barite Mineralization

Barite is generally concentrated to a significant degree in an extensive area where the drilling exploration was carried out in the current project. All drill holes intersected significant barite mineralization. The zone of barite concentration is illustrated in

Figure II-4-4 (3).

The barite mineralization in the holes MJVD-1, 10 and 13 is weak compared to that in the other holes. The horizontal distribution of the barite mineralization is extensive beyond the limit of the rare earth mineralization. Its vertical distribution is unrelated to the rare earth concentrations without any notable correlation between the types of mineralization for their concentrations. The high grade zones of barite mineralization tend to thicken to the north from the south and to the west from the east, with increasing the average barite contents. No correlation is seen between the barite and fluorite concentrations as well.

Table II-4-3 summarizes the particularly high grade zones of barite mineralization that were intersected by the holes.

Table II-4-3 Summary of the High Grade Zones of Barite Mineralization

Section No.	Boring No.	Depth (m)	Width (m)	Content $BaSO_4$(%)
A-A'	MJVD-16	10.00～33.00	23.00	62.03
	Ditto	36.00～75.00	39.00	68.01
B-B'	MJVD-6	0.00～76.00	76.00	50.95
	MJVD-12	1.00～90.00	89.00	58.93
C-C'	MJVD-8	1.00～59.00	58.00	60.20

(4) Description of the Mineralization

1) Modes of Occurrence of Ore Minerals

F3 ore body is weathered to variable degrees both on outcrops and in drill cores. It is, therefore, very difficult to visually identify ore minerals with the aid of hand lenses. Accordingly, the ores and rocks in the mineralized zones are classified by their color tones, such as brown, black gray to gray, yellow to light yellow, white, purple and so forth. Characteristics of ores and rocks according to the color tone classification are summarized below.

- Brown to dark brown, partly dark gray : observed mainly in surface soil.
- Brown to light brown : features mainly of intensely weathered syenite
- Black gray to gray : features of ores that are relatively high in manganese content and usually indicate total rare earth contents of less than 10 % T-RE_2O_3 (Figure II-4-5, P3).
- Yellow to light yellow : ores that contain an appreciable amount of bastnaesite, indicating total rare earth contents of more than 10 % T-RE_2O_3 (Figure II-4-5, P2, P4).
- White : barite ores, often fragmental or sandy due to weathering.

- Purple : fluorite ores, crystalline in limestone but sandy where intensely weathered (Figure II-4-5, P6), becoming dark purple where manganese is contained.

An outcrop of F3 ore body is observed along the road cuttings in the vicinity of the drilling sites of the holes MJVD-3, -4 and -5. The sample locations of the outcrop along the road are presented in Figure II-4-6, together with the assay results. The sketch of the outcrop is shown in Figure II-4-7. The yellow to light yellow parts in the outcrop sketch contain abundant bastnaesite and indicate total rare earth content higher than 10 % T-RE_2O_3, including the highest assay of 56.28 % T-RE_2O_3. These parts transit to the neighboring black gray parts, where the total rare earth content is reduced to less than 10 % T-RE_2O_3. A part of white barite concentration is seen in the upper-left of the sketch, while a part of purple fluorite concentration is intercalated in the bastnaesite concentrations in the lower-left. These bastnaesite, barite and fluorite concentrations form laterally extended lenses. The barite lens rests on the bastnaesite lens, while the fluorite lens is intercalated in the bastnaesite lens. No correlation between these three minerals can be recognized in the assay results of the outcrop samples. This sketch appears to represent the mode of occurrence of F3 ore body as a miniature.

2) Mineralogy

The result of microscopic observation of thin sections of ore samples is attached in Apx. 1 and that of X-ray diffraction analysis, in Apx 2.

The ore minerals that occur in F3 ore body are bastnaesite, synchysite, barite, fluorite and minor monazite. The gangues comprise quartz, calcite and K-feldspar, accompanied by minor illite, kaolinite, halloysite, smectite and boehmite.

Bastnaesite is fine-grained and occurs mostly filling interstices between barite, fluorite or quartz crystals (Figure II-4-5 (4)). Bastnaesite-calcite veinlets occasionally crosscut crystals of barite and fluorite, the occurrence of which is shown in the microphotograph in Figure II-4-5 (5).

3) Pattern of Rare Earth Elements

The contents of rare earth elements in the selected drill core samples (9 samples) and the pit samples for the metallurgical testing are normalized with the chondrite standards in order to examine the characteristics of the rare earth elements occurring in F3 ore body. The chondrite standards used for the normalization are of the C1 chondrite (Evensen et al., 1978). The chondrite-normalized REE pattern is illustrated in Figure II-4-8, compared to those of bastnaesite from Mountain Pass and of monazite from Yoganup.

The drill core and the metallurgical test samples are higher in the proportion of light rare earths than in that of heavy rare earths, compared to the standard chondrite, as shown in Figure II-4-8. The chondrite normalized REE patterns for these samples demonstrate fair agreement with that of the Mountain Pass bastnaesite rather than with that of the Yoganup monazite which is proportionally high in light to medium rare earths. The characteristics of F3 ore body demonstrated in the REE patterns, in combination with the results of the microscopic observation and the X-ray diffraction analysis, indicate that bastnaesite is the main component of the rare earth mineralization.

The metallurgical test sample is more enriched in La and Ce than the drill core samples. This may be attributed to the near-surface secondary enrichment of these elements due to weathering, because the sample was collected from pits excavated along a cliff. The core sample of MJDV-5-2 shows a negative anomaly of Ce in the REE pattern, which suggests the possibility that more bastnaesite (La) than bastnaesite (Ce) is contained in the MJDV-5-2 sample.

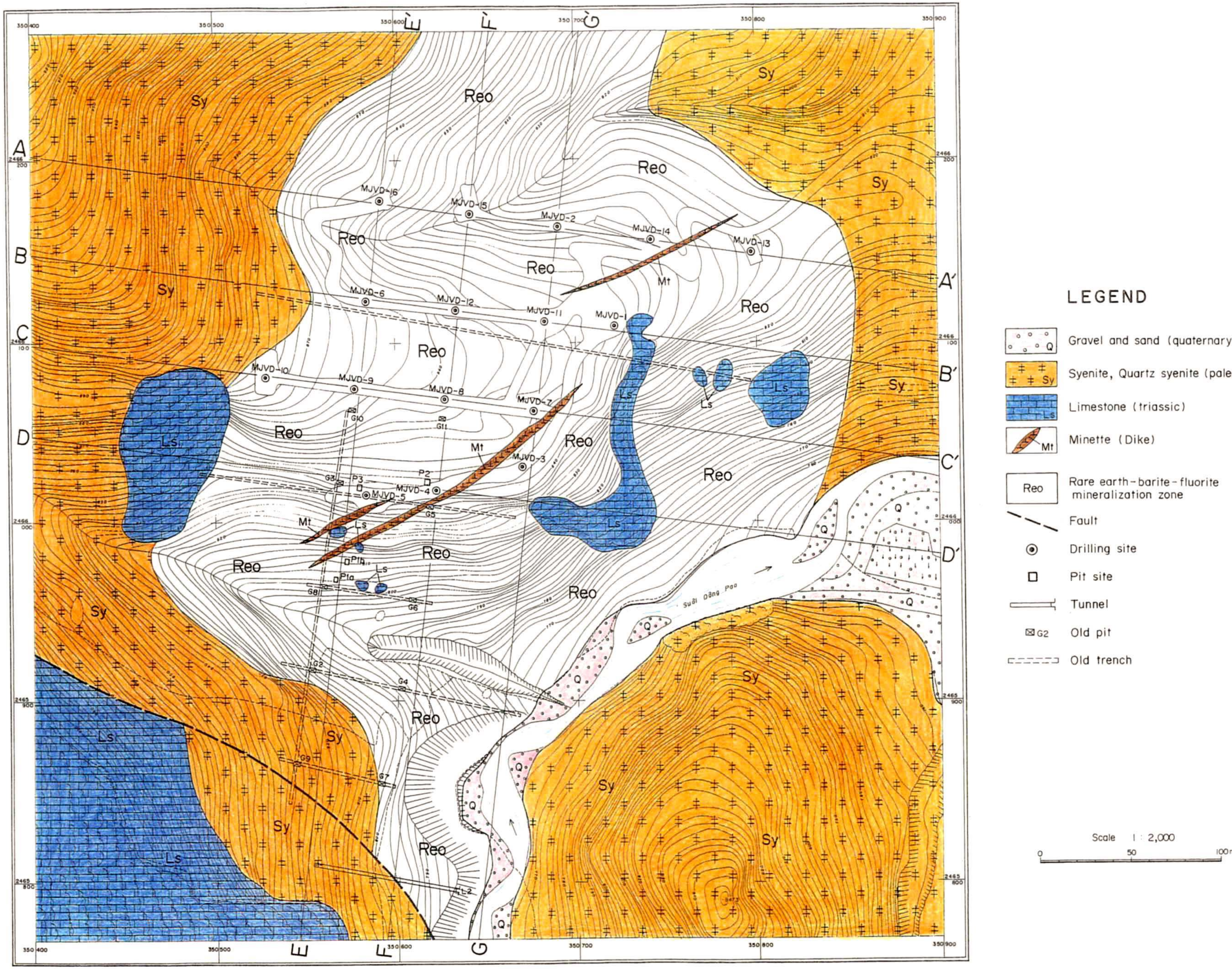


Figure II-4-1 The geology-mineralization map of F 3 orebody

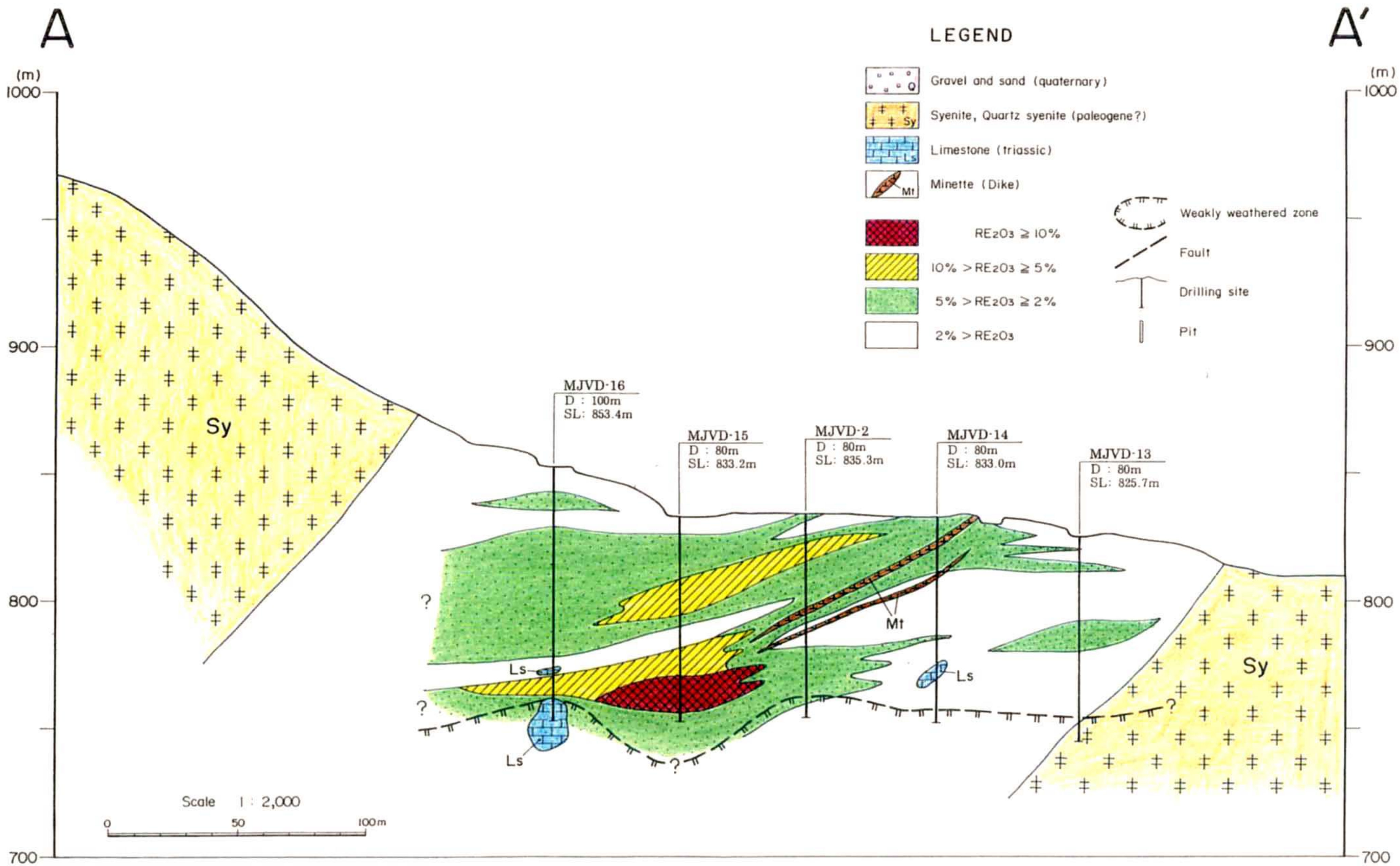


Figure II-4-2 (1/7) Geology-mineralization cross-section of F3 orebody (A-A')

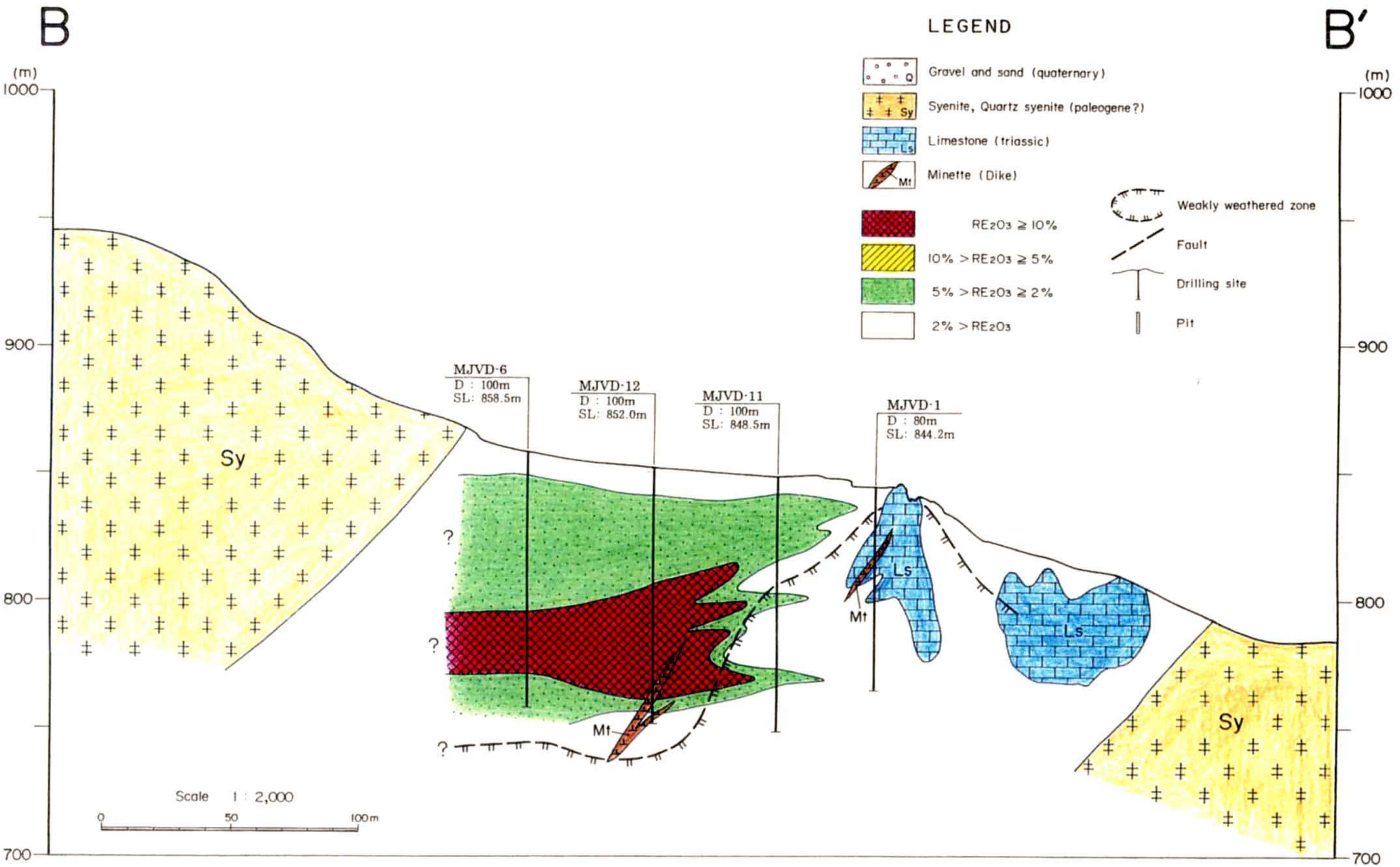


Figure II-4-2 (2/7) Geology-mineralization cross-section of F3 orebody (B-B')

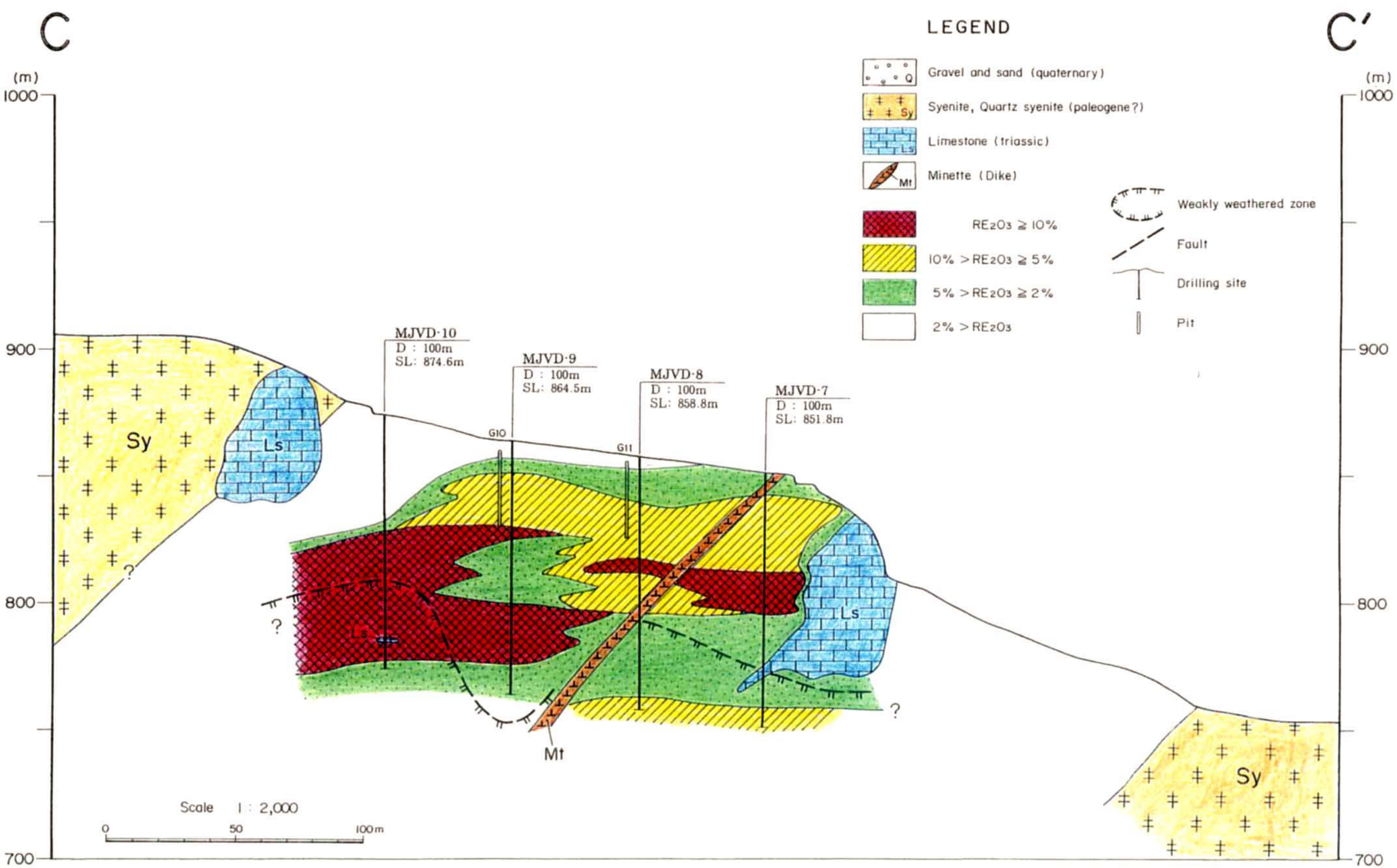


Figure II-4-2 (3/7) Geology-mineralization cross-section of F3 orebody (C-C')

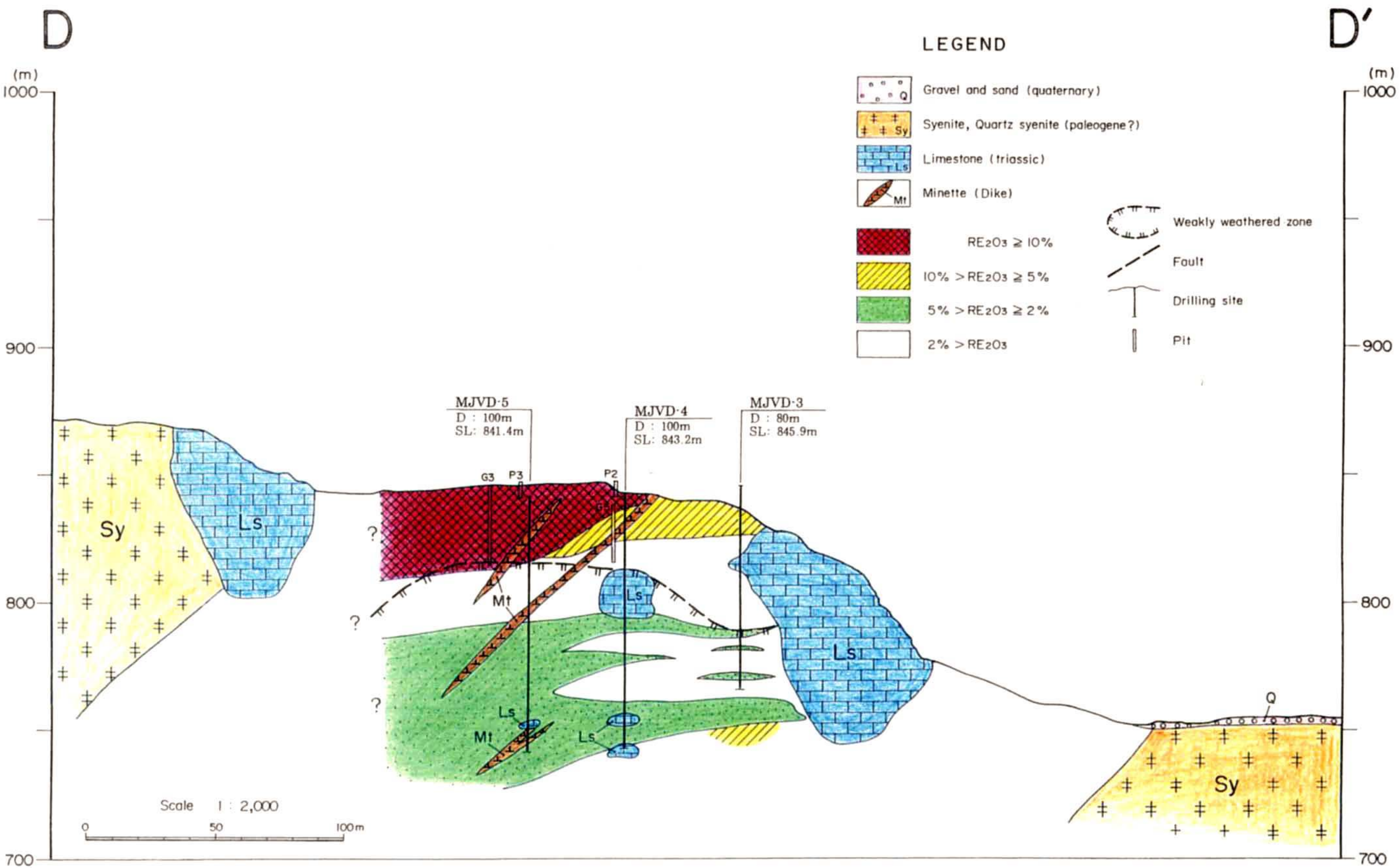


Figure II-4-2 (4/7) Geology-mineralization cross-section of F3 orebody (D-D')

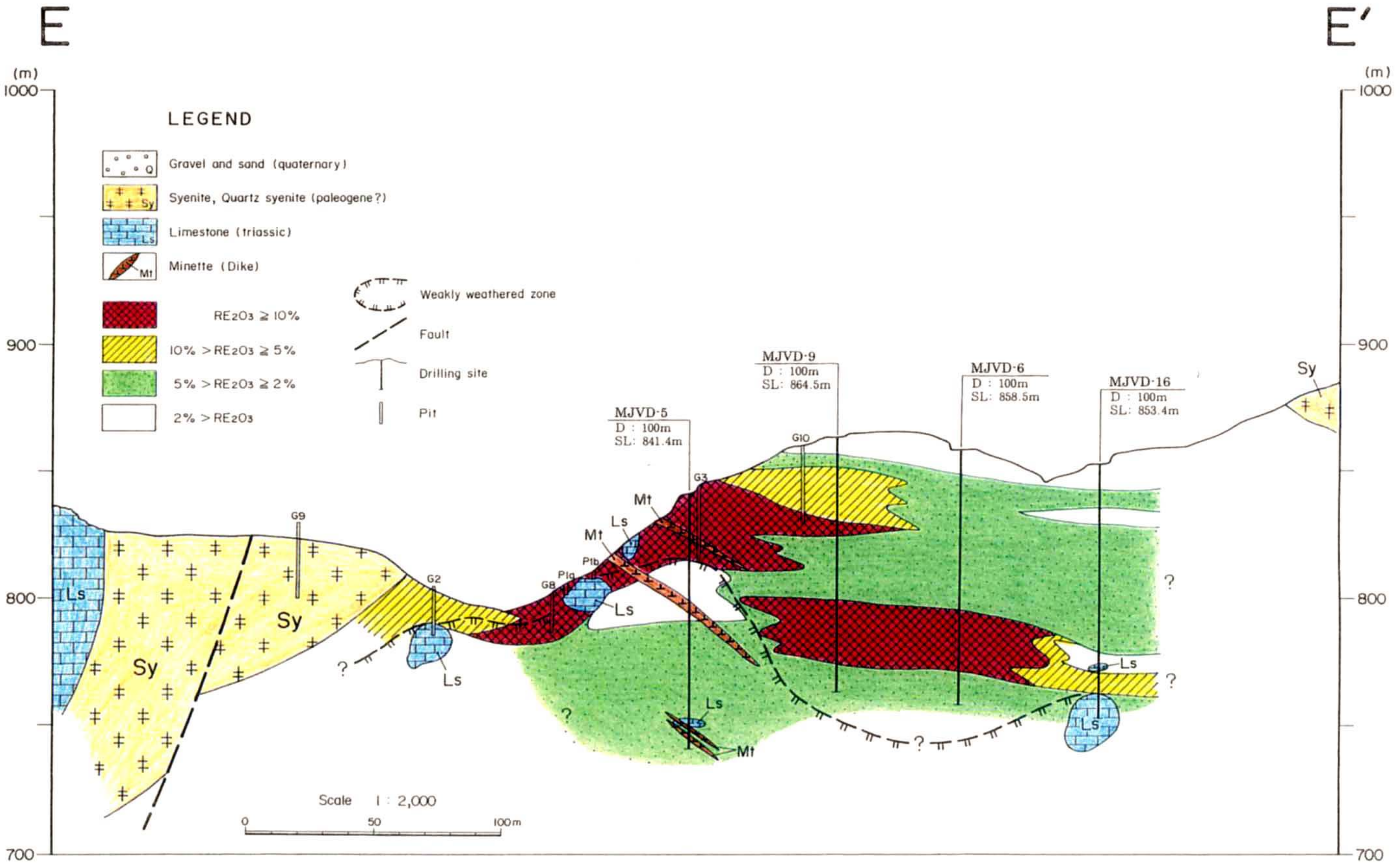


Figure II-4-2 (5/7) Geology-mineralization cross-section of F3 orebody (E-E')

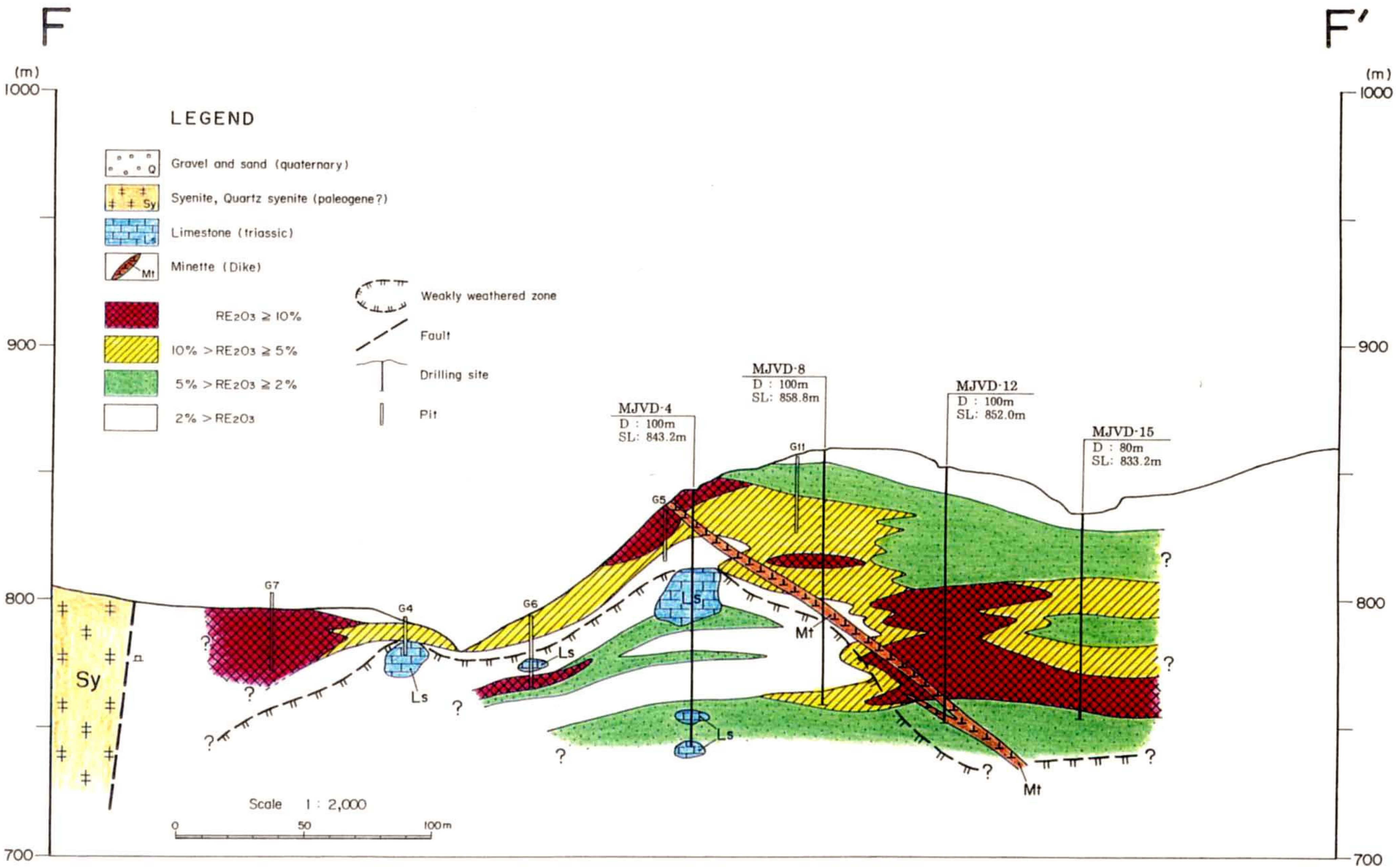


Figure II-4-2 (6/7) Geology-mineralization cross-section of F3 orebody (F-F')

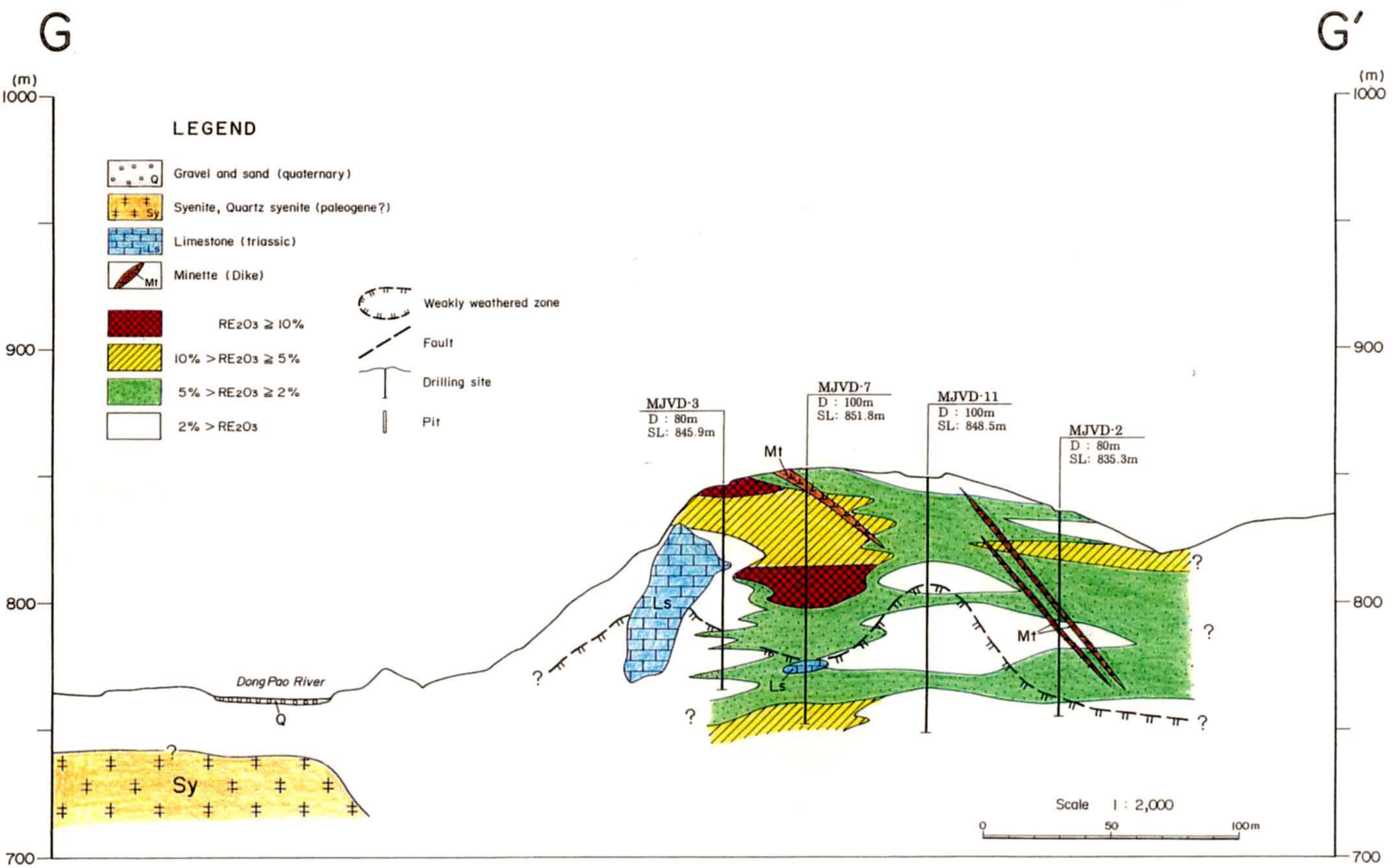


Figure II-4-2 (7/7) Geology-mineralization cross-section of F3 orebody (G-G')

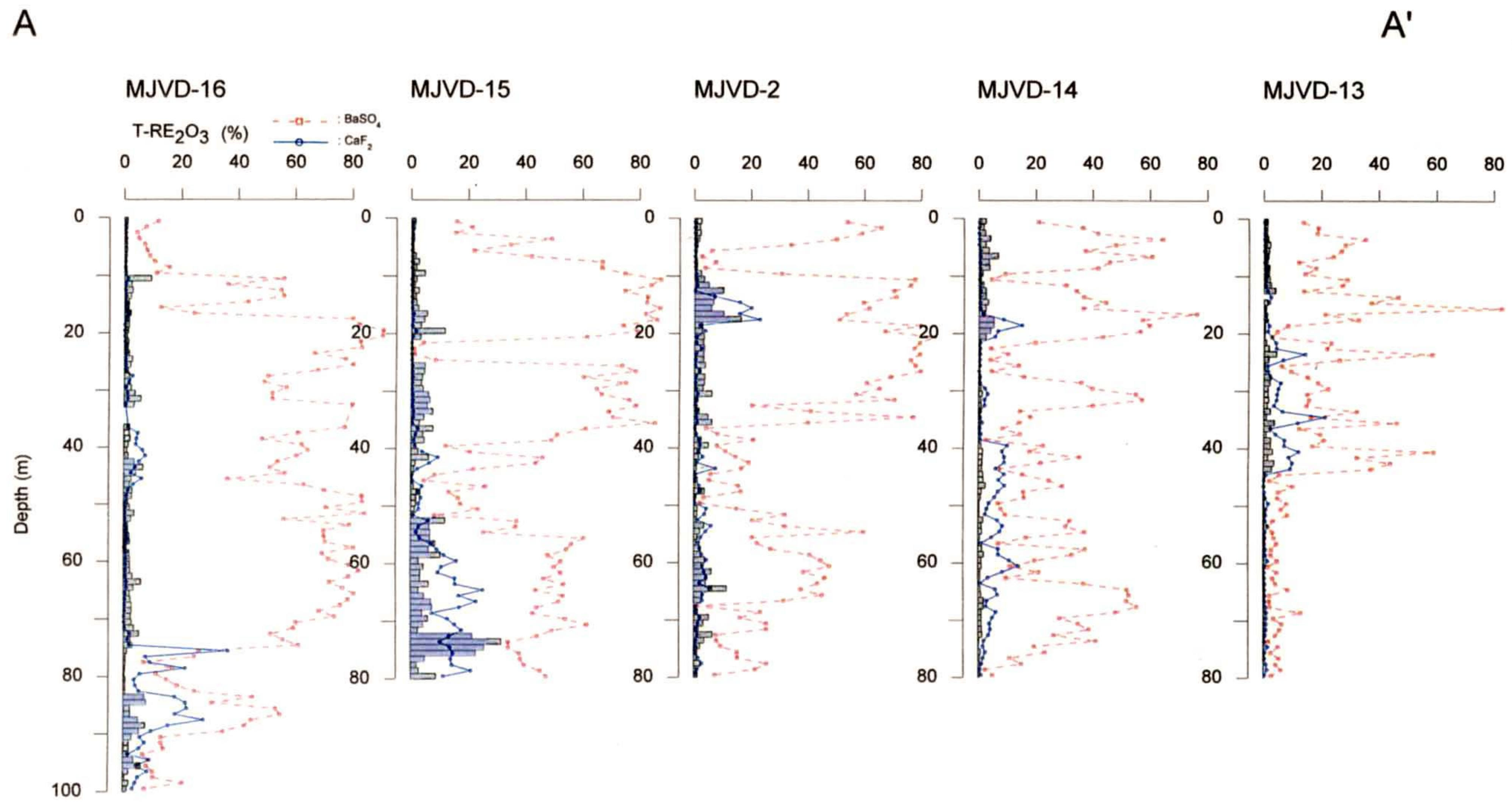


Figure II-4-3 (1/4) Bar graphs for T-RE_2O_3, line graphs for CaF_2 and $BaSO_4$ (A-A')

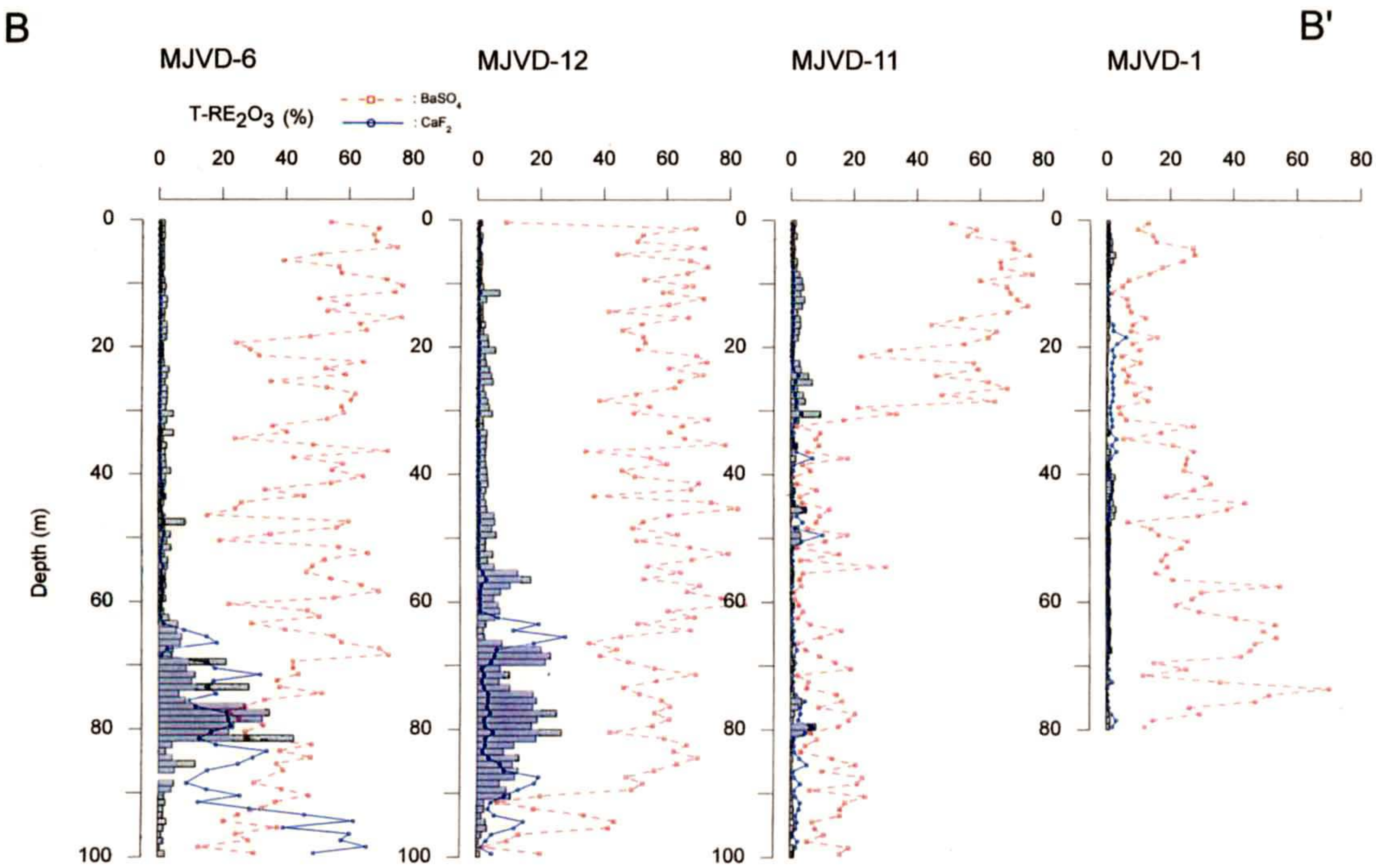


Figure II-4-3 (2/4) Bar graphs for T-RE_2O_3, line graphs for CaF_2 and $BaSO_4$ (B-B')

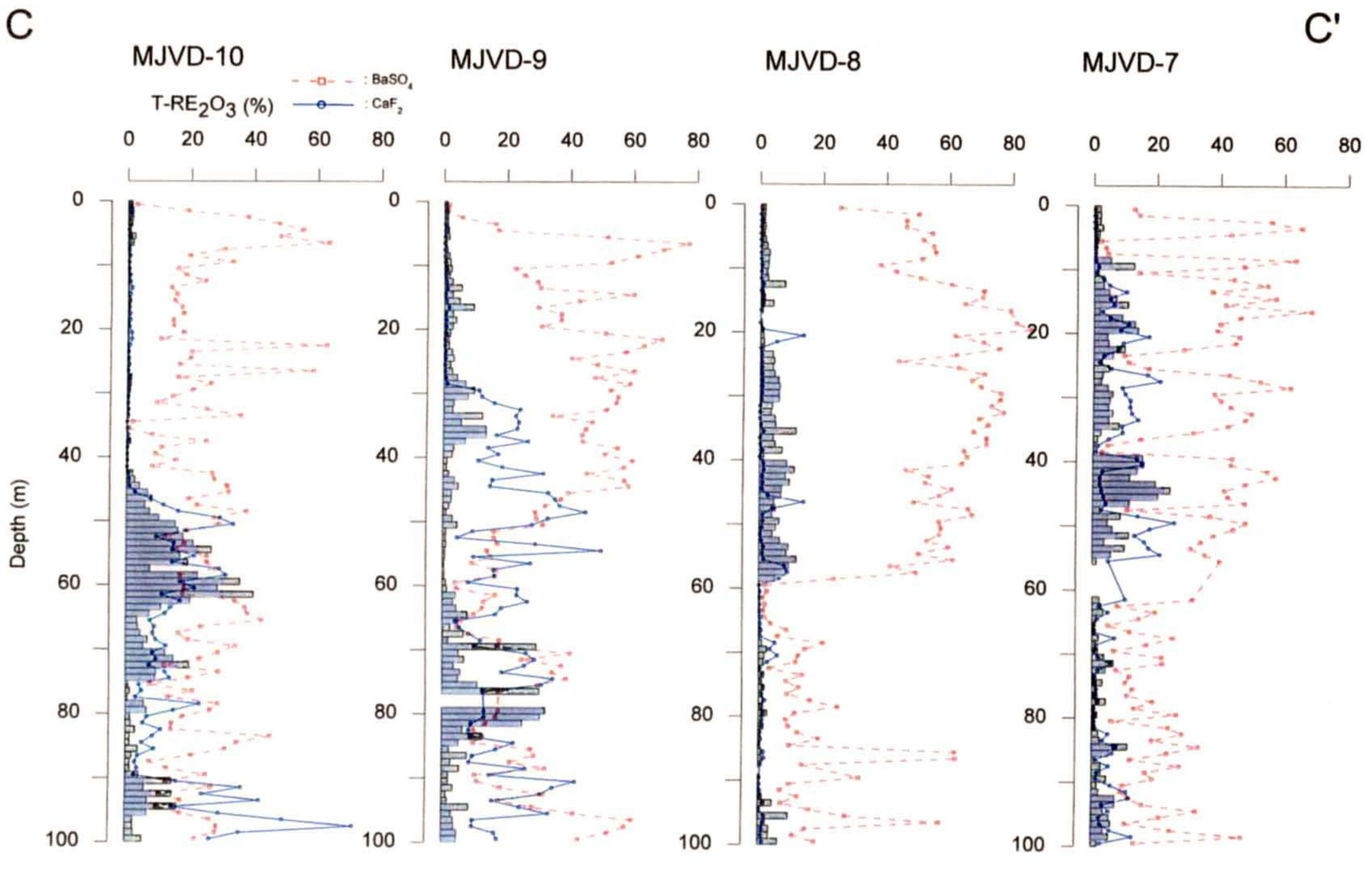


Figure II-4-3 (3/4) Bar graphs for T-RE_2O_3, line graphs for CaF_2 and $BaSO_4$ (C-C')

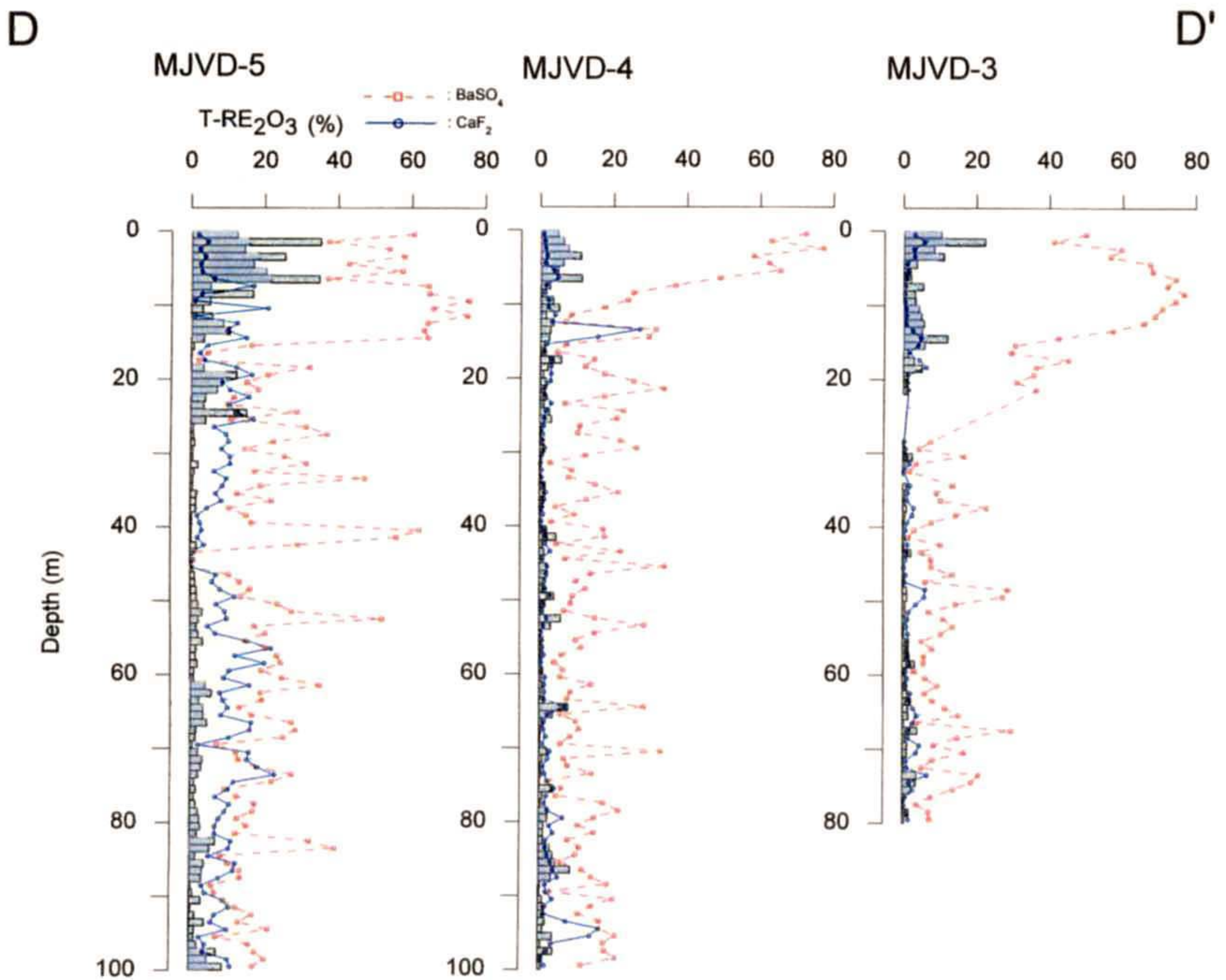


Figure II-4-3 (4/4) Bar graphs for $T\text{-}RE_2O_3$, line graphs for CaF_2 and $BaSO_4$ (D-D')

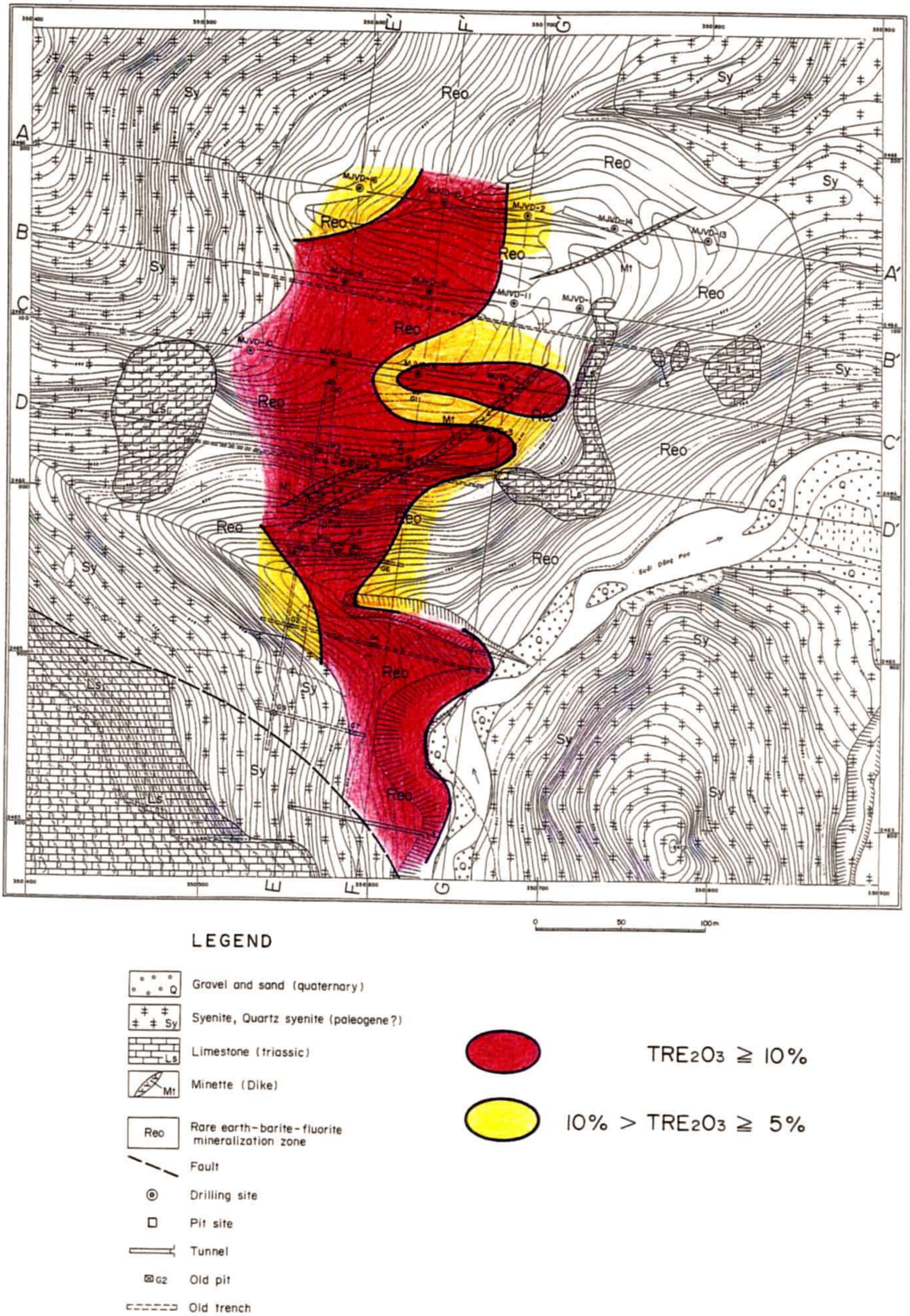


Figure II-4-4 (1) Plan map of the horizontal distribution of high grade REO mineralization

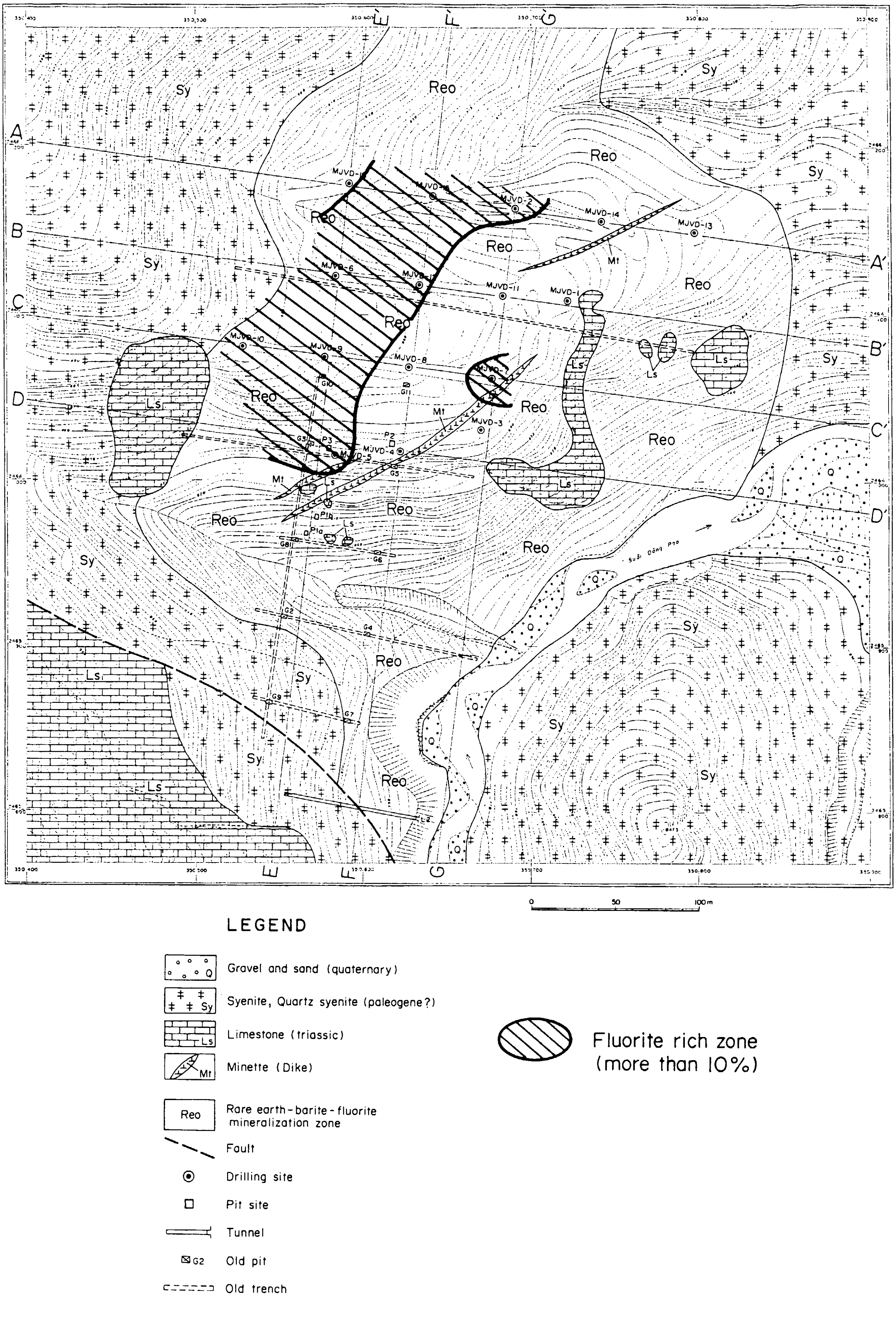
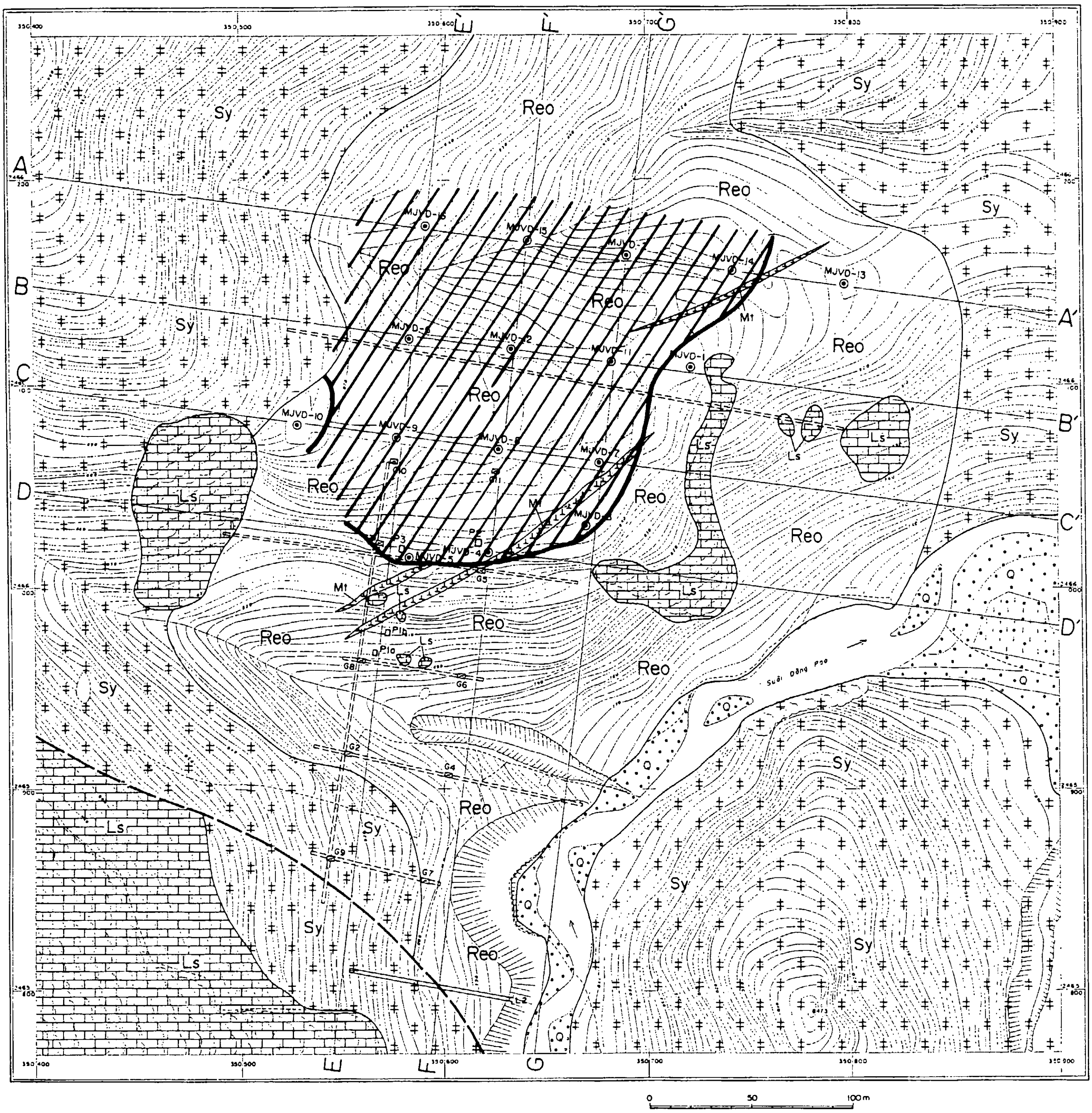


Figure II-4-4 (2) Plan map of the horizontal distribution of high grade fluorite mineralization



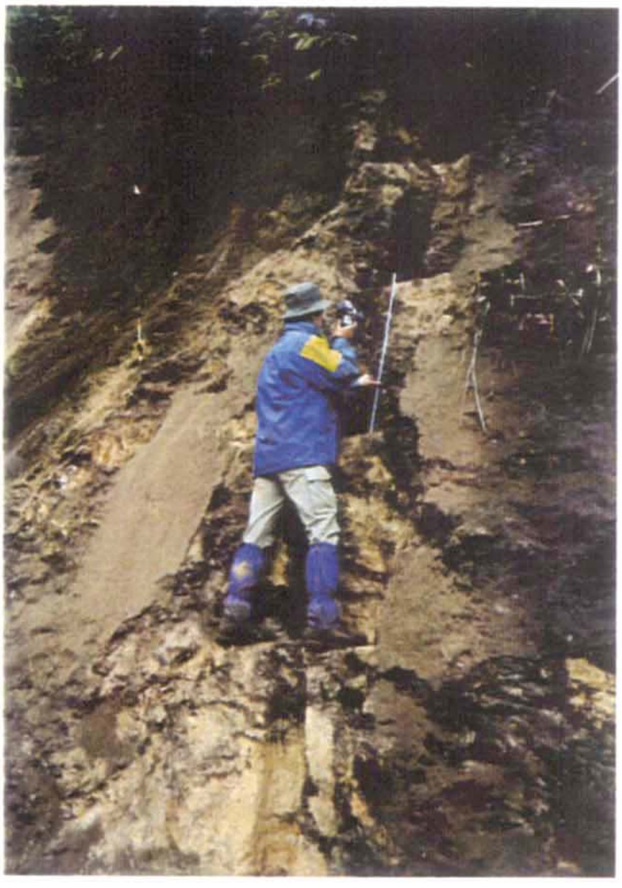
LEGEND

- Gravel and sand (quaternary) — Q
- Syenite, Quartz syenite (paleogene?) — Sy
- Limestone (triassic) — Ls
- Minette (Dike) — Mt
- Rare earth-barite-fluorite mineralization zone — Reo
- Fault
- Drilling site
- Pit site
- Tunnel
- Old pit — G2
- Old trench

Barite rich zone (more than 40%)

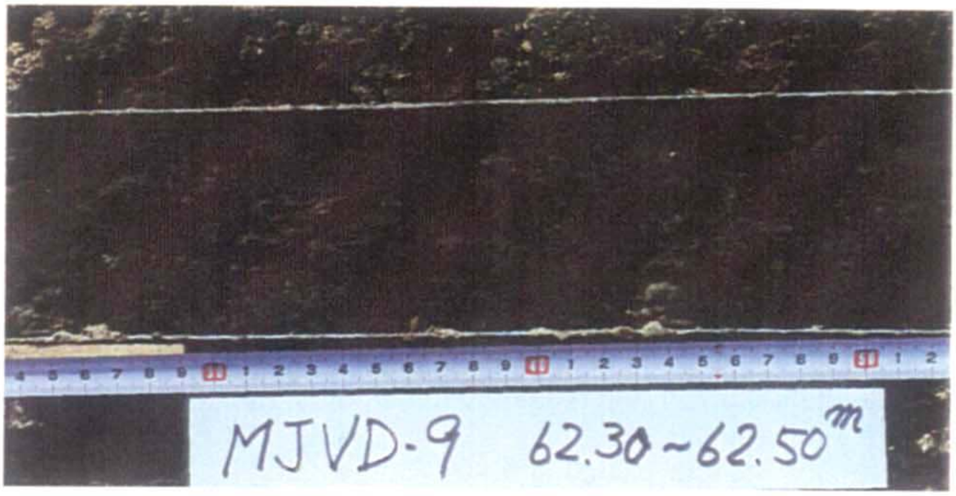
Figure II-4-4 (3) Plan map of the horizontal distribution of high grade barite mineralization

P. 1 View of F3 orebody from north-west



P.2 Pit 3 cutting
(Yellow part contains bastnaesite)

Figure II-4-5 (1) Photographs of F3 ore body



P.3 MJVD-9 62.30~62.50m strongly weathered black ore

(TRE_2O_3:3.36%, CaF_2:26.92%, $BaSO_4$:13.09%)

P.4 MJVD-6 72.00~72.50m

Batnaesite: yellow, Fluorite:Purple, Barite:white

(TRE_2O_3:10.36%, CaF_2:17.22%, $BaSO_4$:37.22%)

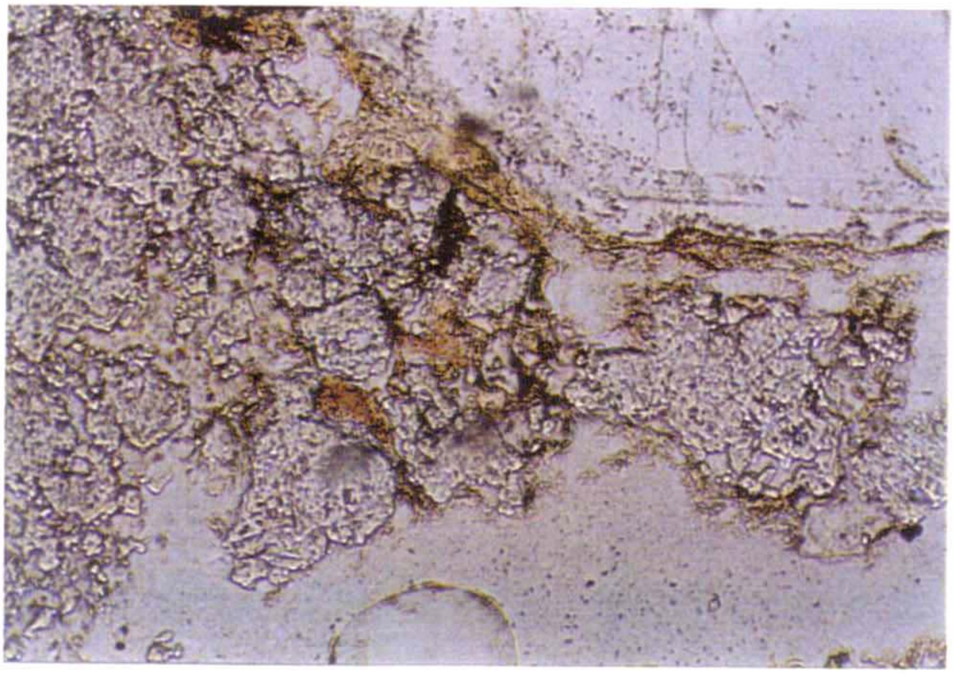
Figure II-4-5 (2) Photographs of F3 ore body

P.3 MJVD-4 13.60~13.80m
Fluorite:purple, Barite:white

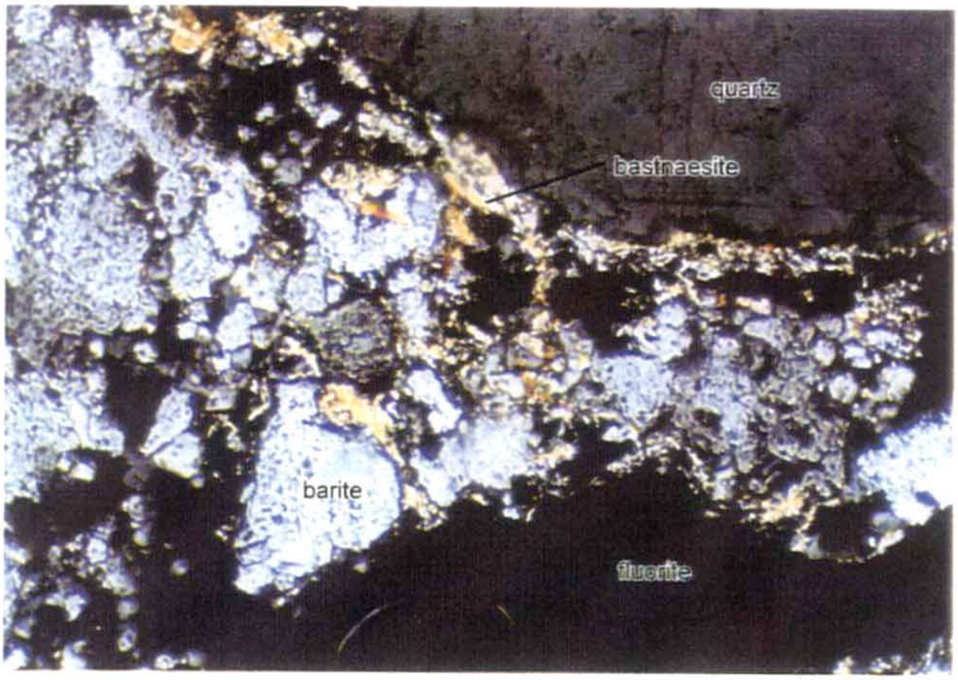
P.4 MJVD-10 50.60~50.80m
Fluorite:purple, Barite:white

Figure II-4-5 (3) Photographs of F3 ore body

Sample No. P3-550
Rock Name : Barite and Fluorite
Location : Pit



Opened



Crossed

0.1mm

P.7 Sample from Pit P3, depth 550cm

Figure II-4-5 (4) Photographs of F3 ore body

Sample No. MJVD-10-96.40
Rock Name : Barite and Fluorite ore
Location : Drilling core

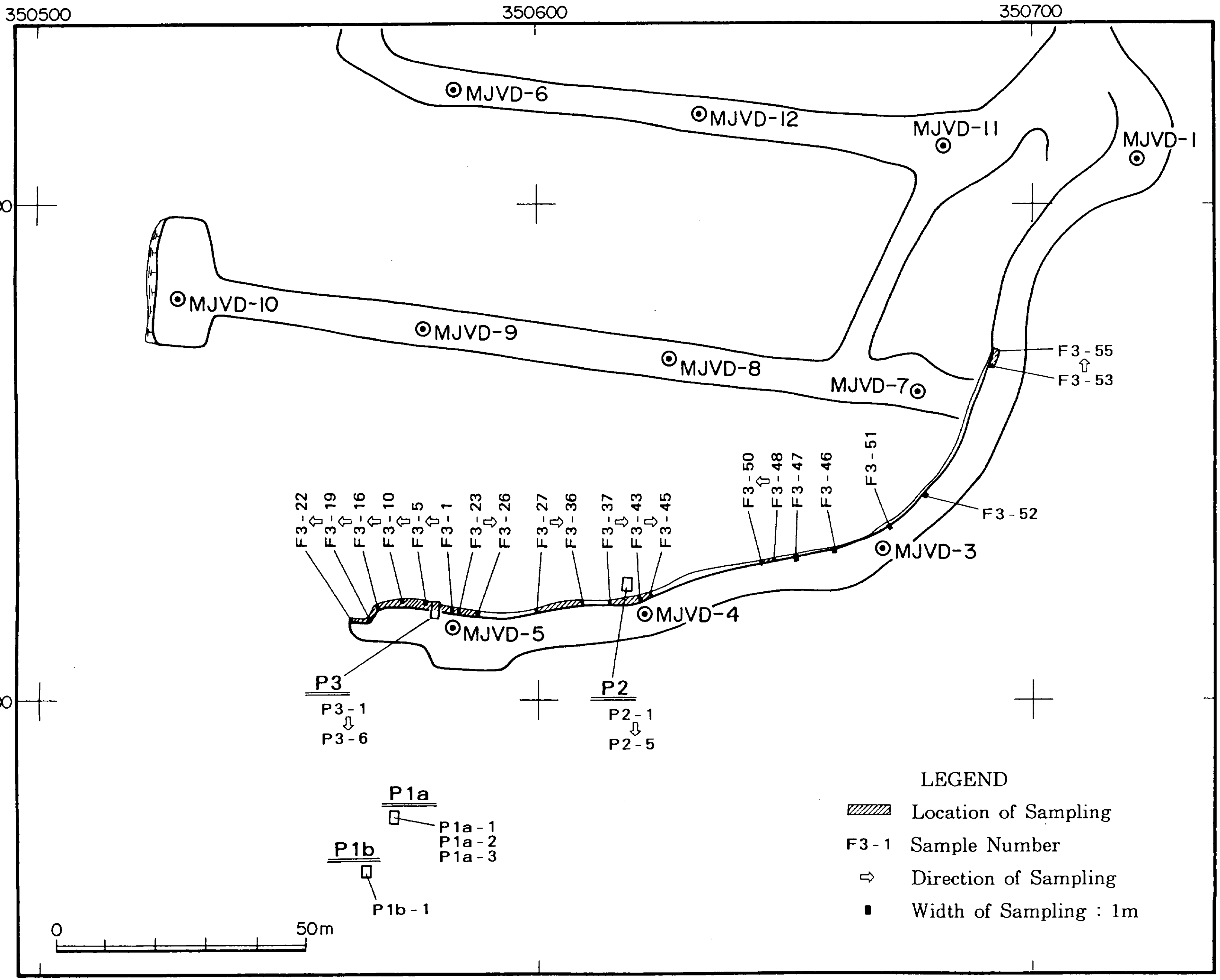
Opened

Crossed

1mm

P.8 Sample from Core of MJVD-10, depth 96.40m

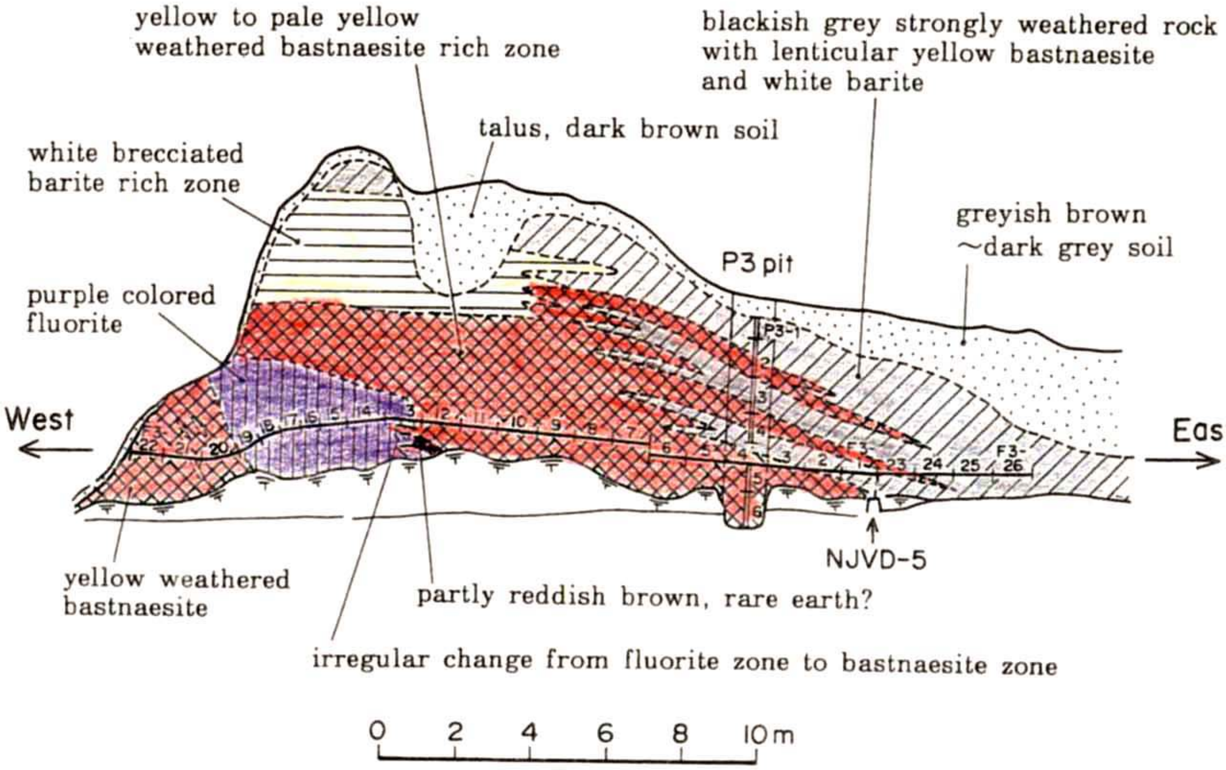
Figure II-4-5 (5) Photographs of F3 ore body



Sample No.	Width	Assay result (%) T-RE₂O₃	BaSO₄	CaF₂
F3-1	1	4.10	64.07	0.39
F3-2	1	3.91	64.27	0.39
F3-3	1	7.27	64.11	0.39
F3-4	1	15.33	52.96	0.78
F3-5	1	3.44	61.40	0.39
F3-6	1	24.13	47.96	0.39
F3-7	1	14.15	59.47	0.39
F3-8	1	8.31	58.00	13.05
F3-9	1	22.25	39.02	4.29
F3-10	1	40.55	20.33	2.73
F3-11	1	56.28	16.87	1.17
F3-12	1	18.44	55.28	1.17
F3-13	1	6.39	57.77	14.03
F3-14	1	7.33	43.01	26.69
F3-15	1	2.92	17.02	65.84
F3-16	1	9.22	52.47	13.64
F3-17	1	8.45	37.54	24.35
F3-18	1	12.49	30.80	28.64
F3-19	1	7.79	15.12	64.09
F3-20	1	22.33	45.42	1.56
F3-21	1	33.94	42.10	0.97
F3-22	1	45.99	25.33	2.73
F3-23	1	3.91	64.52	0.195
F3-24	1	8.00	60.71	0.195
F3-25	1	7.88	67.05	0.195
F3-26	1	6.18	67.35	0.29
F3-27	1	7.15	68.03	0.97
F3-28	1	18.13	60.23	0.48
F3-29	1	29.05	49.48	0.58
F3-30	1	18.50	63.20	0.39
F3-31	1	29.83	49.79	0.58
F3-32	1	1.82	80.90	0.195
F3-33	1	7.17	65.99	0.195
F3-34	1	37.97	41.28	0.58
F3-35	1	39.61	39.89	0.49
F3-36	1	30.50	51.32	0.39
F3-37	1	0.37	90.81	0.19
F3-38	1	4.31	74.72	0.19
F3-39	1	5.20	65.14	0.19
F3-40	1	2.95	78.18	0.19
F3-41	1	8.83	70.26	0.39
F3-42	1	4.28	76.04	0.39
F3-43	1	4.26	78.52	0.29
F3-44	1	8.61	56.26	0.39
F3-45	1	1.53	74.05	0.19
F3-46	1	21.52	41.25	0.57
F3-47	1	0.10	31.50	3.90
F3-48	1	8.77	67.69	0.39
F3-49	1	16.58	57.06	0.37
F3-50	1	5.60	54.93	0.19
F3-51	1	10.48	67.09	0.39
F3-52	1	17.69	57.91	0.39
F3-53	1	3.59	58.98	0.19
F3-54	1	6.31	61.33	0.19
F3-55	1	6.79	60.44	0.19
Total		758.48	3022.22	282.98
Average		13.79	54.95	5.15

Sample No.	Width	Assay result (%) T-RE₂O₃	BaSO₄	CaF₂
P1a-1	1	6.53	41.93	19.87
P1a-2	1	6.04	37.10	19.48
P1a-3	1	13.80	39.41	19.67
P1b-1	1	10.77	36.80	32.14
P2-1	0.4	2.59	58.22	0.19
P2-2	1	3.36	59.15	0.19
P2-3	1	4.00	65.10	0.19
P2-4	1	5.07	73.69	0.19
P2-5	1	5.74	78.98	0.39
P3-1	0.6	9.16	57.05	0.19
P3-2	1	12.13	61.01	0.19
P3-3	1	12.16	62.20	0.39
P3-4	1	15.40	54.35	0.19
P3-5	1	28.71	44.89	0.39
P3-6	1	2.61	79.66	0.19
Total		138.07	849.54	93.85
Average		9.20	56.64	6.26

Figure II-4-6 The sample locations and assay results of the outcrop in F3 ore body



Sample No.	Width	Assay result (%)			Description
		T-RE_2O_3	$BaSO_4$	CaF_2	
F3-1	1	4.10	64.07	0.39	black and grey mixed ore
F3-2	1	3.91	64.27	0.39	black and grey mixed ore
F3-3	1	7.27	64.11	0.39	black ore network
F3-4	1	15.33	52.96	0.78	yellow ore
F3-5	1	3.44	61.40	0.39	yellow >black ore
F3-6	1	24.13	47.96	0.39	black ore with yellow ore
F3-7	1	14.15	59.47	0.39	yellow ore
F3-8	1	8.31	58.00	13.05	yellow>>black ore
F3-9	1	22.25	39.02	4.29	yellow and black mixed ore
F3-10	1	40.55	20.33	2.73	mainly yellow ore
F3-11	1	56.28	16.87	1.17	mainly yellow ore
F3-12	1	18.44	55.28	1.17	mainly yellow ore
F3-13	1	6.39	57.77	14.03	yellow and black mixed ore
F3-14	1	7.33	43.01	26.69	fluorite>yellow =black ore
F3-15	1	2.92	17.02	65.84	fluorite>yellow ,partly grey
F3-16	1	9.22	52.47	13.64	fluorite>yellow ,partly grey
F3-17	1	8.45	37.54	24.35	fluorite>yellow ,partly grey
F3-18	1	12.49	30.80	28.64	fluorite>yellow =black ore
F3-19	1	7.79	15.12	64.09	fluorite rich ore
F3-20	1	22.33	45.42	1.56	yellow =black>fluorite ore
F3-21	1	33.94	42.10	0.97	yellow >>fluorite ore
F3-22	1	45.99	25.33	2.73	yellow >>fluorite ore
F3-23	1	3.91	64.52	0.195	black>>yellow ore
F3-24	1	8.00	60.71	0.195	black>>yellow ore
F3-25	1	7.88	67.05	0.195	black>>barite ore
F3-26	1	6.18	67.35	0.29	black ore with yellow ore
P3-1	0.6	9.16	57.05	0.19	dark brown ore
P3-2	1	12.13	61.01	0.19	dark grey ore
P3-3	1	12.16	62.20	0.39	grey and yellow mixed ore
P3-4	1	15.40	54.35	0.19	grey and yellow mixed ore
P3-5	1	28.71	44.89	0.39	yellowish grey ore
P3-6	1	2.61	79.66	0.19	yellow bastnaesite rich ore

Figure II-4-7 The sketch of the outcrop and assay results

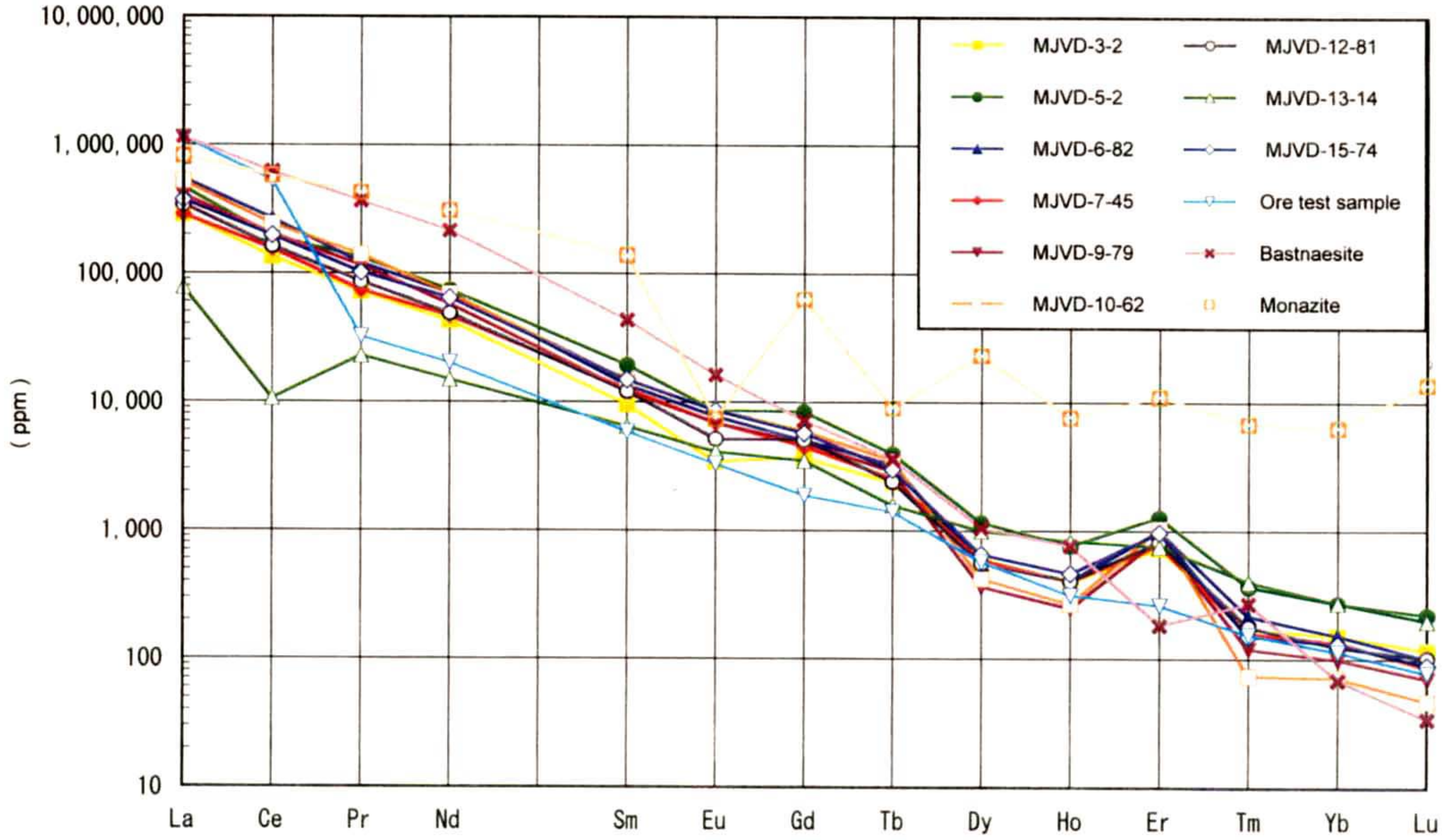


Figure II-4-8 Chondrite-normalized REE distribution

4-3 Preliminary Estimation of Geological Reserves of F3 Ore Body

The geological reserves of F3 ore body are preliminarily estimated for the extent prospected by the drilling program of the current project. The plan and the set of cross-sections of the ore blocks are shown in Figures II-4-9 and II-4-10 respectively. The estimation result is summarized in Table II-4-4. The estimation is still in a preliminary stage because the northern and western limits have not been defined.

A total of 13 ore blocks are set up centering the drill holes that intersected ore zones with the average T-RE_2O_3 equal to or higher than 10 %. The northern and the western ends of the ore blocks are limited to 25 m beyond the northernmost and westernmost drill holes. The ore density of 1.93, the same as for the estimation in 1986, is also adopted for the current estimation.

Table II-4-4 Result of the Preliminary Geological Reserve Estimation of F 3 Ore Body

Block	MJVD No.	Section area-1	Section area2	Average section area	Depth	Volume	Average grade	Specific gravity	Ore volume	TREO volume
		m^2	m^2	m^2	m	m^3	%	g/cm^3	t	t
C1	15	350		350.00	25	8,750	10.90	1.93	16,888	1,841
C2	6	600		600.00	25	15,000	14.20	1.93	28,950	4,111
C3	6, 12, 15	1,200	175	687.50	25	47,188	11.81	1.93	91,072	10,756
C4	12, 15	1,125	175	650.00	50	32,500	10.84	1.93	62,725	6,799
C5	10	2,556		2556.25	25	63,906	10.45	1.93	123,339	12,889
C6	6, 9	1,031	600	815.63	50	40,781	12.21	1.93	78,708	9,609
C7	6, 12	2,325		2325.00	25	58,125	12.00	1.93	112,181	13,457
C8	9	600		600.00	50	30,000	10.58	1.93	57,900	6,126
C9	8	120				1,600	10.51	1.93	3,088	325
C10	7	624		624.00	50	8,320	11.75	1.93	16,058	1,887
C11	9, 10	3,156		3156.25	25	42,083	10.49	1.93	81,221	8,521
C12	5	700	0	350.00	25	9,333	11.01	1.93	18,013	1,983
C13	5	525				15,438	11.01	1.93	29,794	3,280
Total						373,024	11.33		719,937	81,584

Safety factor 10%	647,943	73,425
Safety factor 20%	575,949	65,267

The geological reserves (Class I) at the safety factors of 0, 10 and 20 % are summarized in the table below.

Safety Factor	Reserves (ton)	T-RE_2O_3 (%)	Contained T-RE_2O_3 (ton)	Remarks
0%	719,937 t	11.33%	81,584 t	
10%	647,943 t	11.33%	73,425 t	
20%	575,949 t	11.33%	65,267 t	①

The ore reserves have been re-estimated for the 18 ore blocks of F3 South ore body based on the ore cross-sections according to the 1986 Exploration result. The re-estimation result is shown in Table I-4-6 of Chapter 4 of Part I in this report. A part of the re-estimated reserves of F3 South ore body are duplicated in the current geological reserves as above mentioned. Excluding the 6 duplicated blocks, CI-13 to CI-18, the re-estimated reserves of F3 South ore body is calculated as shown in the table below.

Safety Factor	Reserves (ton)	T-RE_2O_3 (%)	Contained T-RE_2O_3 (ton)	Remarks
0%	393.322 t	13.44%	52,856 t	
10%	353,990 t	13.44%	47,570 t	
20%	314,657 t	13.44%	42,285 t	②

Taking account of the irregular lens forms of F3 and F3 South ore bodies, it would be safe to employ the safety factor of 20 % for the reserve estimation at this stage with various uncertainties. The combined reserves of F3 and F3 South ore bodies (1+2) is estimated as shown in the table below.

Safety Factor	Reserves (ton)	T-RE_2O_3 (%)	Contained T-RE_2O_3 (ton)
20%	890,606 t	12.08%	107,552 t

The preliminary reserves of the entire F3 ore body for the ore blocks with the average grades equal to or better than 10 % T-RE_2O_3 is estimated approximately at 890.000 tons with the overall average grade of 12 % T-RE_2O_3 containing about 100, 000 tons of T-RE_2O_3.

It is expected that the reserves would substantially increase if the northern and western extensions of the ore bodies are revealed by further exploration.

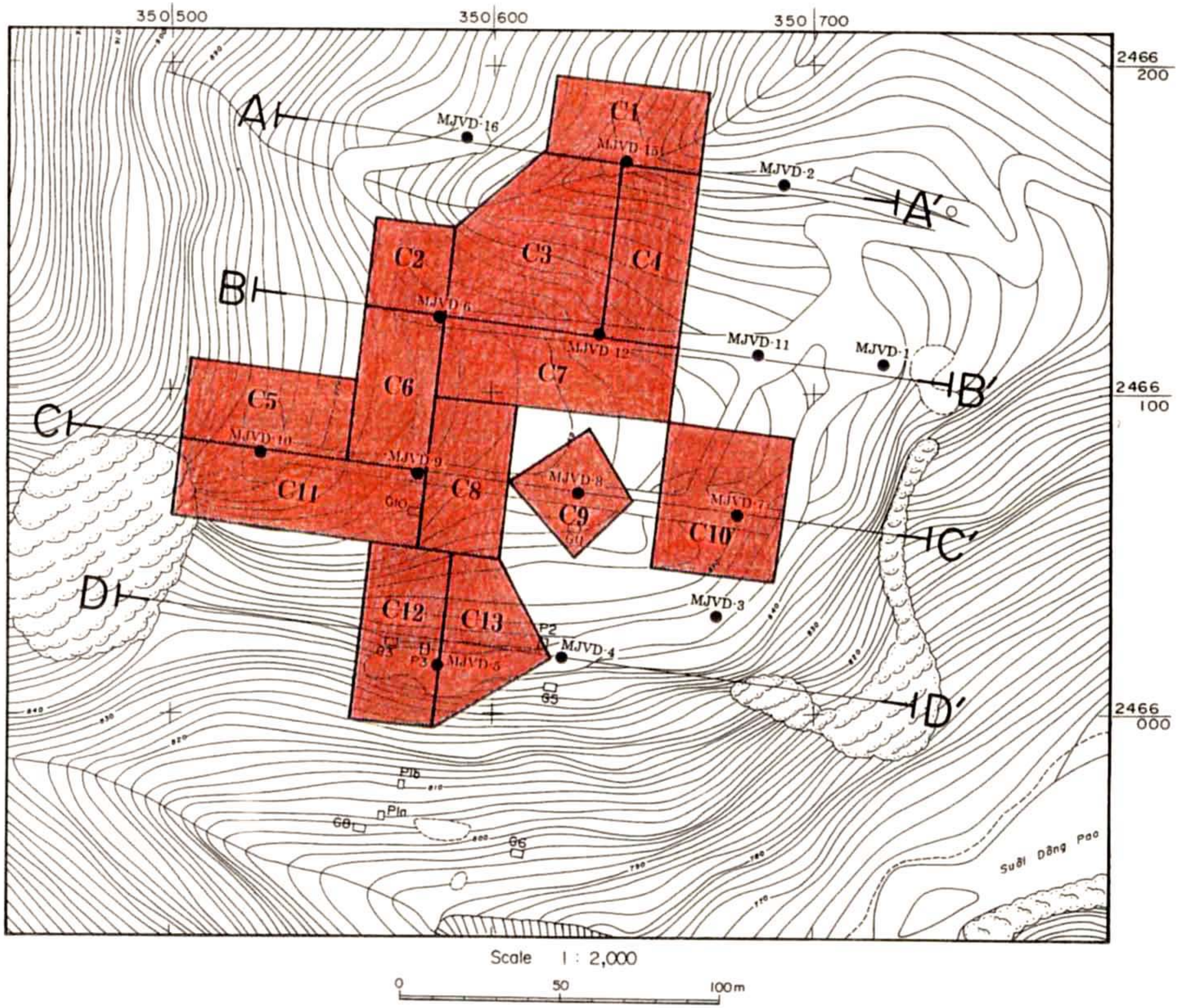


Figure II-4-9 The plan of the ore blocks of F3 orebody (C1～C13)

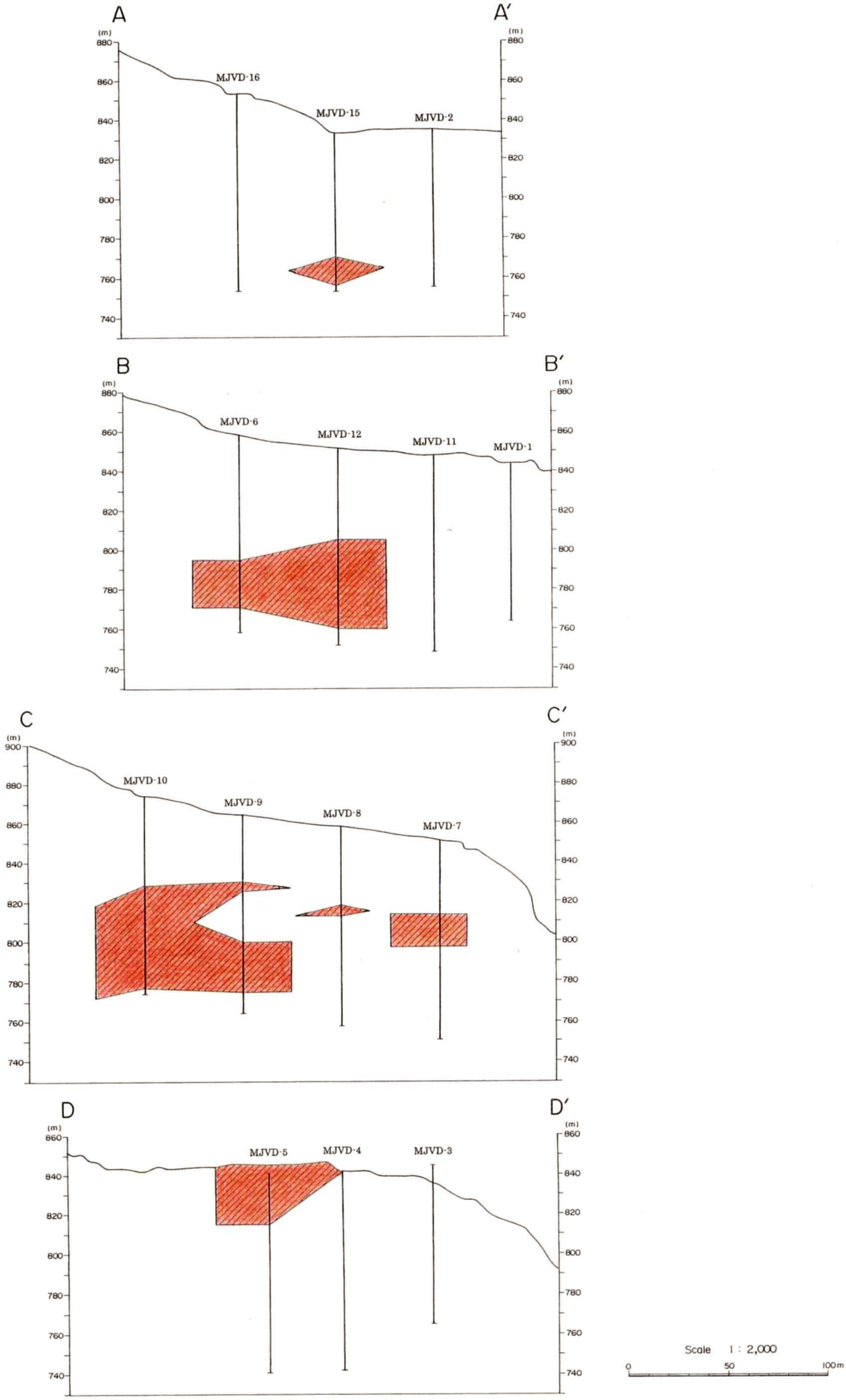


Figure II-4-10 The set of cross-sections of the ore blocks of F3 orebody (A-A'～D-D')

4-4 Proposed Genetic Model of the Rare Earth Deposit

A proposed genetic model for the rare earth deposits in the Project Areas is presented in Figure II-4-11. The process of the formation of the rare earth deposits is, according to this model, explained below.

(1) Intrusion of Alkaline Magma

The Triassic limestone, interbedded shale and sandstone were 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 in the Dong Pao area. The Triassic limestone and other sedimentary rocks, as the alkaline magmas intruded, were collapsed and broken into fragments of various sizes which were taken into the magmas. These magmas reduced the temperature and pressure as they ascent and brought about crystallization of non-volatile matters, which led to formation of syenite bodies. Limestone fragments taken into the magmas became micro-crystalline due to heat from the magmas.

(2) Mineralization Stage

In the course of magmatic differentiation to form syenite, melt at the bottom of magmas was enriched in volatile matters and then in rare earth elements as the vapor pressure increased. The high-pressure and high-temperature vapor enriched in volatile matters migrated through cooling-joints, formed in the peripheries of syenite bodies or though fractures mechanically formed in surrounding limestone by intruding forces of the magmas. The peripheries of syenite bodies were auto-metamorphosed by the high-pressure and high temperature vapor.

The homogenization temperatures of fluid inclusions within quartz and fluorite range from 128 to 281 ℃ according to the measurement carried out during the current project. The temperature range suggests that the rare earth ore deposits in this area was formed under epithermal to mesothermal conditions.

The high grade portions of total rare earth, fluorite and barite indicate no apparent correlation to each other, which implies that the three types of mineralization were formed in different stages of the mineralization. However, their close relationship in space suggest that they were formed in a single sequence of the mineralization process.

Rare earth, fluorite and barite concentrations form relatively sizable lenses or lenticular bodies of irregular shapes within altered syenite bodies, while they tend to occur in limestone as veinlet networks or disseminations in narrow spaces.

(3) Present State of the Ore Deposit

The syenite body has been exposed on the surface as the limestone on the top was eroded out. Its present dimension is, though irregular in its shape, measured at approximately 4 km in the east-west and at 5 km in the north-south. The ore deposits are located in the northern, southern and western peripheries of the syenite body.

F3 ore body is examined from the geological and mineralogical points of view as above. The limestone that occurs in the syenite body and in drill cores is micro-crystalline and partly contains sulfide disseminations (pyrite, sphalerite, galena). The possibility of carbonatite for the limestone has never been seriously questioned and may be required for an elaborated study. In this report, the limestone that was intersected by the drill holes is regarded as a fragment or block that were taken into the syenite body. Because the limestone within the syenite body is extremely discontinuous on the surface, without showing stratiform or vein structures.

It is desirable to conduct a detailed study with respect to the relationship between the syenite body and the surrounding limestone in order to verify the origin of the limestone. The study would serve for upgrading the geological concept for the genesis of the rare earth and associated mineralization in the Project Area.

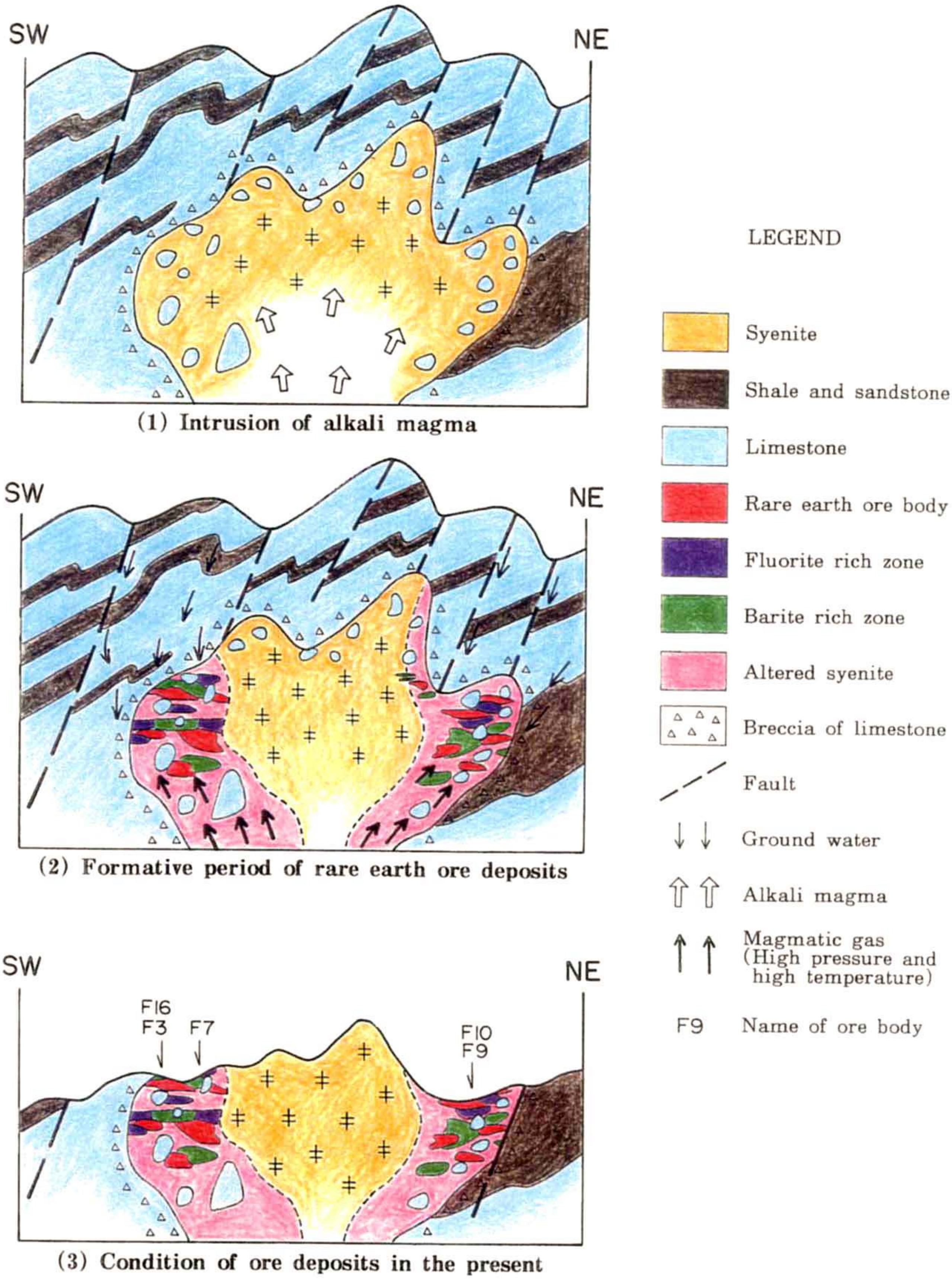


Figure II-4-11 A proposed genetic model for the rare earth deposits in the Dong Pao area

Chapter 5 Prospecting of Excavated Pits

5-1 Sampling

Pits were excavated at three locations on F3 ore body in order to collect ore samples for the metallurgical testing. The three locations were selected in the vicinities of the previous pits G8, G5 and G3 that had been excavated during the 1984-1985 exploration. Two pits P1a and P1b are 3.9 m and 3m deep respectively, and are located close to the G8 pit. P2 and P3 pits are 5m and 6m deep respectively, and are located close to the G5 and G3 pits respectively. The ore portion of each pit, excluding surface soil, were channel-sampled to collect a bulk of ore samples weighing at 1,431 kg for the metallurgical testing as well as 15 samples for chemical analysis.

Pit locations are shown in Figure II-5-1, and pit sketches together with sample locations are presented in Figures II-5-2 and II-5-3. The 15 samples for the chemical analysis were submitted to the laboratory of Geological Division for Rare and Radioactive Elements Enterprise in Hanoi. The analytical results are incorporated in the pit sketches. The averages for the 15 samples are 9.49 % T-RE_2O_3, 56.56 % $BaSO_4$ and 6.69 % CaF_2.

The metallurgical test samples of total 1,431 kg, collected from the pits, were sent to a metallurgical test laboratory in Australia by air cargo. The samples were mixed together to produce a composite sample for the metallurgical testing. The assay result of the composite sample indicates 9.25 % T-RE_2O_3, 62.7 % $BaSO_4$ and 4.47 % CaF_2. The average grade of total rare earth shows a fair agreement between the two batches of samples. Disagreements are observed in the averages of barite and fluorite, although they are tolerable in order of magnitude. These disagreements may be possibly caused by the modes of occurrences of barite and fluorite that form blebs or aggregates of concentrations distributing unevenly.

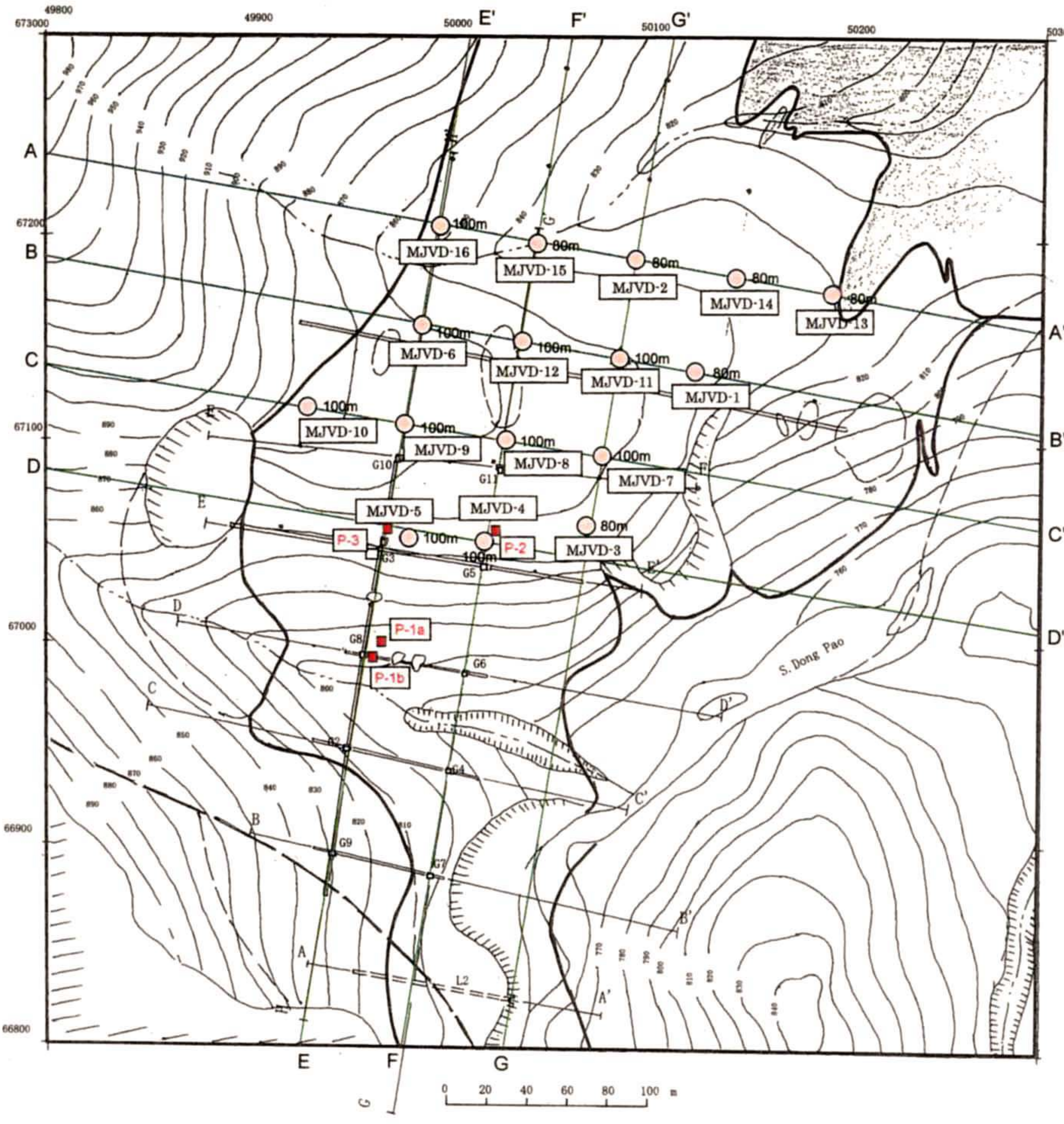
5-2 Pit Observation

Pit P1a was excavated to the depth of 3.9 m at the location about 7 m northeast of the previous Pit G8 at the elevation of 808.3 m. The top 0.5 m comprises dark brown surface soil, underlain by dark gray to white colored (partly yellow) and intensely weathered syenite that is abundant in weakly weathered fragments consisting of barite, fluorite and calcite. The section below the depth of 2.9 m comprises unweathered syenite containing rare earths, barite, fluorite and calcite. Purple fluorite crystals (1 cm±) are commonly recognized by the naked-eye. The average grades for the bottom 3 m section are 8.79 % T-RE_2O_3, 39.48 % $BaSO_4$ and 19.67 % CaF_2.

Pit P1b was excavated to the depth of 3.0 m at the location about 12 m north northeast of the Pit P1a at the elevation of 814.5 m. The top 0.6 m comprises dark brown surface soil, underlain by a dark brown talus deposit for 1.2 m containing barite pebbles. The section below the talus deposit comprises intensely weathered syenite containing rare earths, barite and fluorite and is significantly concentrated with yellow bastnaesite and fluorite in part. Weakly weathered or unweathered hard syenite is exposed at the bottom and includes fluorite, barite and rare earth ores. The average grades for the bottom 1 m section are 10.77 % T-RE_2O_3, 36.80 % $BaSO_4$ and 32.14 % CaF_2. Fluorite mineralization is significant in this pit.

Pit P2 was excavated to the depth of 5.0 m at the location about 15 m north northwest of the previous Pit G5, also west side of the drill hole MJVD-4, at the elevation of 847.8 m. The top 0.4 m comprises brown to reddish brown surface soil, underlain by an intensely weathered ore zone. The section from 0.4 to 2.7 m shows brown, yellowish brown or white colors, that from 3.0 to 3.5 m, light yellow to yellowish brown and the bottom section below 4.0 m, yellowish brown to brown or light gray. The average grades for the 4.6 m section, excluding the surface soil, are 4.29 % T-RE_2O_3, 67.79 % $BaSO_4$ and 0.23 % CaF_2. This pit is well mineralized with barite, though the rare earth value is unexpectedly low. A point sample, collected at the depth of 4.30 m, indicates the total rare earth content of 22.08 % T-RE_2O_3.

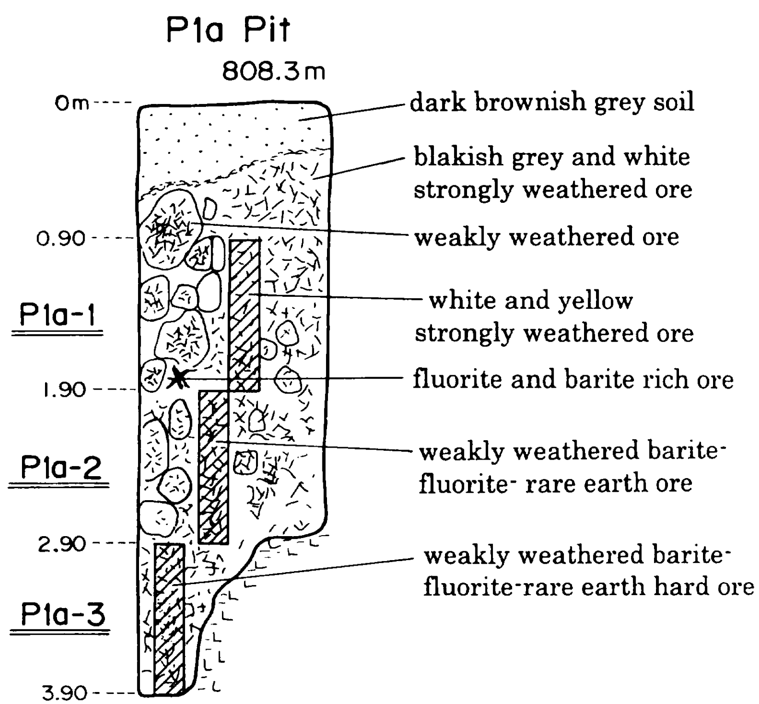
Pit P1a was excavated to the depth of 6.0 m at the location about 10 m east of the previous Pit G3, to the northwest of the drill hole MjVD-5, at the elevation of 846.9 m. The top 0.4 m comprises dark brown surface soil, underlain by intensely weathered syenite consisting of irregular alternation of dark gray and yellow to light yellow mineralized bands. Reddish brown limonite is partly observed in the section below the depth of 5.5 m. The average grades for the 5.6 m section, excluding the surface soil, are 13.66 % T-RE_2O_3, 60.06 % $BaSO_4$ and 0.26 % CaF_2. The mineralization in this pit is significant in rare earths and barite. The yellowish parts are generally well concentrated with bastnaesite. However, one light yellow ore sample indicates a low total rare earth at 0.84 % T-RE_2O_3, but is high in barite at 70.02 % $BaSO_4$.

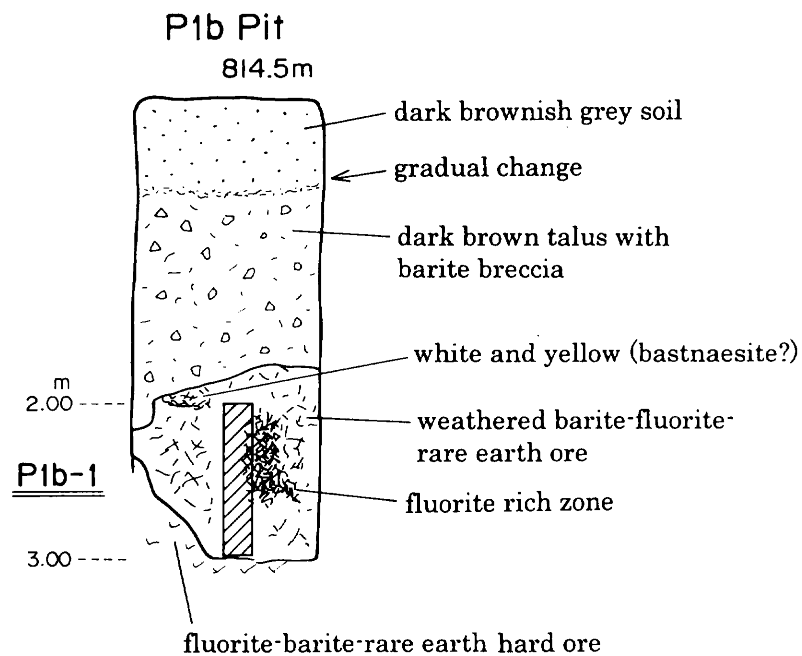


Legend

○ MJVD-1	Drill
■ P-1	Pit
□ G2	Old Pit
H2	Old Trench
L2	Old Tunnel

Figure II-5-1 Location map of pits

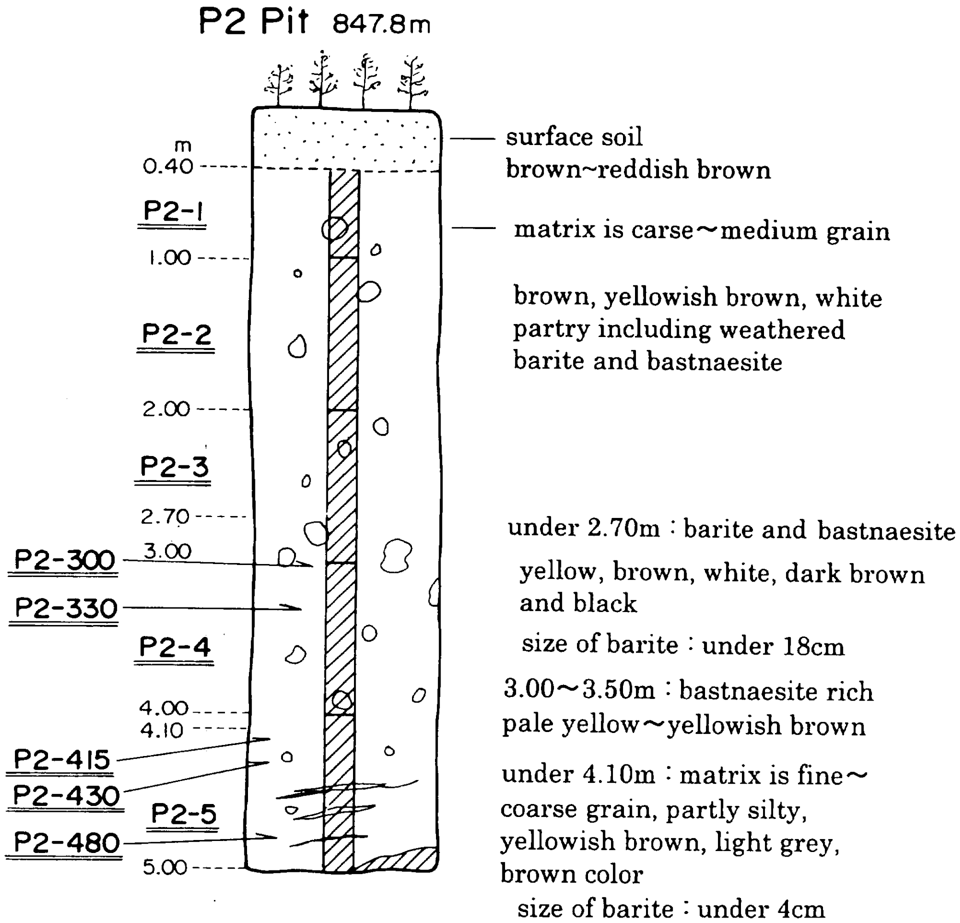




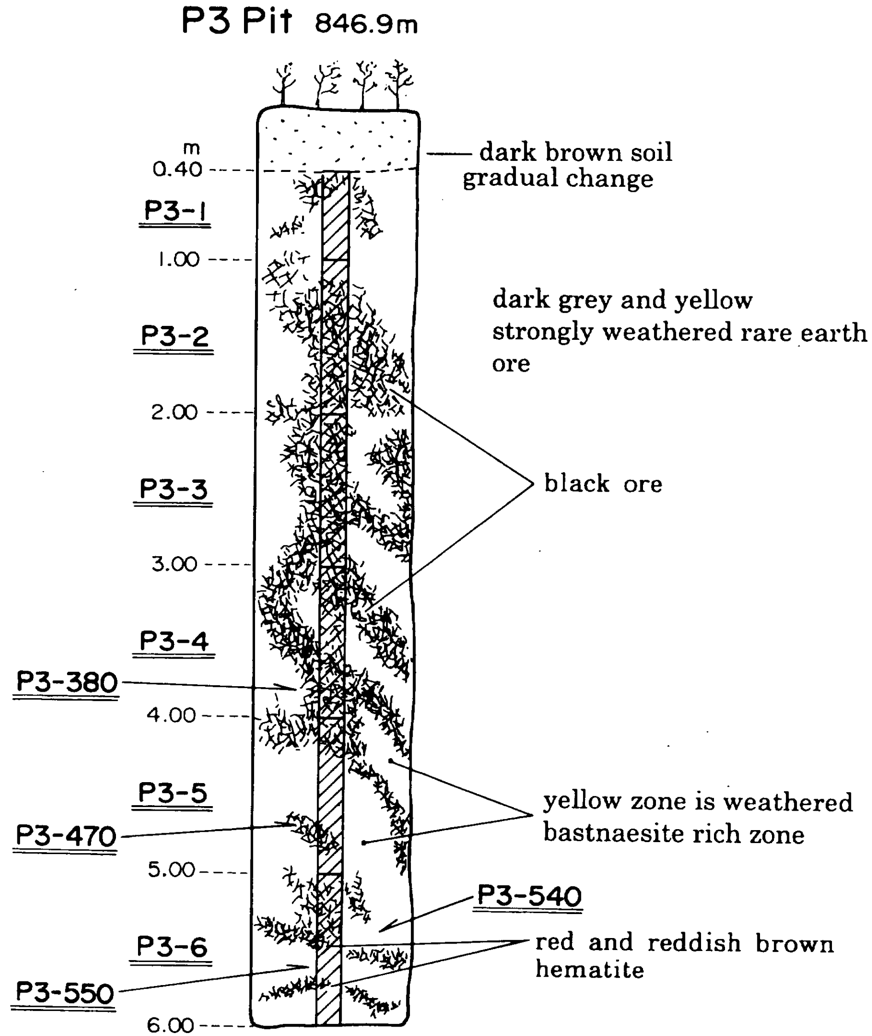
Sample No.	width m	Assay result (%)			Note
		T-RE_2O_3	$BaSO_4$	CaF_2	
P1a-1	1.0	6.53	41.93	19.87	dark brown ore
P1a-2	1.0	6.04	37.10	19.48	dark brownish grey ore
P1a-3	1.0	13.80	39.41	19.67	brown ore
Average		8.79	39.48	19.67	

Sample No.	width m	Assay result (%)			Note
		T-RE_2O_3	$BaSO_4$	CaF_2	
P1b-1	1.0	10.77	36.80	32.14	dark brown ore

Figure II-5-2 Pit schetch (P1a, P1b)



Sample No.	width m	Assay result (%) T-RE2O3	BaSO4	CaF2	Note
P2-1	0.6	2.59	58.22	0.19	dark brown ore
P2-2	1.0	3.36	59.15	0.19	dark brown ore
P2-3	1.0	4.00	65.10	0.19	dark brown ore
P2-4	1.0	5.07	73.69	0.19	dark brown ore
P2-5	1.0	5.74	78.98	0.39	dark brown ore
Average		4.29	67.79	0.23	
P2-300	spot	11.87	76.14	1.52	light brown ore
P2-330	spot	6.00	72.57	0.43	black ore
P2-415	spot	4.32	80.73	0.49	dark brown ore
P2-430	spot	22.08	53.19	3.51	dark brown ore
P2-480	spot	3.23	71.38	0.41	pale yellow - grey ore



Sample No.	width m	Assay result (%) T-RE2O3	BaSO4	CaF2	Note
P3-1	0.6	9.16	57.05	0.19	dark brown ore
P3-2	1.0	12.13	61.01	0.19	dark grey ore
P3-3	1.0	12.16	62.20	0.39	grey and yellow mixed ore
P3-4	1.0	15.40	54.35	0.19	grey and yellow mixed ore
P3-5	1.0	28.71	44.89	0.39	yellowish gery ore
P3-6	1.0	2.61	79.66	0.19	yellow barite rich ore
Average		13.66	60.06	0.26	
P3-380	spot	0.68	56.25	8.67	reddish brown ore
P3-470	spot	5.98	25.66	39.79	black ore
P3-540	spot	0.84	70.02	0.10	pale yellow ore
P3-550	spot	0.72	53.36	4.72	red ore

Figure II-5-3 Pit schetch (P2, P3)

Chapter 6 Metallurgical Testing

6-1 Introduction

6-1-1 Objective

The metallurgical testing has been carried out to verify the optimum metallurgical process for commercially recovering such useful elements and minerals as rare earths, specifically cerium and lanthanum, fluorite, barite and so forth contained in F3 ore body of appreciable sizes in Dong Pao Area.

6-1-2 Sampling

The rare earth ore samples for the metallurgical testing are collected from 4 pits excavated at three locations on F3 ore body. Two pits P1a and P1b are 3.9 m and 3m deep respectively, and are located close to the previous G8 pit. P2 and P3 pits are 5m and 6m deep respectively, and are located close to the previous G5 and G3 pits respectively. The ore samples, weighed at 1,431 kg in total, are submitted to the laboratory in Hanoi for chemical analysis. The analytical result indicates the averages of 9.49 % T-RE_2O_3, 56.56 % $BaSO_4$ and 6.69 % CaF_2.

6-2 Test Sample

6-2-1 Head Assay

The ore samples with the total weight of 1,431 kg, collected from shallow part of the ore body, were compounded into a composite sample. The composite sample were sent to the laboratory of Lakefield Oretest Ltd., for the metallurgical testing at the end of December, 2000. The head assay result of the composite sample is shown in Table II-6-1.

Table II-6-1 Head Assay of the Metallurgical Test Sample

TLnO %	BaSO4 %	CaF2 %	ThO2 ppm	U3O8 ppm	S %
9.25	62.7	4.7	139	117	8.85

6-2-2 X-ray Diffraction Analysis

The minerals that are identified by X-ray diffraction analysis are listed in Table II-6-2.

Table II-6-2 Minerals Identified by X-ray Diffraction Analysis

Mineral	Wt (%)
Barite	74.1
Bastnaesite -Ce	1.2
Bastnaesite -La	1.1
Calcite	1.5
Celestine	3.4
Finnemanite	0.5
Fluorite	4.2
Mordenite	5.5
Perloffite	3.5
Quartz	4.1
Synchysite	0.3

6-2-3 Microscopic Observation

The result of microscopic observation of the ore sample, which was carried out by Roger Townend and Associates Ltd., is summarized below.

Bastnaesite, synchysite, rutile and zircon are the major ore minerals that are identified under the microscope. The majority of bastnaesite forms thin films around rims of barite or occurs as inclusions within barite or goethite, though its single crystals of coarse sizes exceeding 1 mm are occasionally identified. About 40 % of rare earth minerals occur as middlings. Microphotographs of the examined samples are presented in Figure II-6-1.

6-3 Test Procedure

The metallurgical testing was commissioned to Lakefield Oretest Ltd. in Perth, Australia to test a possible procedure for separation and concentration of rare earth minerals with the aim of commercial exploitation of the rare earth ore deposits in Dong Pao area, Vietnam.

A few different flotation processes were examined to separate rare earth minerals from fluorite, barite and other gangues. The test program is shown in Figure II-6-2. The crushed (-2 mm) and ground (P80 = 53 μ m) test samples were examined for their size distribution and then underwent a series of batch flotation and magnetic separation tests. The test program is shown in Figure II-6-2. Effects of the following factors were examined in the course of the flotation tests for their performances.

flotation sequences of rare earth and gangue minerals.

grinding sizes.

kinds and amounts of reagents applied.

flotation temperature.

flotation of different sizing groups

Figure II-6-1 Microphotographs of the examined samples

The magnetic separation tests were carried out using WHIMS (Wet High Intensity Magnetic Separator) and Induced Roll Separator (dry).

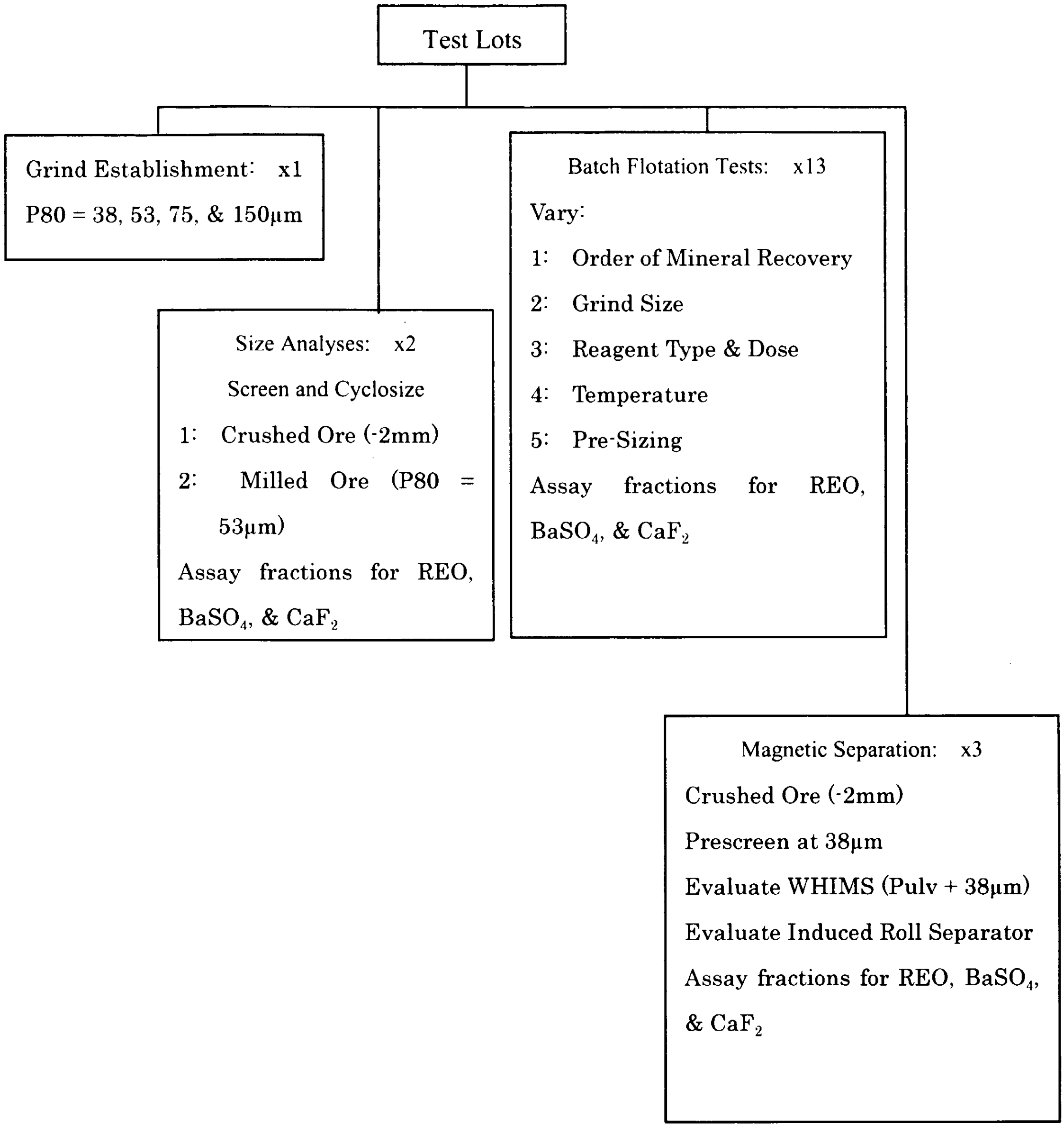


Figure II-6-2 Metallurgical Test Program

6-4 Test Result

6-4-1 Size Analysis of Crushed and Ground Products

The size distributions of the samples crushed to -2mm and ground to P80 = 53 μm are shown in Figures II-6-3 and II-6-4 respectively. In both instances, the fine fractions, say finer than 8 μm, are proportionally enriched in T-RE_2O_3. The -8mm fractions of the crushed and ground samples are assayed at 32.5 % T-RE_2O_3 with the size distribution of

32 % and at 22.1 % T-RE_2O_3 with that of 51 % respectively. The rare earth minerals except very fine grained are, however, distributed through all size ranges to the extent that simple classification such as desliming would be ineffective to improve beneficiation. A method to classify the $-8\mu m$ fraction using cyclones is being practiced for desliming of nickel ores. A classifying method combining multistage grinding and cyclones may be worthwhile for examination in order to separate and recover the rare earth minerals in the fine fraction. It is, however, necessary to study an appropriate flotation and/or magnetic separation procedures suitable for the fine fraction, where further concentration of the rare earth minerals is required.

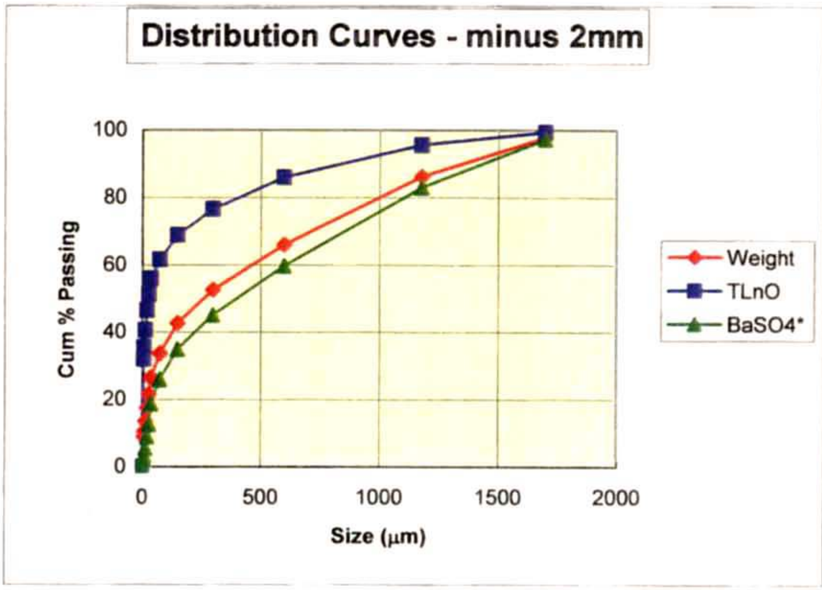


Figure II-6-3 Distribution curves of Crushed (-2mm) products

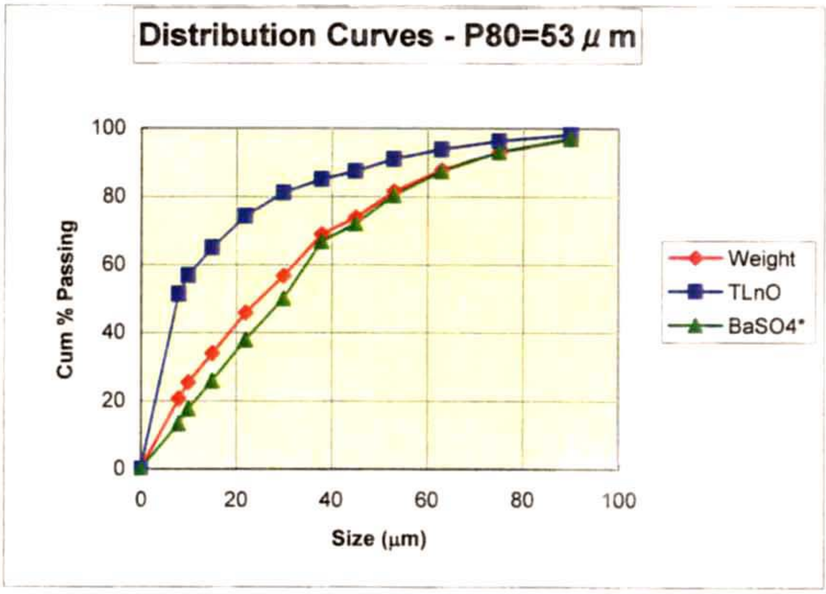


Figure II-6-4 Distribution curves of ground products (P80=53 μm)

6-4-2 Flotation Test

A total number of 13 batch flotation tests were performed in an attempt to differentially recover the rare earth minerals, fluorite and barite. The test results are summarized in Table II-6-3.

Table II-6-3 Summary of Batch Flotation Results

Test No.	Test Conditions	$BaSO_4$ Concentrate* Recoveries (%)			T-RE_2O_3 Concentrate Recoveries (%)		
		$BaSO_4$	REO	CaF_2	$BaSO_4$	REO	CaF_2
RB 2819	Ba/Ca Bulk Float, Followed by REO Float	43.2	20.9	20.9	11.7	31.7	15.5
RB 2843	Similar, Increased Ba/Ca Collectors	95.8	67.6	75.3	4.0	27.9	23.1
RB 2844	REO Float, Followed by Ba/Ca Float	59.7	54.8	78.3	40.1	40.7	19.8
RB 2845	REO Float, Followed by CaF2 Float & BaSO4 Float	59.1	48.9	72.5	40.7	45.4	25.5
RB 2889	Similar to RB 2819, Increased Ba/Ca Collectors & REO depressant.	98.1	87.3	95.3	1.5	9.8	3.5
RB 2890	Repeat at Finer Grind	95.6	84.0	92.7	4.1	14.6	6.5
RB 2891	REO Float, Followed by Ba/Ca Float, Finer Grind	40.9	45.2	57.4	58.8	52.6	41.4
RB 2892	REO/CaF2 Float Followed by BaSO4 Float, Finer Grind	15.9	19.8	25.7	81.5	64.4	66.4
RB 2893	REO Float Followed by CaF2 Float, Different Reagents, Finer Grind	41.5	65.0	66.5	58.5	35.0	33.5
RB 2895	Pre-Size, Float +32um, +10um, Std Grind	90.6	59.5	84.2	1.2	1.8	0.8
PD321	Similar to RB 2889, Heat to 60 C	99.7	98.1	99.2	0.2	1.8	0.7
PD326	Repeat, Increase REO Depressant	99.8	98.3	99.3	0.2	1.7	0.7
PD327	Repeat, Decrease Collector Addition	99.6	97.2	98.8	0.4	2.8	1.2

*Combined CaF_2 and $BaSO_4$ Conc. where produced separately

The results of the test Nos. RB 2889 through RB 2895 are demonstrated in Figures II-6-5 and II-6-6 for the relationships of the total extracted amounts to the rare earth recovery and to the T-RE_2O_3 grades.

Where a line deviates from the line indicating 1 to 1 ratio between the REO Recovery and the Extracted (weight %) in Figure II-6-5, REOs (rare earth minerals) are concentrated either in the extracted, that is in the froth, (upward deviation) or in the sink (downward deviation). A test result that indicates such a deviation in the recovery-extracted ratio would provide possible flotation conditions for separation and concentration of the rare earth minerals. However, no test result shows any significant deviation from the recovery-extracted ratio of 1 to 1, that is, the rare earth minerals are effectively recovered neither in froth nor in sink in any test results.

Since the head assay of the test sample is 9.25 % T-RE_2O_3, the higher assay of the extracted than this figure indicates concentration of the rare earth minerals in froth and the lower assay, that in sink in Figure II-6-6. The test No. R2889 that aimed at barite-fluorite (Ba-Ca) bulk flotation displays relatively high remain of rare earth minerals in sink but not in great deal. Therefore, the rare earth minerals are effectively concentrated neither in froth nor in sink in any test results.

Each of the 13 batch flotation test results is briefly described below.

(RB 2819)

A rare earth flotation was conducted for the sample ground to P80 = 75 μm after applying Ba-Ca bulk flotation. The test resulted in producing the rare earth rougher concentrates at a recovery rate of 32 % with the grade of 20 % T-RE_2O_3, even though the Ba-Ca bulk concentrates contained 21 % T-RE_2O_3.

(RB 2843)

A rare earth flotation test was conducted for the same sample as for RB 2819 with applying different amounts of reagents. Bulk Ba-Ca and rare earth rougher concentrates were produced without differentiating barite and fluorite concentrates. The rare earth minerals were recovered in the bulk and rare earth concentrates in a proportional amount. However, their distribution in the rare earth concentrates accounted for only 28 %, while that in the bulk concentrates was 68 %.

(RB 2844)

A rare earth flotation test was applied, prior to a bulk flotation, for the sample with the same sizing as for the samples for the previous two tests. The rare earth minerals were recovered in an amount comparable to that of concentrates but without any notable concentration in total rare earths. The amount of recovered rougher concentrates was 34 wt. % of the feed with the rare earth recovery rate of 41 % and the concentrate grade of 11.6 % T-RE_2O_3. Fluorite and barite were hardly separated and concentrated.

(RB 2845)

A similar test as for RB 2844 was carried out with changing amounts of reagents. The result was the same for the previous test.

(RB 2889)

A Ba-Ca bulk flotation for the sample with the sizing of P80 = 75 μm preceded a rare earth flotation, using starch as a depressant and lead nitrate and sulfuric acid as activators for rare earth minerals. This test can be compared to the following test RB 2890 for the sample with the finer sizing of P80 = 38 μm. The recovered amount of rare earths was comparable to that of the Ba-Ca bulk concentrates, in which 90 % of the rare earth minerals were recovered. The rare earth flotation resulted in the recovery rate of 10 % with the concentrate grade of 17 % T-RE_2O_3.

(RB 2890)

The same test as RB 2889 was applied to the sample with a finer sizing of the P80 = 38 μm using the same kinds and amounts of reagents. The recovery rate was improved to 15 %, which was, however, too far lower than the satisfactory level.

(RB 2891)

A rare earth flotation preceded a Ba-Ca bulk flotation for the sample with the sizing of P80 = 38 μm, using starch as a depressant and lead nitrate and sulfuric acid as activators for rare earth minerals. No concentration of rare earth minerals was observed. The produced amount of rougher concentrates was 51 % of the feed, with the concentrate grade of 9.5 % T-RE_2O_3 at the recovery rate of 53 %.

(RB 2892)

A rare earth-fluorite bulk flotation preceded a barite flotation for the sample with the sizing of P80 = 38 μm. The produced amount of bulk concentrates was 70 % of the feed, with the concentrate grade of 8.5 % T-RE_2O_3 at the recovery rate of 64 %. No concentration of rare earth minerals was observed.

(RB 2893)

A rare earth flotation for the sample with the same sizing as for RB 2892 was carried out prior to a fluorite flotation, using the two collectors, H2875 and V2711, which were recommended by Clarient Ltd. The produced amount of rare earth concentrates was 47 % of the feed, with the concentrate grade of 7 % T-RE_2O_3 at the recovery rate of 35 %. The collectors were proved ineffective to concentrate rare earth minerals.

(RB 2895)

The sample was classified at 32 μm and 10 μm to produce sub-samples of +32 μmand -32/+10 μm fractions for separate flotation tests. The -10 μm fraction were tested by a gravity separation using a Falcon concentrator. Rare earth minerals mostly moved together with gangues and were recovered in the rare earth concentrates only by 1.8 %. The gravity separation of the -10 μm fraction produced tailings (light fraction) accounting for 95 % of the feed amount. In addition, the feed grade of 24.6 % T-RE_2O_3 was improved only to 25.4 % T-RE_2O_3 in the heavy fraction.

(PD 321)

Flotation temperature was elevated to 60℃ in this test. The same reagents as for RB 2889 were used. The concentrates were produced with the rare earth recovery rate of less than 2 %. No effective mineral separation and recovery was achieved in this test.

(PD 326)

The Ba-Ca bulk flotation was conducted with the increase amount of depressant at the same flotation temperature of 60℃ as for PD 321. The concentrates were produced with the rare earth recovery rate of less than 2 %. No effective mineral separation and recovery was achieved in this test.

(PD 327)

This test was carried out with the increase amount of rare earth collector at the same flotation temperature of 60℃ as for PD 321. The concentrates were produced with the rare earth recovery rate of less than 3 %. No effective mineral separation and recovery was achieved in this test.

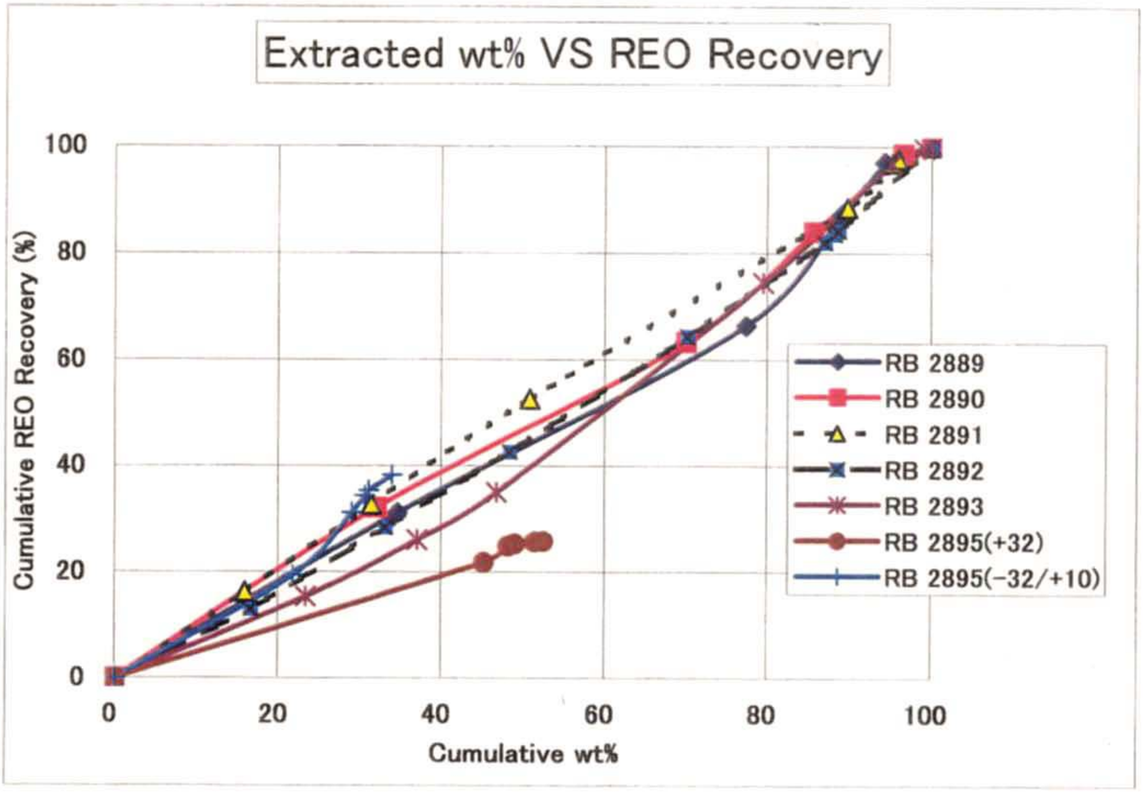


Figure II-6-5 Relation between extracted wt% and REO recovery

(Test No.RB2889-RB2895)

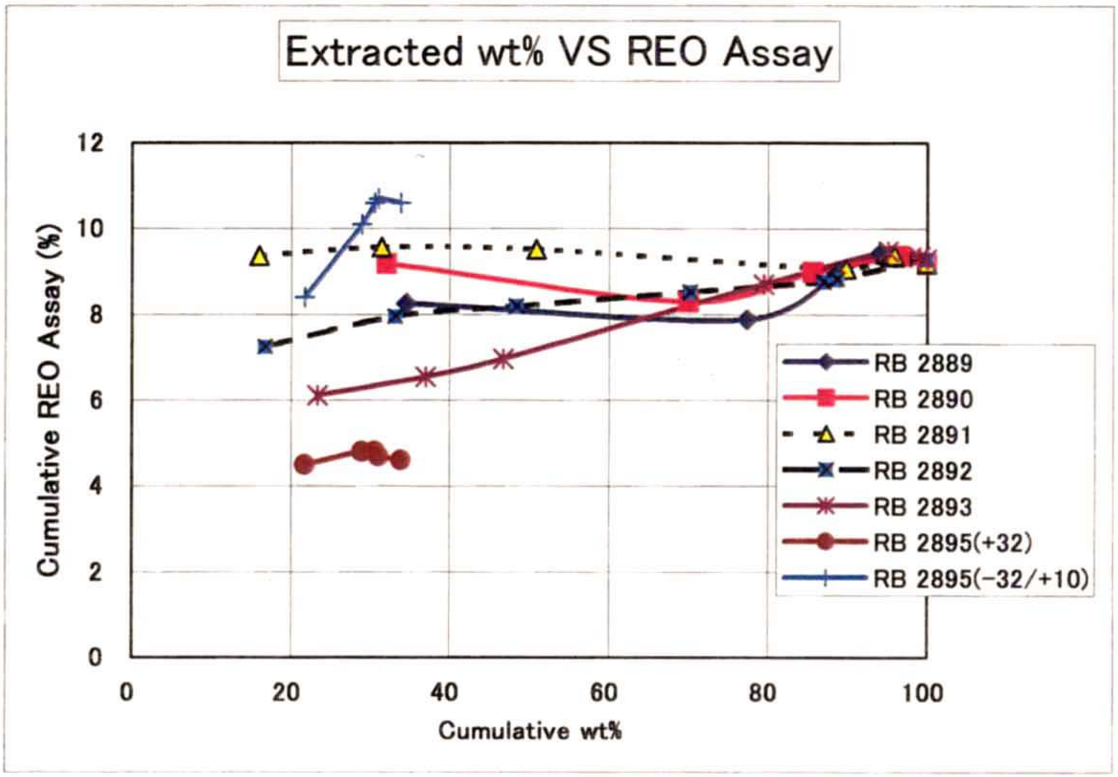


Figure II-6-6 Relation between extracted wt% and REO assay (Test No.RB2889-RB2896)

6-4-3 Magnetic Separation

The magnetic separation test was conducted for the +38 μ m fraction obtained by screening the crushed sample, using a wet HIMS and a dry Induced Roll magnetic separator. Bastnaesite is paramagnetic and should be collected in the magnetic fraction. The result is shown in Table II-6-4.

The feed to the wet HIMS was prepared by further pulverizing the +38 μ m fraction to approximately +30 μ m. The magnetic fraction obtained by the wet HIMS was 3.7 % of the feed and contained 6.6 % of T-RE_2O_3, the recovery rate of which was 2.7 %. That is to say, the magnetic separation using the wet HIMS failed to concentrate rare earth minerals into the magnetic fraction with a satisfactory recovery rate.

The dry induced roll magnetic separation was applied to the +38 μ m fraction and the sample pulverized to +30 μ m. The tests for both samples gave better results than the wet HIMS, having produced more magnetic fractions with better recovery rates and grades in T-RE_2O_3. However, the T-RE_2O_3 grades of the magnetic fractions are still low for satisfactory separation and concentration of bastnaesite. The magnetic fraction collected from the +38 μ m fraction sample contained 21 % T-RE_2O_3 with the recovery rate of 31 %. However, the grade and the recovery were lower at 15 % T-RE_2O_3 and 20 % in the magnetic fraction collected from the pulverized sample, in spite of the increased particle liberation.

Table II-6-4 Results of Magnetic Separation Tests

Magnetic Separation	+38 μm Pulverised	Magnetics						
		Mass (%)	$T\text{-}RE_2O_3$ (%)		$BaSO_4$ (%)		CaF_2 (%)	
			Grade	Rec	Grade	Rec	Grade	Rec
WHIMS	YES	3.7	6.6	2.7	41.0	2.4	4.5	3.5
IND ROLL	NO	13.0	21.3	30.6	25.7	5.3	4.5	12.3
IND ROLL	YES	12.6	14.5	19.8	48.9	9.8	4.7	12.0

6-5 Conclusion

The size analysis and flotation tests that were carried out for the samples of the rare earth deposits in Dong Pao area, Vietnam, turned out unsatisfactory according to the results to date. The reasons are ;

1) the ores are highly weathered, containing very fine-grained bastnaesite,
2) bastnaesite occurs interstitially between fluorite and/or barite, or is attached to rims of other minerals, forming middlings so that it is difficult to be liberated,
3) bastnaesite tends to form bastnaesite-calcite micro-veins within fluorite and /or barite crystals, which is also difficult to be liberated.

The size analysis of the crushed products proved that rare earth minerals were concentrated more in the fine fractions than in the coarse fractions. Therefore, it is possible to produce crude rare earth concentrates with the grade better than 30 % $T\text{-}RE_2O_3$ by separating and concentrating the fine fractions.

In the flotation tests, various conditions such as flotation sequences, kinds and amounts of reagents and flotation temperature were examined, which was unsuccessful to separate and concentrate rare earth minerals to a satisfactory degree. At this stage, no possibility has been identified to improve the flotation test results. The dry magnetic separation in the magnetic separation tests was successful to concentrate rare earth minerals twice (21 % $T\text{-}RE_2O_3$) as much as the feed grade, which was still unsatisfactory from the commercial point of view.

It is necessary for the further metallurgical study to examine optimum combinations of two or more processes for the satisfactory recovery and concentration of rare earth minerals.

Chapter 7 Conclusion and Recommendation

7-1 Conclusion

1) Outline of the 1st Year Campaign

The field operation of the 1st Year Campaign was carried out in the period from November 21st, 2000 to February 4th, 2001. The 1st Year program comprised geological survey, environmental baseline study (soil, hydrology, meteorology and vegetation), drilling prospecting, metallurgical testing and laboratory tests (whole rock analysis, ore analysis, microscopic observation of rock and ore thin sections, X-ray diffraction analysis and fluid inclusion analysis for homogenization temperature and salinity measurements).

2) Geological Survey

The geological survey was carried out in combination with the environmental baseline study. The geology of the Project Area consists of limestone, shale, siltstone and sandstone of Triassic system and Palaeogene syenite intrusions, partly overlain by alkaline volcanics and tuffs of Palaeogene age. A number of minor minette dikes occur within the syenite intrusions.

The regional structural system of NW-SE trend is predominated in the Project Area, represented by two major faults located in the northeastern corner and the southern part of this area. Lineaments in the N-S and the E-W directions are extensively developed, which have probably resulted from conjugated shear stress of the regional structural system of NW-SE trend.

3) Environmental Baseline Study

Soil, hydrological, meteorological and vegetation surveys were carried out for the environmental baseline study.

Significant soil anomalies in T-RE_2O_3, the major commodities of the ore deposits, are associated with such known ore bodies as F1, F3, F 4, F7, F 9, F 10, F 14 and F 16. Soil anomalies in $BaSO_4$ and CaF_2 well coincide with those of T-RE_2O_3 as far as their distributions concern. The content of T-RE_2O_3 is significantly correlated with light rare earth elements and, among other elements than rare earths, with Th, Sr, As, Pb, U, F and Ba, according to the result of the correlation analysis of the analytical data.

Water quality was measured at five localities of the selected drainages. Most of small streams were dried out at the time of the field operation except the main stream of Dong Pao river, the major river in the eastern part of this area, and a few of branch streams. Running water in part of major streams flows into underground and again springs out at places such as seen in the eastern part. The stream water is weakly alkaline to neutral, indicating pH ranging from 7.33 to 8.55. Its temperature and conductivity range from 16.7 to 21.22℃ and from 214 to 303 μ mS respectively, while the hot spring water at the locality DW-4 indicates the temperature of 28.9℃ and the conductivity of 625 μ mS, which are higher than those of stream water. Among trace elements analyzed, arsenic and fluorine are high ranging from 0.25 to 0.32 mg/l and from 0.79 to 2.42 mg/l respectively, which may reflect the mineralization of this area. Stream water is high in Ca among cations and in HCO_3 and CO_3 among anions, possibly due to extensive distribution of limestone.

The meteorologic observation system has been installed at New Tam Duong in order to automatically take continuous records of temperature, humidity, precipitation and wind direction and velocity for the one-year period. This area belongs to a humid-subtropical zone of the Asian-Monsoon region. A regular climatic cycle is observed through the year according to the meteorologic data for the last five years recorded at the Tam Duong meteorologic observatory. The climate of this area is high temperature (20 to 24℃) and high precipitation (200 to 800 mm/month) for the months from May to August, and low temperature (13 to 18℃) and low precipitation (0.3 to 200 mm/month) for the months from September to April in the following year.

Virgin forest lands have been diminishing with increasing areas of farm lands, paddy fields and wastelands due to the agricultural development for many years. A total of 165 species that belong to 110 genera of 71 classes in 4 phyla have been identified in the course of this study. Among these species, 53 common species and 9 rare species are confirmed to exist. Although 9 rare species have been identified, they distribute beyond the premises of the Project Area. Their distribution is by far broader than the extent of an area for possible mining development. Therefore, the future mining development in New Dong Pao area would have least risks to endanger these species.

4) Drilling Investigation

A total number of 16 holes with the aggregated length of 1,480 m were drilled to explore F3 ore body at depth. The hole geology comprises mineralized and altered syenite, limestone blocks taken into the syenite and intruding minette dikes. Of the 16 holes, 7 holes intersected mineralized zones with the grades better than 10 % T-RE_2O_3, and other 5 holes, those with the grades ranging between 5 and 10 % T-RE_2O_3.

5) F3 Ore Body

F3 ore body is principally of a rare earth ore deposit accompanied by fluorite and barite mineralization. The zone of mineralization with the grades better than 10 % T-RE_2O_3 encompasses an area approximately 300 m long in the north-south and 100 m wide in the east-west. The current exploration has not define the northern and the western limits of the mineralized zone.

This zone enriched in rare earth minerals forms an irregular lens that thins out to the east and tends to deepen northwards and southwards. Although its continuation to the north and west has not been determined, the ore body is very attractive in its size and grade according to the result of the drilling exploration of the current project. The rare earth mineralization is closely related to the fluorite and barite mineralization. However, there appears to be differences in the mineralization stages of the three types, because their mineralization centers are slightly shifted from each other in their positions.

Representative rare earth ore zones that have been intersected by the drill holes of the current project are the 52-m section in the hole MJVD-10 with the average grade of 10.44 % T-RE_2O_3 and the 45 m section with the average grade of 10.82% T-RE_2O_3, both in the western part of the ore body.

The ores are more enriched in light rare earths than heavy rare earths according to the chondrite normalized REE pattern based on the analytical results, suggesting that the main rare earth mineral is bastnaesite. According to the result of microscopic observation of ore thin sections, the major ore minerals are bastnaesite, synchysite, barite and fluorite, accompanied by such gangue minerals as quartz, calcite, K-feldspar and minor phlogopite, illite, kaolinite, halloysite, smectite and boehmite. Bastnaesite mostly occurs in fine crystals filling interstices between barite, fluorite and quartz grains or forming micro-veins within barite and fluorite crystals.

The reserves of F3 ore body with the grade better than 10% T-RE_2O_3 are preliminarily estimated at approximately 890,000 tons with the average grade of 12 % T-RE_2O_3 containing 100,000 tons of T-RE_2O_3, based on the data obtained to date. Since the northern and western limits of the ore body has not been determined, there is a possibility that the reserves may substantially increase if its continuation to these directions is proved.

6) Ore Bodies Other Than F3

There are 6 major ore bodies, other than F3, among more than 60 rare earth-fluorite-barite ore bodies that have been located in this area.

F 1 ore body is principally of fluorite and forms a lenticular shape with the width of more than 50m. The ores contain 69.04 to 71.10 % CaF_2 and 0.42 to 3.76 % T-RE_2O_3. This ore body is currently being mined.

F4 ore body is principally of fluorite and forms a lenticular shape with the width of more than 80m. The ores contain 43.36 to 57.74 % CaF_2 and 0.78 to 4.87 % T-RE_2O_3. This ore was mined in the past.

F7 ore body is about 1.5 km long in the east-west and 0.5 km wide in the north-south, and may continue to the southwest joining F3 ore body. An outcrop of ores concentrated in barite and fluorite in the western part indicated an assay result of 11.09 % T-RE_2O_3, 24.35 % CaF_2 and 47.78 % $BaSO_4$. The soil geochemical anomaly associated with this ore body is most significant in its extent and rare earth content. This ore body, with its extensive zone of mineralization, is expected to grow both in size and grade to the depth.

F 9 ore body is 0.7 km long and 0.3 km wide. A mineralized outcrop indicated an assay result of 4.44 % T-RE_2O_3, 40.79 % CaF_2 and 25.92 % $BaSO_4$. The associated soil geochemical anomaly is significant in its extent and mineral contents.

F 10 ore body is 0.7 km long and 0.2 km wide. A mineralized outcrop indicated an assay result of 4.54 % T-RE_2O_3, 15.82 % CaF_2 and 23.45 % $BaSO_4$. The associated soil geochemical anomaly is significant in its extent and mineral contents.

F 16 ore body is 0.6 km long and 0.4 km wide. The associated soil geochemical anomaly, indicating the maximum rare earth content of 16.79 T-RE_2O_3, is significant in its extent and rare earth content.

7) Genetic Model of the Rare Earth Deposits

The Triassic system in this region were 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 in the Dong Pao area and then formed syenite bodies. Magmatic melt at the bottom was enriched in volatile matters and then in rare earth elements as the vapor pressure increased. The high-pressure and high-temperature vapor enriched in volatile matters migrated through cooling-joints, formed in the peripheries of syenite bodies or though fractures formed in surrounding limestone. The vapor, as ascending through joints and fractures, was mixed with groundwater and cooled down to precipitate rare earth minerals, barite and fluorite under certain pressure and temperature conditions, which resulted in formation of ore deposits in this area. The syenite body has been exposed on the surface as the limestone on the top was eroded out. Its present dimension is measured at approximately 4 km in the east-west and at 5 km in the north-south. The ore deposits are located in the northern, southern and western peripheries of the syenite body.

8) Metallurgical Testing

The ore samples with the total weight of 1,431 kg were collected from four pits excavated over the surface of F3 ore body for the metallurgical testing. The analytical result indicated the averages of 9.25 % T-RE_2O_3, 62.7 % $BaSO_4$ and 4.7 % CaF_2.

The size analysis of the crushed products proved that rare earth minerals were concentrated in the fine fractions with sizes less than 8 or 10 μm. The -8mm fractions of the crushed and ground samples are assayed at 32.5 % T-RE_2O_3 with the size distribution of 32 % and at 22.1 % T-RE_2O_3 with that of 51 % respectively. The -8mm fractions of the crushed and ground samples are assayed at 32.5 % T-RE_2O_3 with the size distribution of 32 % and at 22.1 % T-RE_2O_3 with that of 51 % respectively. Therefore, it is possible to produce crude rare earth concentrates with the grade better than 30 % T-RE_2O_3 by separating and concentrating the fine fractions.

In the flotation tests, various conditions such as flotation sequences, kinds and amounts of reagents and flotation temperature were examined, which was unsuccessful to separate and concentrate rare earth minerals to a satisfactory degree. The magnetic separation tests resulted in unsuccessful as well.

The reasons for the poor recovery and concentration in the flotation tests are ;

1) the ores are highly weathered, containing very fine-grained bastnaesite,
2) bastnaesite occurs interstitially between fluorite and/or barite, or is attached to rims of other minerals, forming middlings so that it is difficult to be liberated,
3) bastnaesite tends to form bastnaesite-calcite micro-veins within fluorite and /or barite crystals, which is also difficult to be liberated

The sample for the current metallurgical testing were collected form the surface portion of F3 ore body and might have contained an excessive amount of fine-grained bastnaesite for a representative sample.

7-2 Recommendation

The follow-up works in the next stage of the current project are proposed below, in order to further investigate the possibility of the commercial exploitation of F3 and other ore bodies in Duong Pao area.

7-2-1 Investigation for F3 Ore Body

1) Drilling Exploration

The northern and the western continuations of F3 ore body have not been drill-explored, although a number of the drill holes of the current project intersected high grade zones of rare earth mineralization. It is essential for the economic assessment of F3 ore body to firmly delineate the ore body in its lateral and vertical extensions.

2) Metallurgical Testing (Mineral Processing)

The metallurgical testing for the surface sample of F3 ore body resulted in unsuccessful, although the flotation and the magnetic separation processes were tested under various conditions. The poor recovery and concentration of rare earths are attributed to fine-grained nature of bastnaesite in the test sample due mainly to intense weathering. It is necessary to carry out the flotation and magnetic separation tests, further in detail, for unweathered representative samples collected from drill cores at depth. The test samples should be collected from ore sections of drill holes deeper than 30 m from their collars, and should represent various mineral compositions in the ore body. The ultimate objective is to identify the optimum process for recovery and concentration of rare earth minerals.

3) Hydro- and/or Pyro-metallurgical Testing

Although the flotation tests for the intensely weathered surface sample resulted in unsuccessful, the size analysis proved that the -8mm fractions of the crushed and ground samples contained 32.5 % and 22.1 % of $T\text{-}RE_2O_3$ respectively. If crude concentrates with the grade of this order can be used as raw materials to produce marketable intermediate products such as mischmetal, mineral processing procedures will not be required and hence the overall production cost will be reduced. Therefore, it is worthwhile to test hydro- or pyro-metallurgical processes suitable for treatment of this type of crude concentrates. The objectives are to identify the optimum metallurgical process and to assess its economic viability in comparison with other processes.

4) Ore Reserve Estimation

Upon completion of the drilling exploration, the ore reserves of the entire ore body of F3 should be re-assessed for the tonnage and grade.

5) Preparation of Topographic Maps

It is necessary for the detailed survey of the Project Area to produce appropriate topographic maps at a scale of 1 to 5,000.

7-2-2 Exploration on Other Promising Prospects

The Project Area includes three promising prospects for rare earth resources, namely New Dong Pao in the south including F3 ore body, Ban Hon South in the north and Tong Pao Nieu in the northwest (Figure II-7-1). It will be essential to establish potential REE resources in these prospects in order to secure sufficient mining reserves when carrying out a feasibility study for commercial exploitation of F3 ore body in future.

1. New Dong Pao Prospect

A number of significant soil geochemical anomalies exceeding 2 % T-RE_2O_3 are outlined in association with F 7 ore body. The one in the western part is correlated to the northern extension of F 3 ore body, suggesting that the two ore bodies join to each other. An outcrop sample in the western part of F 7 ore body yielded an assay result of 11.09 % T-RE_2O_3, indicating a possibility of concealed rare earth mineralization with appreciable concentrations. Significant soil geochemical anomalies are also located in the northern and central parts of New Dong Pao prospect.

F 7 ore body is located adjacent to F 3 and may be developed together with F 3 if its mode of occurrence permits.

2. Ban Hon South and Tong Pao Nieu Prospects

F9 and F 10 ore bodies are located in Ban Hon South prospect and F 16 is in Tong Pao Nieu prospect. A number of significant soil geochemical anomalies exceeding 2 % T-RE_2O_3 are outlined in these prospects. Outcrops with rare earth mineralization are associated with these ore bodies, suggesting that sizable ore bodies are concealed in these prospects.

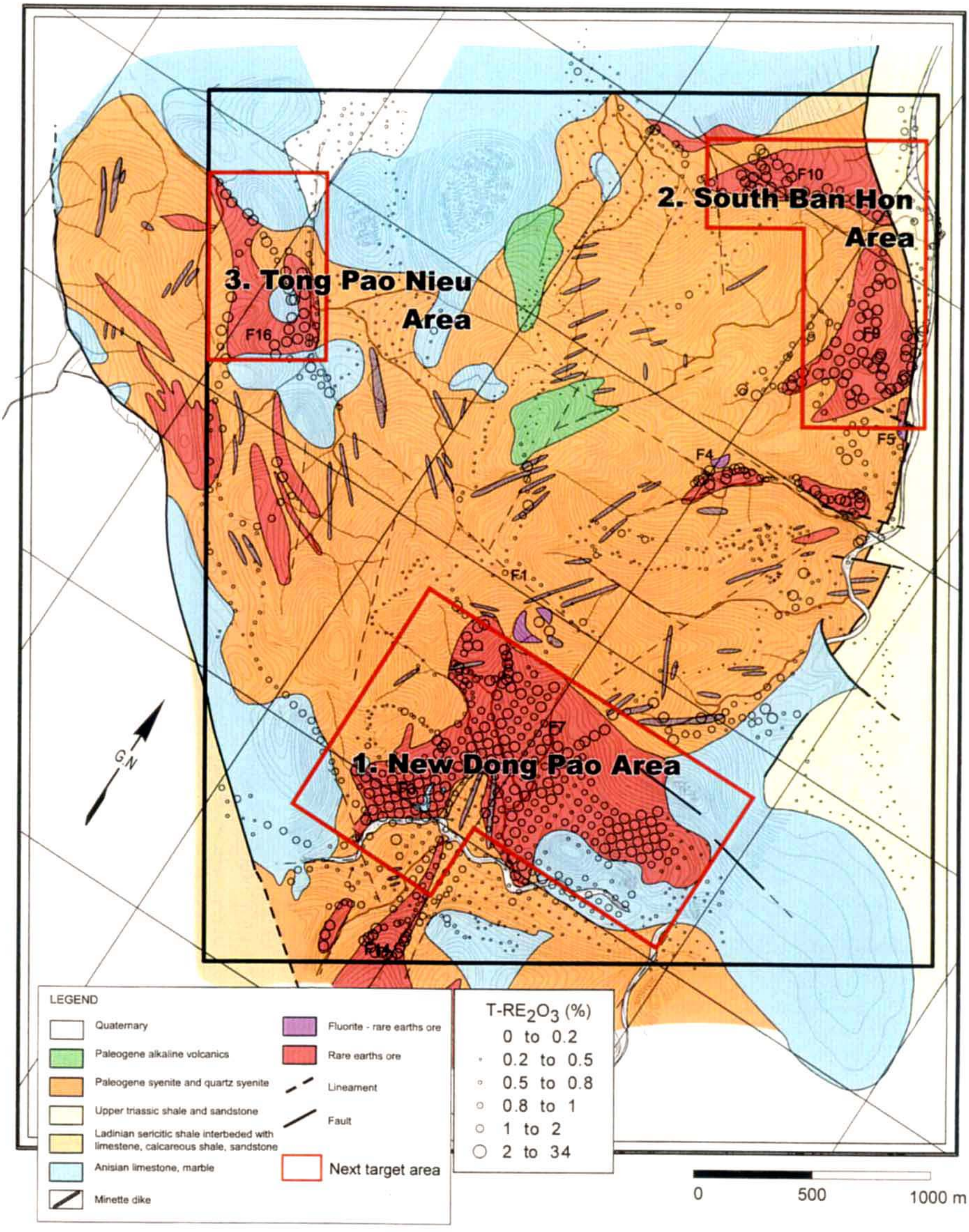


Figure II-7-1 The Project Area includes three promising prospects for rare earth resources

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