GEOCHEMISTRY OF GRANULITE FACIES ORTHGNEISSES OF THE JUIZ DE FORA COMPLEX, CENTRAL SEGMENT OF THE RIBEIRA BELT, SOUTHEASTERN BRAZIL

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RESUMO GEOQUÍMICA DOS ORTOGNAISSES GRANULÍTICOS DO COMPLEXO JUIZ DE FORA, SEGMENTO CENTRAL DA FAIXA RIBEIRA, BRAZIL O Complexo Juiz de Fora *(CJF)* foi investigado em sua área-tipo (região de Juiz de Fora, MG) e está inserido em um contexto de evolução geológica complexa, policíclica, com o envolvimento de eventos deformacionais e metamórficos de alto grau recorrentes, que se desenvolveram desde o Arqueano até o Neoproterozóico-Neocambriano. O CJF é constituído de ortognaisses, migmatitos e metabasitos na fácies granulito, tendo, subordinadamente, ortognaisses na fácies anfibolito. O mapeamento geológico mostrou que o CJF ocorre como escamas tectônicas interdigitadas a rochas metassedimentares pós-1.8 Ga., com paragêneses da fácies anfibolito, e a paragnaisses migmatíticos com ortopiroxênio. Eventos tectônicos recorrentes obliteraram generalizadamente as feições e a paleogeografia original. O artigo visa investigar as características litogeoquímicas dos ortogranulitos do CJF e elucidar aspectos da sua evolução magmática original e ambiente geotectônico. Dados de campo e petrográficos permitem subdivir estes ortogranulitos em granulitos máficos, intermediários e félsicos. Os elementos imóveis e ETR sugerem que (a) os granulitos máficos são toleiitos de provável evolução a partir de um mesmo magma parental, (b) os intermediários e félsicos são calcioalcalinos e possuem evidências que sugerem relação petrogenética entre alguns de seus litotipos, e (c) nenhuma relação petrogenética parece existir entre os granulitos máficos e os demais.

Palavras-chave: Geoquímica, Granulito, Faixa Ribeira, Precambriano.

ABSTRACT The Juiz de Fora Complex (JFC) in the surroundings of Juiz de Fora (MG) town records a complex geological evolution, with recurring deformational and high-grade metamorphic events from the Archean to the Lower Cambrian. The JFC comprises pre-1.8 Ga. granulite facies orthogneisses, migmatites and metabasites, with subordinated amphibolite facies orthogneisses. The JFC occurs as thrust sheets within post-1.8 Ga amphibolite facies metasedimentary rocks and within orthopyroxene-bearing migmatitic paragneisses of undetermined age. Recurring tectonic events led to the general obliteration of original textures, structures and paleogeography. Field and petrographic data allow the subdivision of the orthogranulites into mafic, intermediate, and felsic granulites. Imobile and Rare Earth elements suggest that (a) the mafic granulites are tholeiitic and that each sample represents different stages of differentiation of one parental magma, (b) the intermediate and felsic granulites are calc-alkaline, and (c) no petrogenetic link seems to exist between the tholeiitic and the calc-alkaline rocks, but some evidences point to possible link among the calc-alkaline rocks.

Keywords: Geochemistry, Granulite, Ribeira Belt, Precambrian.

INTRODUCTION The terms Juiz de Fora Series (Ebert 1955), Juiz de Fora Gneisses (Cordani *et al* 1973) belonging to the Paraíba Group (Ebert 1968) and Juiz de Fora Complex (Oliveira 1980, Machado Fº *et al* 1983, Barbosa & Grossi Sad 1983a, b, c, Grossi Sad & Barbosa 1985, Pinto 1991, Heilbron 1993, Nogueira 1994, Duarte *et al* 1994) have always been related to granulite fácies metasediments and /or orthogneisses that crop out along a NE-SW trending belt in southern Minas Gerais State. Geochronological data indicate that these rocks were granulitized during the Transamazonian Event, ca. 2,2 -1,8 Ga. (Delhal *et al* 1969, Cordani *et al.* 1973), although the protholiths may be either of Paleoproterozoic (Cordani *et al.* 1973, Heilbron 1993, Machado *et ai* 1996, Figueiredo & Teixeira 1996) or Archean age (Cordani *et al.* 1973, Machado Fº *et al* 1983). A retrogressive metamorphic event, that took place during the Brasiliano Orogeny, ca. 605 - 490 Ma. (Delhal *et al* 1969, Cordani *et al.* 1973, Valladares 1996, Machado *et al* 1996), led to partial replacement of the granulite fácies paragenesis by those of the high amphibolite fácies. Figueiredo and Teixeira (1996) related this late metamorphic event to the Rio Doce Orogeny (550-500 Ma.), defined by Campos Neto & Figueiredo (1992, 1995).

In this work, the Juiz de Fora Complex is defined as composed of pré-1,8 Ga. granulite fácies orthogneisses, migmatites and metabasites, with subordinated lenses of amphibolite facies orthogneisses which occupy part of the central segment of the Neoproterozoic Ribeira mobile belt (Almeida *et al.* 1973).

GEOLOGICAL SETTING The study area is situated in the surroundings of the Juiz de Fora, Matias Barbosa, Simão Pereira and Belmiro Braga towns, southern Minas Gerais state (Fig. 1). Geological mapping, at 1: 50.000 scale reduced to l .250.000 (Duarte *et al* 1994), shows that the JFC occurs as thrust sheets within post-1.8 Ga amphibolite fácies metasedimentary units probably belonging to the Andrelândia Depositional Cycle (Andreis *et al.* 1989), and orthopyroxene-bearing migmatitic paragneisses of uknown stratigraphic position (Fig. 1).

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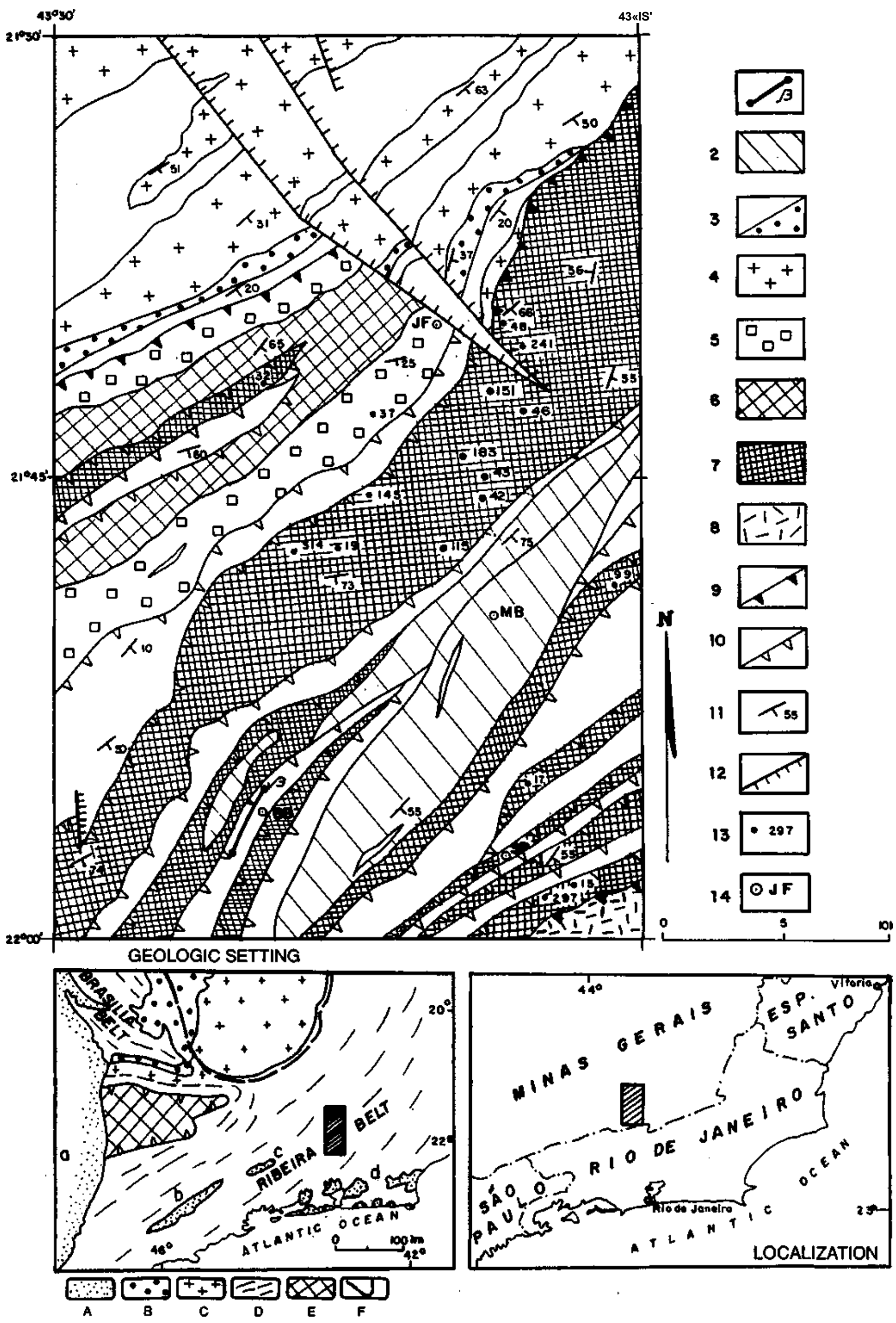

Figure 1- Geologic Map of the Study Area (modified after Duarte et al 1994): 1- Mesozoic mafic dikes; 2 - Neoproterozoic intrusive granitic bodies; 3- Post-1.8 Ga. metasediments (Andrelândia Depositional Cicie and correlated units); 4 - Mantiqueira Complex; 5- Garnet Charnockite; 6 - Opx-bearing paragneisses; 7 - Juiz de Fora Complex (orthogranulites); 8 - Paraíba do Sul Complex; 9 - Main thrust faults; 10 - Thrust faults; 11 - Foliation planes; 12 - Faults with normal component; 13 - Analyzed samples; 14 - Towns (JF - Juiz de Fora; MB - Matias Barbosa; SP - Simão Pereira; BB - Belmiro Braga); A - Phanerozoic Cover (a-Paraná Basin; b- Taubaté Basin; c- Resende Basin; d-Guanabara Rift); B - Bambuí Group; C - San Francisco Craton; D - Neoproterozoic Belts; E - Guaxupé Nappe; F - Craton Limits.

Figura l - Mapa Geológico da Área Estudada (modificado de Duarte *et al.* 1994): l - Diques básicos Mesozóicos; 2 - Rochas graníticas intrusivas Neoproterozóicas; 3 - Rochas metassedimentares pós-1,8 Ga. (Ciclo Deposicional Andrelândia e correlates); 4 - Complexo Mantiqueira; 5 - Granada Charnockitóide; 6 - Paragnaisses com opx; 7 - Complexo Juiz de Fora (ortogranulitos); 8 - Complexo Paraíba do Sul; 9 - Principais Falhas de Empurrão; 10 - Falhas de Empurrão; 11 - Planos de Foliação; 12 - Falha com componente normal; 13 - Amostras analisadas; 14 - Cidades (JF - Juiz de Fora; MB - Matias Barbosa; SP - Simão Pereira; BB - Belmiro Braga); A - Cebertura Fanerozóica (a-Bacia do Paraná; b-Bacia de Taubaté; c- Bacia de Resende; d-Rifte da Guanabara); B - Grupo Bambuí; C - Cráton do São Francisco; D - Faixas Móveis Neoproterozóicas; E - Nappe de Guaxupé ; F - Limites do Cráton.

The orthogranulites of the JFC comprise lithotypes of a wide compositional variety. The opx ± cpx ± grt + plg paragenesis indicate metamorphism under granulite fácies. Enderbitic and charno-enderbitic compositions are the most widespread, although mafic and more felsic rocks also occur. These rocks are greenish or caramel and have granoblastic texture. Compositional banding is common and migmatitic structures, when present, contain green leuco-, melano- and paleosomes, suggesting an *in situ* anatexis before granulitic metamorphism. Granulites become greyish protomylonites, mylonites or ultramylonites near thrust planes of the Brasiliano Orogeny, which in their turn produced retrogessive paragenesis with hydrated minerais such as hornblende and /or biotite at the borders and within pyroxene grains. The new minerais are usually oriented along the younger mylonitic foliation.

FIELD AND PETROGRAPHIC CHARACTERISTICS Fresh exposures of the granulites occur in many quarries and highway and railway cuts, allowing sampling of ali lithotypes. Field and petrographic data classify the lithotypes into three major groups, i.e., mafic, intermediate and felsic granulites.

Mafic Granulites These occur as centimetric bands, lenses, and boudins as well as metric bands within the other groups. They have a dominant granoblastic texture with an opx + cpx ± hb ± grt -f plg paragenesis. Metamorphic retrogressive reactions transformed the pyroxene and plagioclase into hornblende ± garnet.

Intermediate Granulites *MASSIVE ENDERBITEAND CHARNO-ENDERBITE* These rocks are mainly massive, but may show a weak coarse foliation. Their texture is granoblastic. Protomylonitic and mylonitic textures occur near and along thrust faults. Compositional banding may locally occur due to the intercalation of mafic granulites with enderbites and charno-enderbites. The granulite paragenesis is made up of opx, cpx, plag, ort, and qz, with local retrogressive biotite after pyroxene. Hornblende is absent in these rocks. The associated mafic granulites occur either as centimetric lenses and boudin-shaped enclaves, or as centimetric to metric bands or lenses.

ENDERBITIC GNEISSES AND MIGMATITES Unlike the preceeding group, these rocks have pervasive gneissic banding and mylonitic foliation, and stromatic and shollen migmatitic structures. Hornblende and biotite are common retrogressive phases formed after opx and cpx. Associated mafic granulites occur as centimetric lenses and boudin-shaped enclaves.

Felsic Granulites *CHARNOCKITIC LEUCOSOMES AND GNEISSIC CHARNOCKITES* This group is largely dominated by felsic compositions (charnockite and charno-enderbite). These rocks are either massive or slightly foliated. Oriented schlieren is common, suggesting partia! melting during their formation. Petrographically, these lithotypes are characterized by the abundance of biotite retrogressive after orthopyroxene and hornblende, small ammounts of garnet, and by frequent synplectitic intergrowths of biotite and/or hornblende and felsic minerais. Associated mafic granulites occur mainly as small, centimetric bands and lenses. Banding may locally be metric near thrust faults, where it is also more deformed and with mylonitic texture.

INTRUSIVE FELSIC BODIES Felsic bodies commonly show sharp and intrusive contacts with rocks of ali other granulite lithotypes. Two types of felsic intrusive rocks were found and comprise charnockites and quartzose charnockites. The latter, not yet chemically analized, plots within the Ia field of Streckeisen's QAP diagram. The charnockites are médium- grained, hololeucocratic, have few grains of orthopyroxene, and are locally allanite-rich. Mafic granulite were not found in association with this lithotype, although it clearly crosscuts some mafic bands. The quartzose charnockites are coarse grained, essentially composed of quartz and centimetric grains of orthopyroxene, and have enclaves of mafic granulites.

GEOCHEMISTRY AND TECTONIC SETTINGS

Oliveira (1980, 1982) was the first to study the petrology of the JFC rocks and concluded that the mafic granulites have a tholeiitic character, while the intermediate to felsic orthogranulites are of incompatible element-depleted calc-alkaline affinity, being interpreted as residues of crustal melts. Machado Fº *et al* (1983) suggest that the tholeiitic and calc-alkaline granulites of the JFC are part of an Archean continental or basaltic lower crust. Barbosa & Grossi Sad (1983c) reached to the same conclusions by mapping and studying these rocks in the eastern Minas Gerais and Rio de Janeiro states. Pinto (1991) suggests that the orthogranulites (mafic and dioritic granulites) were low-K tholeiites, probably of island are or back-arc basins, and that the enderbitic granulites were calc-alkaline rocks. Heilbron (1993), investigating an area SW of Juiz de Fora, proposes that the JFC contains four distinct magmatic groups: (a) mafic tholeiitic granulites with alkaline affinity; (b) mafic tholeiitic granulites; (c) intermediate to felsic calc-alkaline granulites, and (d) intermediate to felsic high-K calc-alkaline granulites. Figueiredo and Teixeira (1996), studying an area north of Juiz de Fora, conclude that the orthogranulites of the JFC derive from (a) a low-K calc-alkaline series and (b) a medium- to high-K calc-alkaline series.

In this study, field data show that the orthogranulites of the JFC are polyciclic and occur as thrust sheets within metasedimentary rocks (Fig. 1). As tectonics and metamorphism obliterated their original textures, structures and paleogeography, the geochemistry of these rocks is an important tool to decifer their original magmatic evolution and tectonic settings.

Field and petrographic data determined the selection of 34 samples of the JFC for chemical analysis. Among these samples, 8 are of mafic granulites, 4 of intermediate massive granulites, 9 of intermediate granulite gneisses and migmatites, 7 of felsic granulites (charnockitic leucosomes and gneissic charnockite), and 7 of intrusive charnockite bodies. The analytical results are shown in Tables l to 5. Major, trace, and Rare Earth (REE) elements were determined at the Activation Laboratory (Canada). ICP was used to analyze the major elements and Sc, V, Zr, and Ba, while INAA and ICP for the remaining trace elements and the REE.

Major and Trace Element Geochemistry From the chemical classification diagrams of the studied samples (Figs. **2** to 5), it may be concluded that the mafic granulites are gabbros (Fig. 2), the intermediate granulites are quartz

Table 1 - Chemical composition of the Mafic Granulites. (HMgT - high-Mg tholeiites; MMgT - medium-Mg tholeiites; LMgT- low-Mg tholeiites) (explanation in text). na - not analyzed; nd - not detected; (13) - estimated values

Tabela l - Composição química dos Granulitos Máficos. (HMgT - toleiitos de alto Mg; MMgT - toleiitos de médio Mg; LMgT - toleiitos de baixo Mg) (explicação no texto), na - não analisado; nd - não detectado; (13) - valores estimados

Sample	MB - 17A (HMgT)	MB - 42 (MMgT)	MB - 46P (MMgT)	MB - 17B (HMgT)	MB - 15C (MMgT)	MB - 183A (LMgT)	MB - 514B (LMgT)	MB - 514C (LMgT)
SiO_2	47.21	47.62	48.67	48.77	49.21	49.41	49.72	47.8
TiO_2	0.76	1.53	0.98	0.56	1.06	1.94	2.18	2.22
Al_2O_3	15.3	13.29	13.69	15.12	15.22	13.85	12.86	13.27
FeO*	10.37	14.95	12.62	9.28	11.9	14.42	13.25	12.75
MnO	0.17	0.22	0.19	0.17	0.2	0.23	0.22	0.21
MgO	8.85	6.48	6.43	8.93	6.68	4.74	5.32	6.19
CaO	13.03	10.08	10.33	13.02	9.75	8.06	9.57	10.25
Na_2O	2.22	2.56	2.98	2.35	1.45	2.94	3.19	3.26
K_2O	0.66	0.38	0.83	0.46	0.58	0.74	0.61	0.88
P_2O_5	0.04	0.15	0.08	0.06	0.12	0.22	0.31	0.22
LOI	0.45	nd	0.05	0.37	0.85	0.7	0.68	2.02
Total	100.21	98.93	98.25	100.12	98.34	98.86	99.38	100.49
Mg #	60.34	43.57	47.6	63.17	50.02	36.93	41.72	46.38
Cr	120	na	na	270	140	na	100	129
Ni	146	136	103	131	75	61	37	78
Co	49	na	na	45	48	na	43	55
Sc	43	41	40	42	42	38	40	41
V	226	276	229	194	255	274	267	385
Cu	109	103	69	20	37	74	78	57
Pb	nd	8	16	nd	nd	11	11	12
Zn	60	112	89	48	96	115	27	28
Rb	17	nd	nd	nd	28	nd	3	8
Cs	nd	nd	nd	nd	0.6	2.6	nd	nd
Ba	45	38	54	24	69	119	150	138
Sr	116	145	222	94	240	317	264	237
Ta	nd	0.5	0.7	nd	0.8	0.8	1.13	0.78
Nb	na	(8.5)	(11.9)	na	(13.6)	(13.6)	18.6	13.1
Hf	0.8	2	1.8	0.8	1.6	3.3	5.1	3.9
Zr	54	79	63	56	98	129	192	142
Y	20	31	23	20	38	35	43	32
Th	nd	nd	0.8	0.5	0.6	0.4	1.09	1.22
U	nd	nd	0.4	0.8	nd	nd	0.45	0.65
La	1.9	5.6	6.8	2.2	4.8	11.1	23.1	13.3
Ce	6	15	16	5	12	27	51.3	29.9
Pr	na	na	na	na	na	na	5.88	3.58
Nd	5	9	9	5	10	20	28.1	18.5
Sm	1.4	3.46	2.43	1.1	2.6	5.03	7.2	5
Eu	0.69	1.3	0.8	0.4	0.93	1.4	2.27	1.72
Gd	na	na	na	na	na	na	7.7	5.6
Tb	0.5	0.9	0.7	0.5	0.6	1.1	1.3	0.9
Dy	na	na	na	na	na	na	8	5.8
Ho	na	na	na	na	na	na	1.6	1.2
Er	na	na	na	na	na	na	4.5	3.4
Tm	na	na	na	na	na	na	0.66	0.49
Yb	1.4	2.9	2.5	1.14	2.15	3.8	4.1	2.9
Lu	0.22	0.42	0.37	0.19	0.35	0.51	0.66	0.46
$(La/Yb)_N$	0.92	1.31	1.84	1.31	1.51	1.98	3.82	3.11

Table 2 - Chemical composition of the Intermediate Massive Granulites. na - not analyzed; nd - not detected; (13) - estimated values

Tabela 2 - Composição Química dos Granulitos Intermediários Maciços, na - não analisado; nd - não detectado; (13) - valores estimados

Sample	MB - 99D	MB - 15B	MB - 19	MB - 32A	MB - 32D	MB - 145 B	MB - 297D	MB - 297B	MB - 115B
SiO_2	54.99	57.95	61.12	61.80	62.82	63.79	64.35	64.44	66.24
TiO_2	0.98	0.86	0.92	1.03	1.13	0.78	0.70	0.63	0.52
Al_2O_3	16.70	16.41	15.37	16.42	15.76	15.15	15.60	16.39	15.41
FeO*	7.89	6.74	5.67	6.14	6.19	6.24	6.25	5.15	4.21
MnO	0.13	0.11	0.10	0.11	0.12	0.09	0.12	0.07	0.07
MgO	3.74	3.22	2.71	1.93	1.94	2.78	2.50	2.09	2.50
CaO	6.24	4.41	4.34	3.69	3.77	4.97	3.01	3.24	4.34
Na_2O	3.58	3.90	4.24	4.08	3.72	3.05	4.34	4.65	4.51
K_2O	1.91	2.32	1.90	3.10	3.31	1.66	2.20	2.00	1.19
P_2O_5	0.31	0.18	0.34	0.40	0.39	0.20	0.19	0.12	0.22
LOI	0.20	0.79	0.26	0.21	0.30	0.50	0.51	0.32	0.30
Total	96.47	96.10	96.71	98.70	99.15	98.90	99.26	98.78	99.98
Mg #	45.79	45.99	46.00	35.91	35.83	44.27	41.60	41.98	51.41
Cr	na	95	79	23	17	na	113	122	na
Ni	17	36	26	27	26	48	36	57	45
Co	na	23	16	15	na	na	19	20	na
Sc	23	15	13	9	na	12	15	11	8
V	103	89	74	60	77	81	94	91	51
Cu	47	30	13	45	45	100	18	13	76
Pb	22	13	16	19	20	21	27	17	15
Zn	83	82	86	90	95	69	77	76	71
K	15855	19259	15772	25734	27477	13780	18263	16603	9879
Rb	40	96	34	89	86	59	87	71	70
Cs	nd	1.50	nd	0.50	na	nd	2.10	0.50	1.10
Ba	990	448	800	1210	1263	492	740	890	723
Sr	570	346	470	327	334	303	527	667	637
Ta	nd	nd	nd	1.40	1.62	nd	0.44	0.19	nd
Nb	na	na	na	23.8	27.6	na	8.2	6.5	na
Hf	6.90	4.50	7.40	(8.30)	nd	5.00	9.80	3.80	4.80
Zr	201	223	285	349	335	193	315	142	220
Ti	5875	5156	5515	6175	6774	4676	4197	3777	3117
Y	23	24	30	54	39	25	18	6	8
Th	nd	11.00	14.00	4.90	na	1.40	7.94	6.39	5.70
U	nd	1.30	nd	0.20	na	nd	1.52	0.46	nd
La	34.30	81.50	74.50	64.30	na	23.70	35.30	35.70	52.70
Ce	67.00	136.00	125.00	108.00	na	45.00	67.60	64.60	86.00
Pr	na	na	na	na	na	na	6.62	6.08	na
Nd	33.00	48.00	51.00	44.00	na	23.00	26.70	23.90	33.00
Sm	6.33	5.90	7.50	7.20	na	4.65	4.60	3.80	4.47
Eu	1.50	1.49	1.86	1.78	na	1.20	1.17	1.42	1.00
Gd	na	na	na	na	na	na	3.40	2.20	na
Tb	0.80	0.50	0.90	1.20	na	0.80	0.50	0.20	na
Dy	na	na	na	na	na	na	3.00	1.10	na
Ho	na	na	na	na	na	na	0.60	0.20	na
Er	na	na	na	na	na	na	1.90	0.50	na
Tm	na	na	na	na	na	na	0.28	0.06	na
Yb	2.10	0.96	1.32	3.83	na	2.40	1.80	0.40	0.60
Lu	0.30	0.15	0.23	0.60	na	0.31	0.30	0.08	0.11
$(La/Yb)_N$	11.07	57.53	38.21	11.37	-	6.69	13.29	60.61	59.44

Table 3 - Chemical composition of the Intermediate Gneissic and Migmatitic Granulites. na - not analyzed; nd - not detected; (13) - estimated values

Tabela 3 - Composição química dos Granulitos Intermediários Gnáissicos e Migmatíticos. na - não analisado; nd - não detectado; (13) - valores estimados

Sample	MB - 43C	MB - 46C	MB - 46A	MB - 46T
SiO_2	55.90	58.07	61.59	62.40
TiO_2	1.43	0.66	1.13	0.38
Al_2O_3	16.42	17.65	14.51	16.25
FeO*	9.71	5.69	6.73	5.64
MnO	0.27	0.11	0.12	0.13
MgO	3.55	3.76	4.37	3.01
CaO	4.78	3.80	4.64	4.49
Na_2O	4.18	5.23	4.10	4.99
K_2O	1.95	2.24	0.76	1.02
P_2O_5	0.49	0.17	0.31	0.48
LOI	0.74	0.78	0.08	0.40
Total	100.50	98.79	99.09	99.82
Mg #	39.45	54.09	53.64	48.74
Cr	163	242	130	na
Ni	111	79	92	68
Sc	na	na	na	11
V	132	105	171	66
Cu	46	26	28	61
Pb	18	26	21	21
Zn	120	97	97	78
K	16188	18595	6309	8467
Rb	27	73	32	21
Ba	983	525	523	220
Sr	465	360	198	303
Ta	0.73	0.55	0.86	0.60
Nb	12.4	9.4	14.6	(10.2)
Hf	na	na	na	0.70
Zr	279	83	156	17
Ti	8573	3957	6774	2278
Y	33	10	37	27
Th	na	na	na	6.00
U	na	na	na	1.60
La	na	na	na	27.20
Ce	na	na	na	53.00
Nd	na	na	na	28.00
Sm	na	na	na	6.23
Eu	na	na	na	0.90
Tb	na	na	na	0.90
Yb	na	na	na	1.60
Lu	na	na	na	0.22
(La/Yb)N	-	-	-	11.51

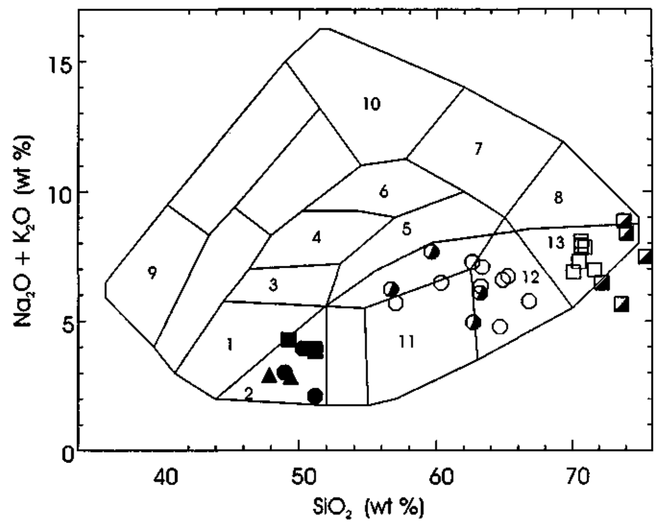

Figure 2 - Chemical classification of the rocks of lhe JFC (Cox et al. 1979); the dividing Une between the alkalic and subalkalic magma series is from Miyashiro (1978). 1,2, 3 - Gabbro; 4,5 - Syeno-diorite; 6,7 - Syenite; 8 - Alkali-granite; 9 - Ijolite; 10 - Nepheline syenite; 11 - Diorite; 12 - Quartz-dioríte (Granodioríte); 13 - Granite. Symbols: Mafic granulites (closed triangles, circles and squares); Intermediate granulites (half-closed circles - massive; and open circles - gneissic and migmatitic granulites); Felsic granulites (open squares -charnockitic leucosomes and gneissic charnockites; and half – closed squares – intrusive charnockites). .

Figura 2 - Classificação química das rochas do Complexo Juiz de Fora (CJF) (Cox *et al.* 1979); a linha divisória dos campos alcalino e subalcalino foi proposta por Miyashiro (1978). l, 2, 3 - Gabro; 4, 5 - Sieno-diorito; 6, 7 - Sienito; 8 - Álcali-granito; 9 - Ijolito; 10 - Nefelina sienito; 11 - Diorito; 12 - Quartzo-diorito (Granodiorito); 13 - Granito. Símbolos: Granulitos básicos (triângulos, círculos e quadrados fechados); Granulitos intermediários (círculos abertos - granulitos gnáissicos e migmatíticos; círculos parcialmente fechados - granulitos maciços); Granulitos ácidos (quadrados abertos - leucossomas charnockíticos e gnáissicos; quadrados parcialmente preenchidos - charnockitos intrusivos).

diorites, tonalites, and granodiorites, and that the felsic granulites are granodiorites and granites. A compositional gap occurs between 66,2 and 69,5% SiO_2 (see below), separating less from more silicic granodiorites. Trondhjemitic compositions were not found (Fig. 5), but studies on the possibility of the JFC being, to some extent, a granulitized TTG association are in course.

Figures 6 and 7 show that ali the studied granulites are subalkalic rocks, and that the mafic granulites delineate a tholeiitic trend, while the intermediate and felsic granulites have a calc-alkaline character. The main characteristics of each individual group are presented below.

MAFIC GRANULITES The mafic granulites have a basaltic composition (Fig. 2). Major and trace element abundance alio w the recognition of three distinct subgroups (Figs. 8, 9 and 10), which comprise (i) high-Mg tholeiites (HMgT), characterized by higher MgO and CaO, and lower FeO, Sr, HFSE (and also REE; see below) contents as compared to the other tholeiites; (ii) a medium-Mg tholeiite (MMgT) with a composition which is intermediate between the HMgT and the low-Mg tholeiite (LMgT); and (iii) the LMgT, character-

Table 4 - Chemical composition of the Charnockitic Leucosomes and Gneissic Charnockites. na - not analysed; nd - not detected; (13) - estimated values

Tabela 4 - Composição química dos Leucossomas Charnockíticos e Charnockitos gnáissicos. na - não analisado; nd - não detectado; (13) - valores estimados

Sample	MB - 32C	MB - 241 A	MB - 48A	MB - 514E	MB - 151B	MB - 32B	MB - 514A
SiO_2	68.77	69.00	69.49	70.17	70.18	70.82	70.79
TiO_2	0.43	0.35	0.55	0.40	0.51	0.36	0.34
Al_2O_3	14.29	14.90	14.76	15.22	14.80	15.06	15.08
FeO*	2.66	2.11	2.87	2.74	2.58	2.54	2.07
MnO	0.05	0.03	0.06	0.03	0.04	0.05	0.03
MgO	0.84	0.75	1.30	0.84	0.84	0.71	0.67
CaO	2.46	2.37	3.05	2.71	2.39	2.46	2.81
Na_2O	3.17	3.82	4.39	3.76	3.70	3.38	4.00
K_2O	4.48	3.80	2.43	3.49	4.14	4.72	2.89
P_2O_5	0.12	0.12	0.24	0.17	0.16	0.16	0.11
LOI	0.31	0.50	0.28	0.31	0.35	0.39	0.31
Total	97.88	97.98	99.74	100.15	99.98	100.93	99.33
Mg #	35.98	38.83	44.66	35.29	36.69	33.27	36.58
Cr	13	na	25	23	na	8	20
Ni	11	3	14	9	2	9	19
Co	8	na	na	6	na	5	6
Sc	1	2	na	4	5	2	3
V	21	28	46	30	21	17	50
Cu	14	5	8	500	5	17	19
Pb	24	26	23	74	23	22	26
Zn	36	43	48	26	32	37	24
K	37190	31545	20172	28972	34367	39182	23991
Rb	110	116	53	67	110	97	54
Cs	0.50	na	nd	na	nd	nd	nd
Ba	1896	1200	772	1644	1466	1478	1836
Sr	303	402	358	652	415	290	520
Tl	na	na	na	0.50	na	na	0.40
Ga	na	na	na	19	na	na	19
Ta	nd	0.50	0.39	0.21	nd	0.70	0.19
Nb	(8.5)	(8.5)	(6.6)	5.5	nd	11.9	4.5
Hf	5.20	6.70	nd	5.50	4.70	5.80	4.40
Zr	226	181	208	222	262	230	174
Ti	2578	2098	3297	2398	3057	2158	2038
Y	10	8	10	7	11	22	5
Th	0.50	25.70	nd	25.77	15.70	7.30	1.04
U	0.60	0.90	na	0.47	nd	0.70	0.39
La	24.20	77.90	na	101.20	49.90	49.10	23.90
Ce	35.00	117.00	na	165.60	73.00	79.00	35.60
Pr	na	na	na	14.19	na	na	3.04
Nd	12.00	41.00	na	50.20	25.00	30.00	10.80
Sm	1.90	5.59	na	6.50	3.69	4.10	1.90
Eu	1.25	1.30	na	1.36	1.10	1.38	1.12
Gd	na	na	na	3.20	na	na	1.40
Tb	0.50	nd	na	0.30	0.60	0.50	0.20
Dy	na	na	na	1.60	na	na	0.80
Ho	na	na	na	0.30	na	na	0.20
Er	na	na	na	0.50	na	na	0.40
Tm	na	na	na	0.06	na	na	nd
Yb	1.21	0.70	na	0.30	0.50	1.08	0.40
Lu	0.22	0.12	na	0.08	0.08	0.20	0.06
(La/Yb)N	13.55	75.46	-	228.29	67.63	30.82	40.58

Table 5 - Chemical composition of the Intrusive Charnockites. na - not analyzed; nd - not detected; (13) - estimated values
Tabela 5 - Composição Química dos Charnockitos Intrusivos. na - não analisado; nd - não detectado.

Sample	MB - 151 A	MB - 43B	MB - 37 (1)	MB - 46R	MB - 46B	MB - 46U	MB - 43A
SiO_2	72.05	73.61	71.50	71.92	74.55	74.97	79.43
TiO_2	0.21	0.19	0.53	0.19	0.08	0.02	0.19
Al_2O_3	13.75	13.59	14.02	13.98	13.66	13.81	11.63
FeO*	1.23	1.30	2.65	1.88	0.74	0.25	1.23
MnO	0.02	0.02	0.04	0.03	0.02	nd	0.02
MgO	0.35	0.76	0.77	0.88	0.39	0.09	0.61
CaO	1.47	1.30	3.00	3.18	1.92	1.98	3.05
Na_2O	3.30	2.56	3.22	4.22	3.70	3.71	3.22
K_2O	4.85	6.26	3.18	1.28	3.68	3.44	0.72
P_2O_5	0.05	0.04	0.15	0.07	0.03	nd	0.02
LOI	0.20	0.32	nd	1.15	1.19	0.35	0.62
Total	97.62	100.10	99.35	98.99	100.04	98.65	100.88
Mg #	33.60	50.93	34.15	45.47	48.50	38.90	46.86
Cr	na	39	na	na	9	na	13
Ni	2	6	4	12	8	2	7
Sc	1		3	2	na	nd	na
V	10	28	23	24	11	2	25
Cu	4	5	16	64	23	9	9
Pb	184	41	17	19	28	27	10
Zn	17	22	35	19	9	4	11
K	40261	51966	26398	10626	30549	28556	5977
Rb	145	94	80	24	79	75	5
Ba	1543	1440	1486	385	1762	1659	373
Sr	344	268	311	291	312	281	272
Ta	nd	0.08	nd	nd	0.12	nd	0.11
Nb	nd	1.4	na	na	2.0	na	1.8
Hf	3.70	nd	6.20	3.40	na	2.00	na
Zr	130	105	259	134	87	60	47
Ti	1259	1139	3177	1139	480	120	1139
Y	6	3	10	3	4	nd	2
Th	21.30	na	2.50	0.40	na	3.50	na
U	nd	na	nd	nd	na	1.00	na
La	42.30	na	32.00	14.50	na	13.30	na
Ce	61.00	na	44.00	21.00	na	16.00	na
Nd	20.00	na	16.00	10.00	na	8.00	na
Sm	3.21	na	2.63	1.16	na	0.52	na
Eu	0.80	na	1.40	0.80	na	0.80	na
Yb	0.40	na	1.20	0.30	na	nd	na
Lu	0.08	na	0.18	0.05	na	nd	na
(La/Yb)N	71.82	-	18.08	30.61	-	>30.61	-

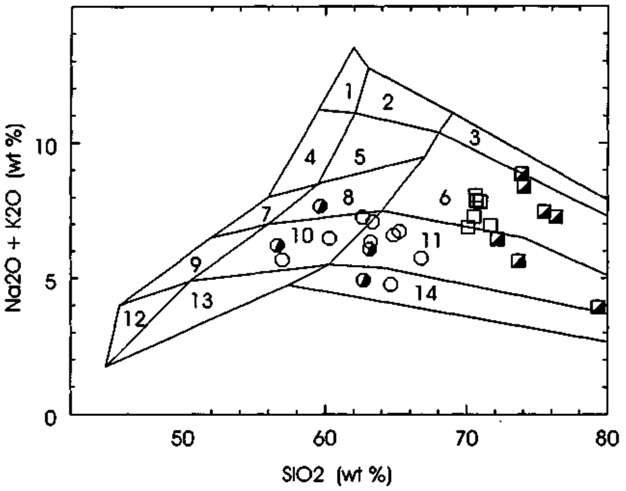

Figure 3 - Chemical classification of the rocks of the intermediate andfelsic granulites (Middlemost 1985). 1 - Alkali-feldspar syenite; 2 - Alkali-feldspar quartz syenite; 3 - Alkali-feldspar granite; 4 - Syenite; 5 - Quartz syenite; 6 - Granite; 7 - Monzonite; 8 - Quartz monzonite; 9 - Monzodiorite; 10 - Quartz monzonite; 11 -Granodioriie; 12 - Diorite and gabbro; 13 - Quartz diorite; 14 - Tonalite. Symbols as in figure 2.

Figura 3 - Classificação química dos granulitos intermediários e ácidos (Middlemost 1985). 1 -Álcai-feldspato sienito; 2 - Álcali-feldspato quartzo sienito; 3 - Álcali-feldspato granito; 4 - Sienito; 5 -Quartzo sienito; 6 - Granito; 7 - Monzonito; 8 - Quartzo monzonito; 9 - Monzodiorito; 10 - Quartzo monzonito; 11 -Granodiorito; 12 - Diorito e gabro; 13 - Quartzo diorito; 14 - Tonalito. Símbolos como na figura 2.

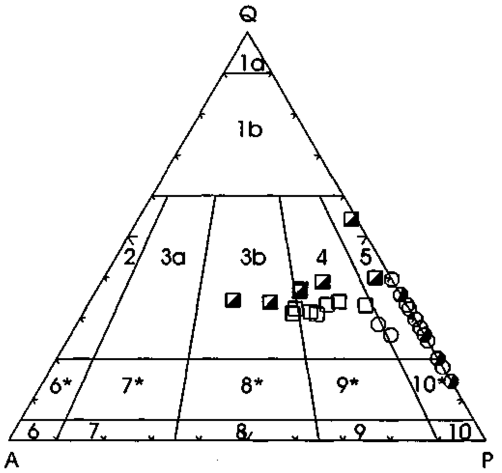

Figure 4 - Plots of the intermediate andfelsic granulites in the QAP normative diagram (Le Maitre 1989). 1a and 1b-quartz-rich granitoids ; 2-Alkali feldspar granite; 3a-Syenogranite; 3b-Monzogranite; 4-Granodiorite; 5-Tonalite; 6-Alkali feldspar syenite; 6-Nepeline-alkali feldspar syenite; 7-Syenite; 7*-Nepheline syenite; 8-Monzonite ; 8*-Latite; 9-Monzogabbro ; 9*- Nepheline monzogabbro; 10-Diorite, anorthosite, gabbro, norite; 10* -Nepheline diorite, nepheline gabbro. Symbols as in figure 2.*

Figura 4 - Granulitos intermediários e ácidos em diagrama QAP normativo (Le Maitre 1989). 1a and 1b-granitóides ricos em quartzo; 2-Álcali feldspato granito; 3a-Sienogranito; 3b-Monzogranito; 4-Granodiorito; 5-Tonalito; 6-Álcali feldspato sienito; 6*-Nefelina-álcali feldspato sienito; 7-Sienito; 7*-Nefelina sienito; 8-Monzonito; 8*-Latito; 9-Monzogabro; 9*-Nefelina monzogabro; 10-Diorito, anortosito, gabro, norito; 10*-Nefelina diorito, nefelina gabro. Símbolos como na figura 2.

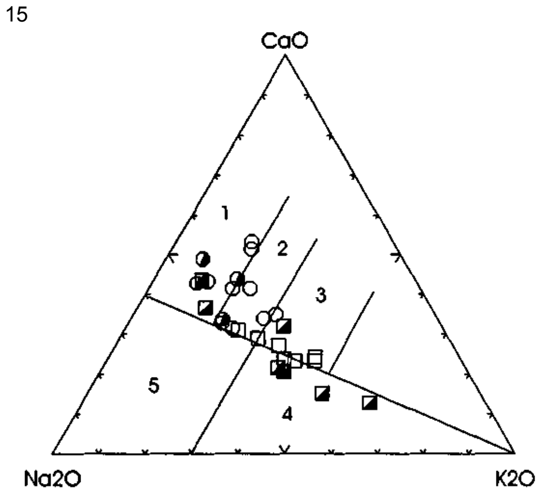

Figure 5 - Chemical classification of the intermediate and felsic granulites in Na_2O x CaO x K_2O (Glikson 1979). 1 - Tonalite; 2 - Granodiorite; 3 - Adamellite; 4 - Granite; 5 - Trondhjemite. Symbols as in figure 2.

Figura 5 - Classificação química dos granulitos intermediários e félsicos em diagrama Na_2O x CaO x K_2O (Glikson 1979). 1 - Tonalito; 2 - Granodiorito; 3 -Adamellito; 4 - Granito; 5 - Trondhjemito. Símbolos como na figura 2.

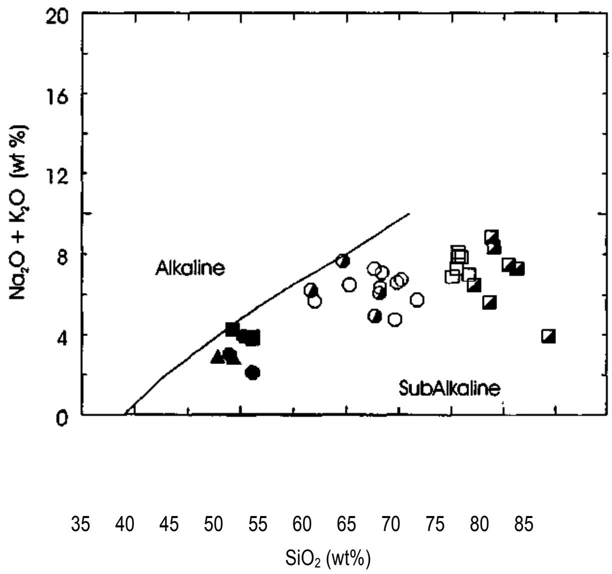

Figure 6 - SiO_2xNa_2O + K_2O diagram (Le Maitre 1989) with the dividing Une of the Alkaline and Subalkaline fields, proposed by Irvine & Baragar (1971). Symbols as in figure 2.

Figura 6 - Diagrama SiO_2 x Na_2O + K_2O (Le Maitre 1989), com a curva limite dos campos Alcalino e Subalcalino proposta por Irvine & Baragar (1971). Símbolos como na figura 2.

ized by higher FeO, LILE, HFSE (and also the REE, see belo w). The HMgT occurs as centimetric enclaves in the intrusive charnockites, whereas the MMgT and the LMgT occur either as small bodies and as metric bands within ali the calc-alkaline rocks.

INTERMEDIATE AND FELSIC GRANULITES In the Harker diagrams (Fig. 9), the compositional gap between the intermediate and the felsic granulites is also evident when other oxides than SiO_2 are considered. The behaviour of the more immobile elements (Mg, Ti, Ni, V and Zr) suggest that

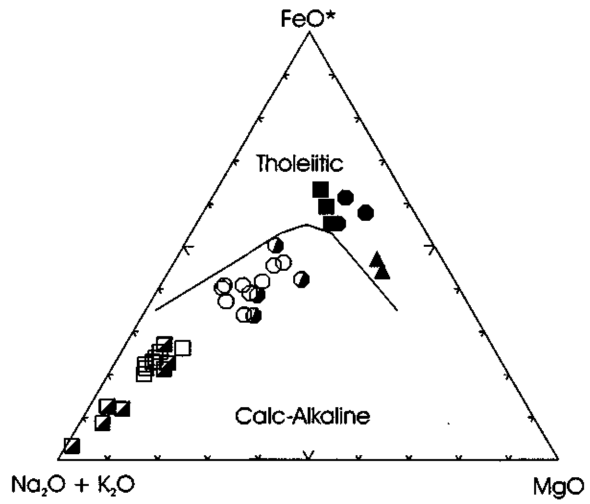

Figure 7 - AFM diagram (Irvine & Baragar 1971). Symbols as in fgure 2.

Figura 7 - Diagrama AFM (Irvine & Baragar 1971). Símbolos como na figura 2.

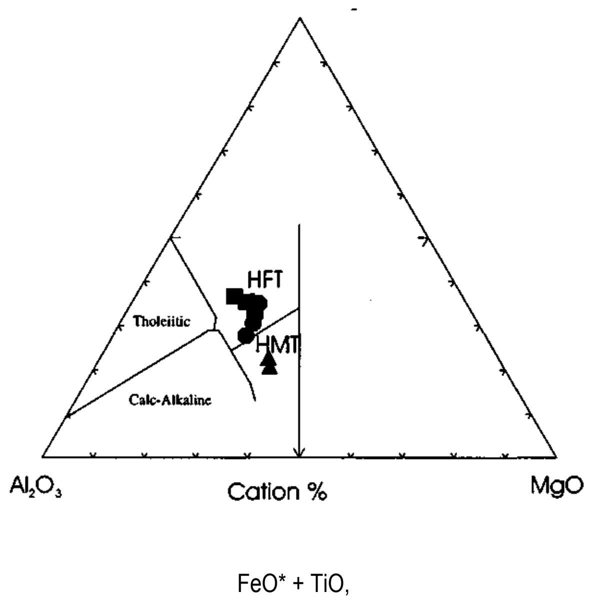

Figure 8 - Plot of the tholeiitic rocks in the cationic ternary diagram of Jensen (1976). HFT-high-Fe tholeiites; HMT - high-Mg tholeiites. Symbols: High-Mg tholeiites (closed triangles); Medium-Mg tholeiites (closed circles); Low-Mg tholeiites (closed squares).

Figura 8 - Classificação das rochas toleiíticas em diagrama ternário catiônico proposto por Jensen (1976). Símbolos: Toleiitos de alto Mg (triângulos cheios); Toleítos de médio Mg (círculos cheios); Toleítos de baixo Mg (quadrados cheios).

each group has a characteristic magmatic trend. As compared to these elements, Fe, Ca, and Al also behaved as immobile elements, as suggested by the small or lack of scatter of these elements for each group of granulite. Some of the diagrams (MgO, FeO*, Ni, V and Zr) suggest that the massive intermediate granulites are geochemically different from the gneissic and migmatitic intermediate ones. The former have higher contents of compatible elements (FeO, MgO and Ni), Na_2O, and V, and lower abundance of Zr. Considering the more incompatible elements (K, Rb, Ba, Sr), the massive granulites are more depleted than the other intermediate granulites. Scattering occurs in Ba, Rb, Hf and Y.

A comparison between the two groups of felsic granulites shows that the charnockitic leucosomes and gneissic granulites have a very restrict SiO_2 range, which is more variable in the intrusive charnockites. Additionally, the latter are richer in MgO, FeO*, Ni and V, poorer in Sr and Y, and their K_2O. Rb, and Ba variation is scattered.

REE Geochemistry The REE contents of the studied granulites are in Tables l to 5, and their patterns in figure 11.

MAFIC GRANULITES The chondrite-normalized REE patterns of the HMgT are roughly flat, 6 to 8 times chondrite. One of the patterns is slightly light-REE depleted (Fig. l Ia). In contrast, the REE patterns of the MMgT and the LMgT groups are, respectively, slightly and moderately fractionated, with absent to negative Eu anomalies. The LREE-enriched rocks have a $[La/Yb]_N$ ratio (Table 1) that increases with decreasing MgO. As this negative correlation is expected to take place during magmatic differentiation, the mafic granulites may have formed by differentiation from a single parental magma. However, considering that sample 17A is slightly depleted in light-REE and that both 17A and 17B are samples from the same outcrop, it is convenient to treat them as a separate group.

INTERMEDIATE GRANULITES Two distinct REE patterns (Fig. 11 b) occur in the intermediate granulites. One is characterized by a moderate fractionation ($[La/Yb]_N = 6$ to 12), with slight to strong negative Eu anomalies (samples 99D, 32A, 46T and 145B), while the other has a strong fractionated pattern ($[La/Yb]_N \approx 13$ to 60), and lacks Eu anomaly. The lack of correlation between the degree of REE fractionation and SiO_2 suggests that these rocks are not all genetically related.

FELSIC GRANULITES ***Charnockitic leucosomes and Gneissic Charnockites*** These granulites show two different REE patterns (Fig. 11 c). Two samples are moderatly fractionated ($[La/Yb]_N \approx 13$ to 30), with the most fractionated having a slight positive Eu anomaly, while the other lacks Eu anomaly. The remaining samples are more fractionated ($[La/Yb]_N \approx 40$ to 230), and the least fractionated sample hás a positive Eu anomaly, while the others lack Eu anomalies. Since this group of granulites hás a narrow SiO_2 variation, Na_2O was taken as an alternative differentiation index. The lack of correlation between the REE fractionation and Na_2O suggests either that at least some of these rocks are not genetically related, or that Na_2O is not an adequate differentiation index. REE patterns of samples 151B, 241 A, 514E and, to a lesser extent, 514A, resemble those of the highly fractionated intermediate granulites and, thus, could be genetically related.

Intrusive Charnockites Two distinct REE patterns are shown by these rocks (Fig. 11 d). Most samples are moderatly fractionated ($[La/Yb]_N$ 18 - >30), and have a positive Eu anomal that increses with the ammount of SiO_2. Sample 46U displays a negative Sm anomaly, which is probably due to the fractionation of garnet. One sample (151 A) is highly fractionated, and lacks Eu anomaly, resembling the highly

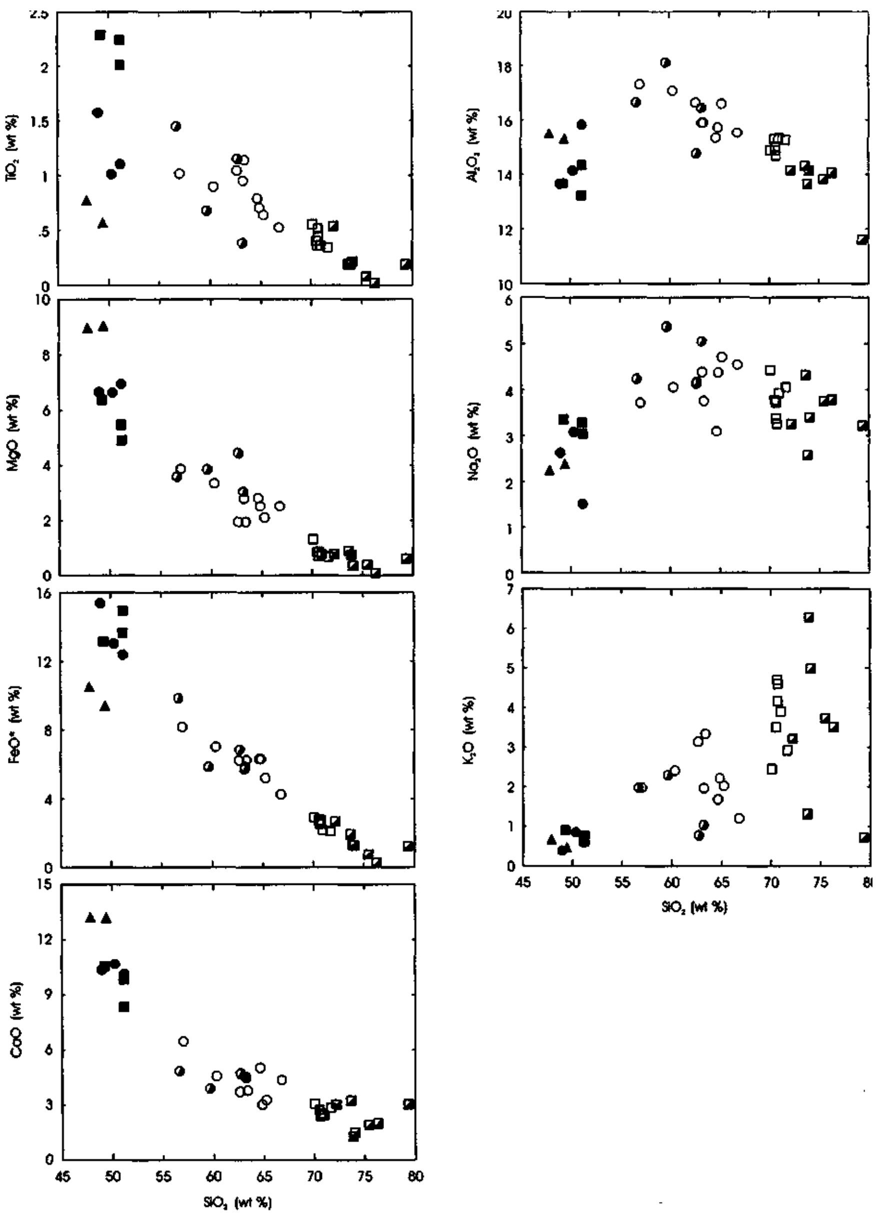

Figure 9 - Harker-type variation diagrams of the rocks from the JFC (major elements). Symbols as in figures 2 and 8.

Figura 9 - Diagramas de variação tipo Harker para as rochas do CJF (elementos maiores). Símbolos como nas figuras 2 e 8.

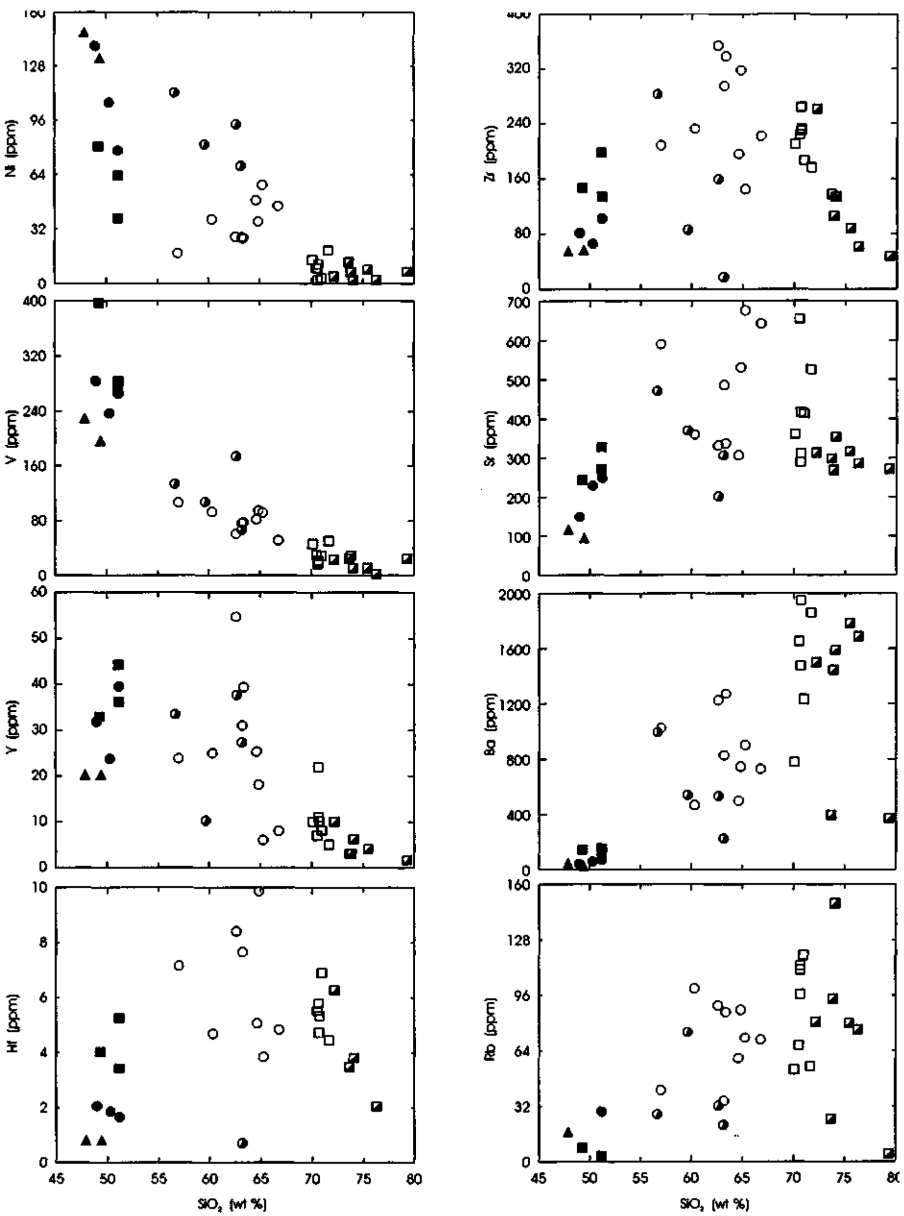

Figure 10 - Harker-type variation diagrams of the rocks from the JFC (trace elements). Symbols as in figures 2 and 8.

Figura 10 - Diagramas de variação tipo Harker para as rochas do CJF (elementos traços). Símbolos como nas figuras 2 e 8.

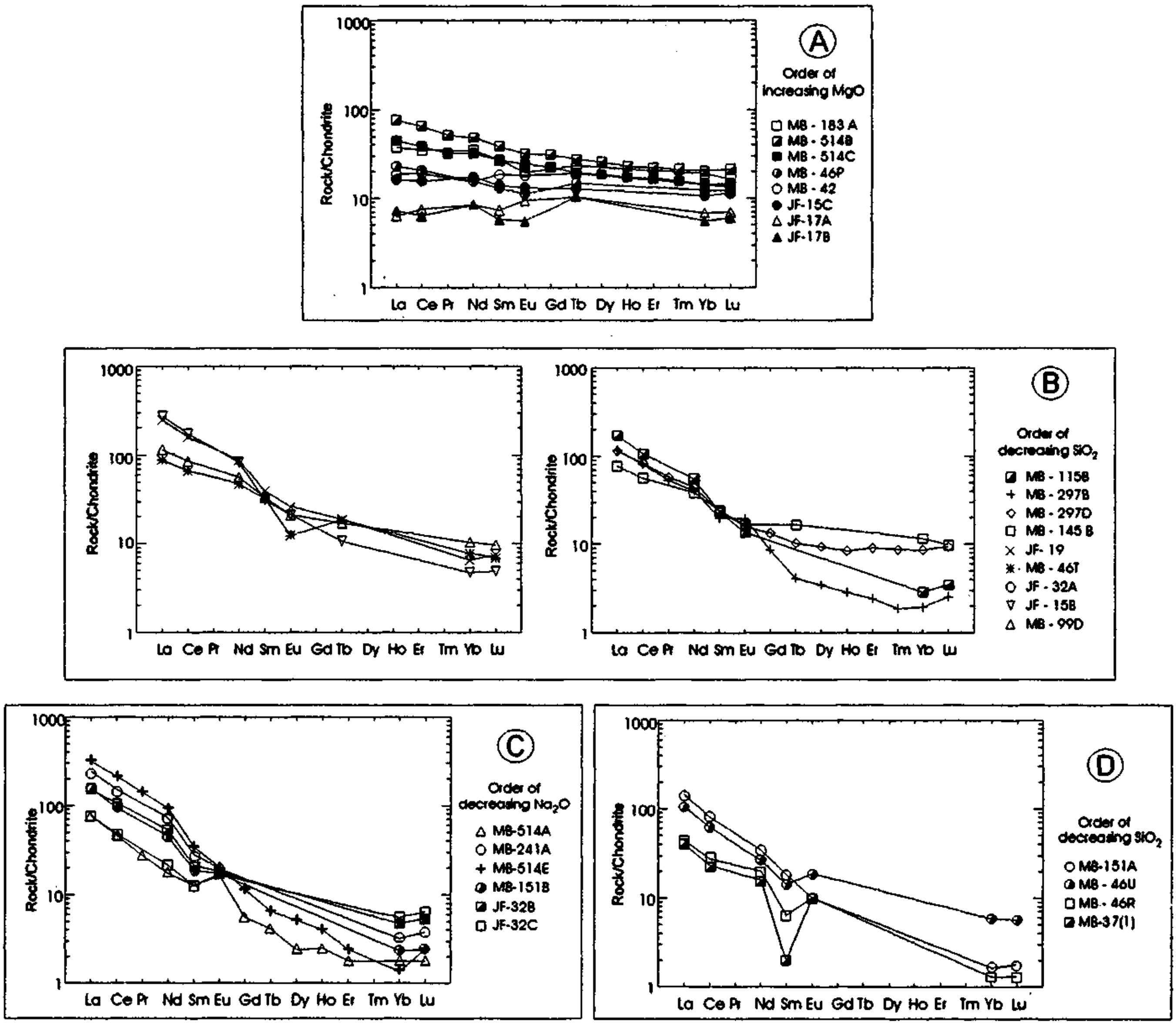

*Figure 11 - Chondrite-normalized REE diagrams of the studied JFC granulites. Normalization to values of Boynton (1984). **(a)** - Mafic granulites. Symbols: HMgT (triangles); MMgT (circles); LMgT (squares).**(b)** -Intermediate granulites. **(c)** - Charnokitic leucossomes and gneissic charnolites. **(d)** - Intrusive chanokites.*

Figura 11 - Diagramas de ETR normalizados ao condrito dos granulitos do CJF. Normalização aos valores de Boyton (1984). (**a**) - Granulitos máficos. Símbolos: toleiitos de alto Mg (triângulos); toleiitos de médio Mg (círculos); toleiitos de baixo Mg (quadrados), (**b**) - Granulitos Intermediários, (**c**) - Leucossomas charnokíticos e gnáissicos. (**d**) Charnockitos intrusivos.

fractionated charnockitic leucosomes and gneissic charnockites, to which it might be cogenetic.

Tectonic Setting *MAFIC GRANULITES* N-MORB normalized spidergrams (Fig. 12) indicate that the three groups of tholeiites are characterized by a selective enrichment in low ionic potential incompatible elements (Sr, K, Rb, Ba, Th).

Considering most of the elements of high ionic potential (Ce, P, Zr, Hf, Sm, Ti, Y, Yb), the MMgT group shows N-MORB abundance, while the HMgT are strongly depleted. The Ta contents of the MMgT are similar to intra-plate tholeiites. The patterns of the above mentioned elements in the HMgT resemble those of modern island are tholeiites, whereas the MMgT is similar to E-MORB. For comparison, typical island are and E-MORB patterns are included in the diagrams of HMgT and MMgT, respectively (Fig. 12).

In the N-MORB normalized variation diagram (Fig. 12), the LMgT has a hump-shaped pattern, characteristic of intraplate tholeiites. Plots of the Deccan flood basalts are shown to enable comparison.

The plots of the HMgT in tectonic discriminam diagrams (Fig. 13) are generally coincident with those of the low-K island are tholeiites.

In the diagrams of figures 13a, b and c, the MMgT plots in the field of ocean floor basalts. The trace element and REE

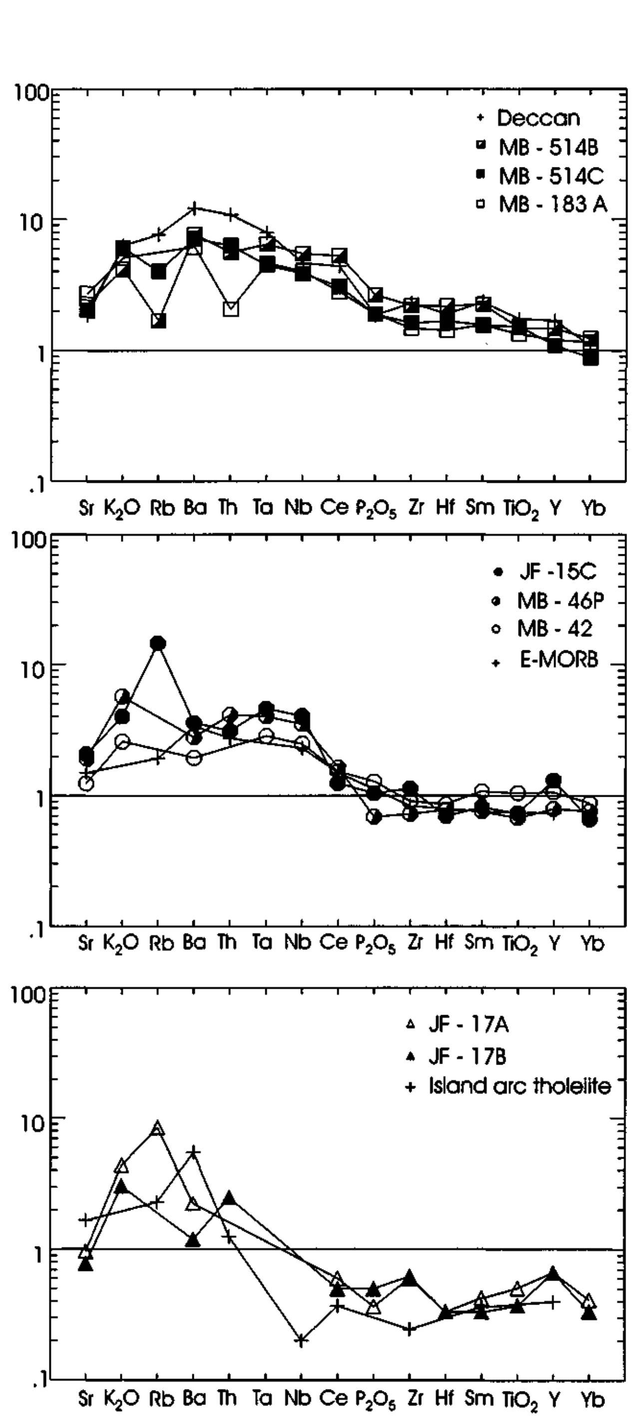

Figure 12 - MORB-normalized multi-element variation diagrams of the tholeiitic rocks (Pearce 1983). Symbols as in figure 11. Distribution patterns of the Deccan flood basalts (Thompson et al. 1983) and average modern E-MORB and islandarc tholeiites (Sun 1980) are shown for comparison.
Figura 12 - Diagramas multi-elementares das rochas tholeiíticas, normalizados pelo MORB de Pearce 1983. Símbolos como na figura 11. Padrões de distribuição dos basaltos de platô do Deccan (Tompson *et al.* 1983) e de composições médias de E-MORB e arcos de ilhas modernos (Sun 1980) são mostrados para comparação.

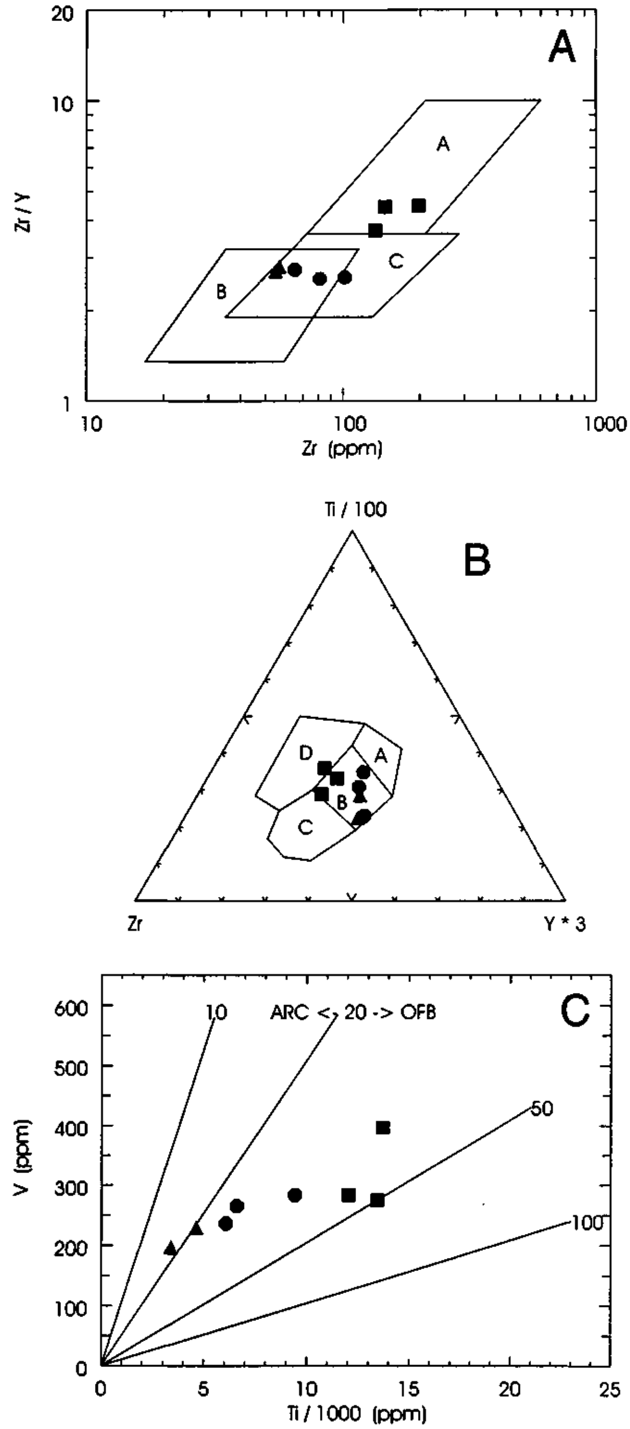

*Figura 13 - Tectonic discriminant diagrams for the tholeiitic rocks. Symbols as in figures 2 and 8.(**a**) after Pearce & Norry (1979). A - Within-plate basalts; B - Island are basalts; C - Mid ocean ridge basalts. (**b**) - after Pearce and Cann (1973). A, B - Low-K tholeiites; B - Ocean floor basalts; B, C - Calcalkaline basalts; D - Within-plate basalts. (**c**) - after Shervais (1982). ARC - Islandarc basalts; OFB - Ocean floor basalts.*
Figura 13 -.Diagramas discriminantes de ambientes tectônicos para as rochas toleiíticas. Símbolos como nas figuras 2 e 8. (**a**) - segundo Pearce & Norry (1979). A - Basaltos intra-placa; B - Basaltos de arcos de ilha; C -Basaltos de cadeias meso-oceânicas. (**b**) - segundo Pearce & Cann (1973). A, B - Toleiitos de baixo K; B - Basaltos de fundo oceânico; B, C - Basaltos calcioalcalinos; D -Basaltos intra-placa. (**c**) - segundo Shervais (1982). ARC -basaltos de arcos de ilha; OFB - Basaltos de fundo oceânico.

abundance of this group is similar to E-MORB rather than N-MORB. E-MORB signatures may be found in several extensional tectonic environments, such as mid-ocean ridge, back-arc and intra-plate continental settings.

The LMgT has within-plate characteristics and is similar to the Deccan flood basalts, leading to their interpretation as tholeiites of intra-continental plate regime.

Based on these and REE data, the MMgT and the LMgT are interpreted as derived from magmatic rocks of extensional tectonic settings, and probably represent distinct stages of magmatic differentiation. Moreover, considering that the MMgT and the LMgT occur as metric bands resembling dike and sill-like bodies, or as enclaves, within the calc-alkaline rocks of the study area, both groups are interpreted as within-plate tholeiitic basalts.

INTERMEDIATE AND FELSIC GRANULITES The intermediate granulites and the charnockitic leucosomes and gneissic charnockites plotted in Ocean Ridge Granite-normalized spidergram (Fig. 14) display, respectively, volcanic are and syn-collisional characteristics. The latter tectonic environment was expected for the charnockitic leucosomes, corroborating the interpretation, based on field data, that these rocks are anatectic products of continental rocks.

The intrusive charnockites have patterns that are similar, but somewhat depleted, to those of modern volcanic are and collisional granites. Thus, the JFC intermediate and felsic granulites are considered as magmatic products of convergent tectonic settings, representing different stages and/or different calc-alkaline island or cordilleran ares of pre-1.8 Ga. ages.

CONCLUSIONS The JFC orthogranulites have mafic, intermediate and felsic compositions. Their geochemistry suggests that the mafic granulites are tholeiitic, whereas the intermediate and felsic granulites are calc-alkaline. Based on Green *et al.* (1972), Drury (1978) and Weaver and Tarney (1980,1981), it is possible to conclude that, except for Eu, the REE patterns and abundance remained unchanged in most cases, regardless of metamorphism. Thus, the more immobile elements (Mg, Fe, Na, Ni, V, Zr and REE) suggest the absence of a petrogenetic link between the tholeiitic and the calc-alkaline granulites. Within each group, the following features are strong indicators of cogenetic origin:

a) the degree of REE fractionation increases with decreasing MgO in the mafic granulites, suggesting that they might represent distinct stages of differentiation of the same parental magma, more evident in the MMgT and the LMgT, but less in the HMgT;

b) each of the calc-alkaline groups (intermediate granulites and both groups of felsic granulites) have two distinct REE patterns and, in each group, the degree of fractionation does not correlate positively with SiO_2 or any other index, which, along with the similarity of REE patterns and abundance in ali groups, strongly suggest that some of the intermediate and felsic granulites may be genetically related, in its turn also true for the two groups of felsic granulites.

All JFC lithotypes, regardless of composition and structure, underwent only partial retrogressive metamorphism. Independent of the cause of dehydration (magmatic or metamorphic) of these rocks, the available data suggest that granulitization was due to metamorphism. However, it is still uncertain if anhydrous magmatism also took place, as metamorphic and magmatic processes may occur simultaneously

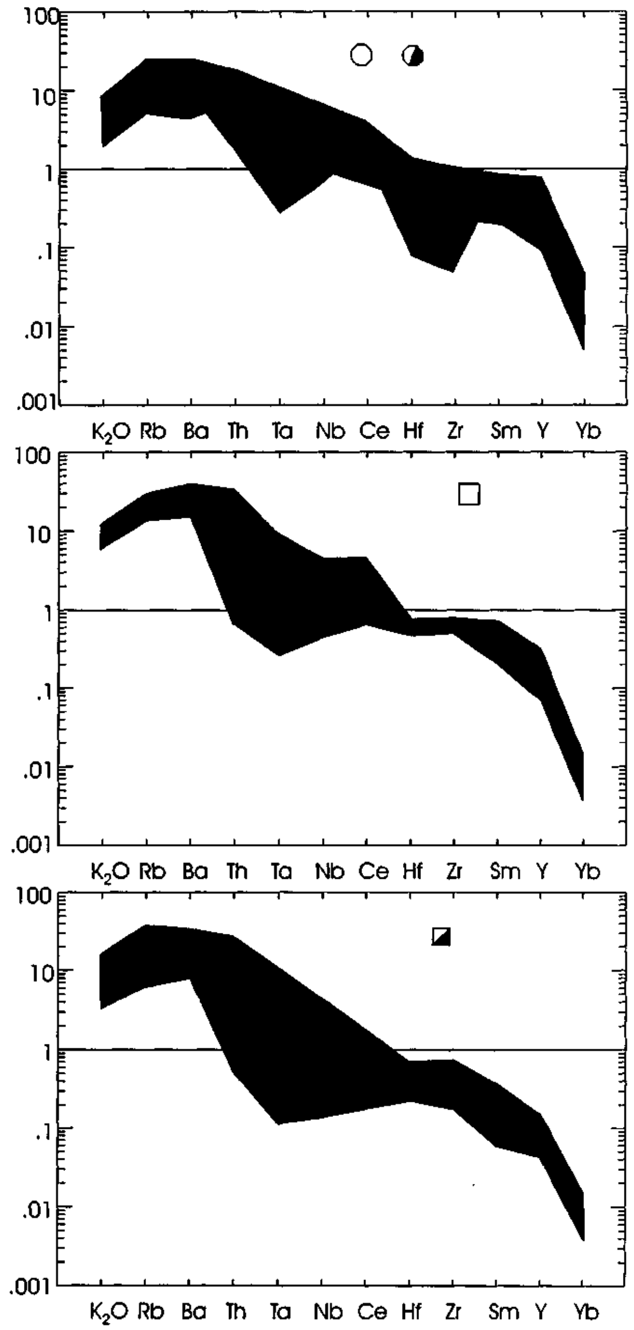

Figure 14 - ORG-normalized multi-element variation diagrams (Pearce et al 1984) for the intermediate and felsic granulites suites. Symbols as in figure 2.

Figura 14 - Diagramas de variação multi-elementar para os granulitos intermediários e ácidos, normalizados pelo ORG de Pearce *et al.* (1984). Símbolos como na figura 2.

during orogenies. Two main petrogenetic hypotheses are in dispute to explain the mechanism of granulitization, i.e., partial melting (Fyfe 1973) and CO_2 metamorphism (Newton *et al.* 1980). The former hypothesis is less probable to have taken place in the study area due to:

a) the occurrence of orthpyroxene in ali studied rocks, regardless of composition and structure;

b) if, as presumed in this study, the analyzed samples are quantitatively and qualitatively representative of the JFC, then the average granodioritic composition of this terrane is fairly similar to the upper average crust of Taylor (1969) and the partial melting hypothesis, that considers a compositional difference between upper (granodioritic) and lower (intermediate) continental crust, does not match to the JFC terrane, and

c) the large volume of felsic granulites of the JFC should not be considered as a residue of intra-crustal melts.

Therefore, the dehydration that caused granulitization of the JFC rocks is interpreted as most probably related to degassing of a CO_2-rich fluid, that expelled and substituted H_2O, as strongly indicated by the CO_2-rich fluid inclusions of the JFC granulites (Nogueira 1994).

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