INSIGHTS IN METAMORPHIC PROCESSES IN GRANULITES FROM GUAXUPÉ, MINAS GERAIS, BRAZIL, DEDUCED FROM REE PATTERNS

CHOUDHURI, A.[1], ENZWEILER, J.[1]; FIGUEIREDO, A.M.G.[2]

[1] Instituto de Geociências, UNICAMP, Campinas, SP
[2] Instituto de Pesquisas Energéticas e Nucleares, IPEN, São Paulo,SP

RESUMO

Os padrões de elementos terras raras (ETR) em pares de rochas máfica e félsica (ou intermediaria) do mesmo afloramento mostram diferenças claras dependendo do caráter do processo envolvido na sua formação. Assim, consegue-se distinguir rochas que exibem evidência de fusão parcial in situ das rochas que sofreram injeção de material durante o metamorfismo em fácies granulito. Um charnockito e um enderbito possuem padrões distintos dos demais, enquanto as rochas graníticas da mesma região se caracterizam pela evidente anomalia negativa de Eu, provavelmente devido à remoção de plagioclásio da sua fonte.

Palavras-Chave: granulitos, elementos terras raras, processos, fonte.

INTRODUCTION

The high-grade rocks of the Guaxupé Massif have been subjected to a number of tectonic-metamorphic-magmatic processes during and subsequent to granulite facies metamorphism.Besides the metamorphism itself, and the formation of the large nappe structure, these processes encompass partial melting, melt injection, and emplacement of charnockite suites (Oliveira, 1984; Choudhuri et al., 1992; Janasi, 1995).An investigation of the above processes can contribute to a better understanding of evolution of high-grade terrains.Here we present preliminary rare earth element (REE) data for felsic and mafic granulites in order to assess what happens to REE during these processes, and to what extent we can tell melt injections from partial melting.This question has been addressed before on the basis of major element analyses (Choudhuri & Enzweiler, 1993).

The rocks analysed for REE can be assigned to three groups: a) felsic and mafic granulite pairs from the same outcrop; b) one charnockitic and one enderbitic gneiss e, c) one pair of pink, potassic granites

Group a) has one pair which clearly represents original mafic rock and its tonalitic melt product.This is evident on outcrop scale as well as in thin sections (Choudhuri et al., op. cit.).Other pairs may either be products of partial melts, or melt injections (tonalitic or enderbitic) into mafic granulite bands. Except the granites, all others contain olive green amphibole (most probably hornblende, considering the basaltic composition, paragenesis, and metamorphic grade of these rocks), pyroxenes - pale green clinopyroxene and buff to pink pleochroic orthopyroxene, or clinopyroxene alone, plagioclase, quartz, and biotite as a late mineral formed at the expense of amphibole and pyroxene.These minerals occur in variable proportions, depending on the rock type. On the whole the granulites are granoblastic and gneissic, with or without deformation of pyroxenes, while the tonalite veins and patches in the mafic rock clearly show igneous textures. Felsic members of the other pairs show signs of ductile deformation and recrystallization.The granitic rocks are coarse grained and hypidiomorphic granular, that is, they have igneous textures.

ANALYTICAL METHOD

The rare earth elements were analyzed by instrumental neutron activation analysis at IPEN/CNEN. The samples and reference samples used as standards (GS-N and BE-N) were weighed into small polyethylene bags previously cleaned with a solution of diluted nitric acid. The bags were sealed and inserted in the irradiation recipients and irradiated for 8 hours in a thermal neutron flux of 10^{12} n cm^{-2} s^{-1}. After five days, samples and standards were measured on a Canberra gamma spectrometer with a hyperpure Ge detector, a multichannel analyzer and a microcomputer. A new series of measurements was effectuated 15 days after the irradiation. The energies of peacks of interest and their areas on the gamma spectra were analyzed using an in-house developed software. Precision and accuracy are better than 4-10 % (RSD) depending on the concentration of the element in the sample.

REE PATTERNS

The REE patterns for the three groups of rocks are shown in figura, and the relation of the rock pairs in each group allow a better interpretation of the processes they have undergone than what was previously thought, or at least modify our original conclusions based on major element data (Choudhuri and Enzweiler, 1993). In general, the REE bring out the similarities and differences between the rocks, depending on these processes.The felsic and mafic pairs, No. 222 and 223 (Fig. B), for example, hardly show any difference in their patterns, except for higher Nd in the mafic rock, and a slightly more pronounced positive Eu anomaly in the felsic rock - the latter no doubt due to a little more modal plagioclase. Then again, the pair No. 224 and 225 (Fig. D) do not differ in their LREE, but the felsic member shows a distinct depletion in the HREE, probably due to a decrease in the amount of mafic minerals. In our opinion, these rocks cannot be interpreted as in situ partial melts, but are very likely injection of melts that were introduced into mafic material which these melts picked up to a greater or lesser extent.During this introduction of melts, strong ductile deformation gave rise to the banded nature of these rocks in the field.In contrast, the pair No. 227 and 274 (Fig. C) appear to confirm our field and petrographic observations that they represent a mafic rock and its in situ felsic (intermediate) melt segregation. Their REE patterns have opposing trends - that is, the felsic, quartz-plagioclase-rich segregation is clearly enriched in LREE and depleted in HREE, while the mafic rock shows the opposite relations.It is interesting to note that neither of them show an Eu anomaly, which means that there was no plagioclase fractionation.That is to say, plagioclase was not removed when melt was formed.

As far as the charnockite, enderbite, and granitic rocks are concerned, their REE patterns are very different. The granitic rocks show strong negative Eu anomalies, the charnockite none, and the enderbite has a positive Eu anomaly (Fig A). From the style of their patterns it could well be that, in a process of melt generation, subtracting the enderbite from the charnockite gives the pattern for the granites, but it is too premature to make such sweeping statements without further investigation , and we prefer not to overinterpret our results.It should be pointed out, however, that enderbite No. 224 (Fig. D) is quite different from enderbite No. 226, the latter being strongly depleted in HREE. One could easily speculate that they are products of different source materials.Here again further study is needed to make sure what these source materials might be.Fig. E shows patterns for othe mafic rocks that are fairly similar.

For the moment, we can summarize our observations and REE data as follows: a) Seemingly, mafic and felsic (or intermediate) granulite pairs from the same outcrop can be classified according to field observations, petrography, and REE patterns, to show that the felsic portions are products of in situ partial melting, melt injections; b) enderbites and charnockites have patterns which distinguish them from others; c) granitic rocks are altogether different, and show evidence of plagioclase removal at their source.

Table 1. Rare earth element concentration values (ppm) obtained by instrumental neutron activation analysis.

	221	222	223	224	225	226	227	228	229	230	274	275	276
La	61	33.7	36.2	52.1	50.3	35.1	29.4	156.7	83.0	40.0	43.4	59.2	23.7
Ce	137	78	75	99	98	54	67	280	143	89	88	116	50
Nd	71	53	34.3	39	42	20	28	86	45	40	38.1	52.5	25.0
Sm	14.5	8.4	7.5	6.5	7.7	2.0	6.9	16	8.1	8.2	7.6	9.6	5.0
Eu	4.2	3.2	3.6	1.88	1.98	0.97	2.22	2.10	1.64	3.26	2.2	2.8	1.62
Tb	1.96	1.08	1.03	0.76	1.07	0.23	1.2	2.1	0.95	1.11	0.95	1.00	0.58
Yb	5.4	2.1	2.5	1.57	2.6	0.78	4.6	5.3	1.9	4.4	2.3	1.7	1.74
Lu	0.65	0.27	0.26	0.18	0.31	0.11	0.55	0.60	0.25	0.50	0.34	0.26	0.21

Key to Rock Numbers: 221= charnockite, 222 and 223 = mafic and felsic pair, 224 and 225 = mafic and felsic pair, 226 = enderbite, 227 and 274 = mafic rock and felsic (intermediate) equivalent, 228 and 229 = pink, potassic granites, 230, 275 and 276 = mafic rocks.

Sample symbols:

○ 221	▼ 224	▲ 227	+ 228
◆ 222	▽ 225	△ 274	× 229
◇ 223	□ 226	⬓ 230	● 275
			◐ 276

ACKNOWLEDGEMENTS

This is a part of A.C's study of granulites of the Guaxupé Massif for which financial support from CNPq is gratefully acknowledged.

REFERENCES

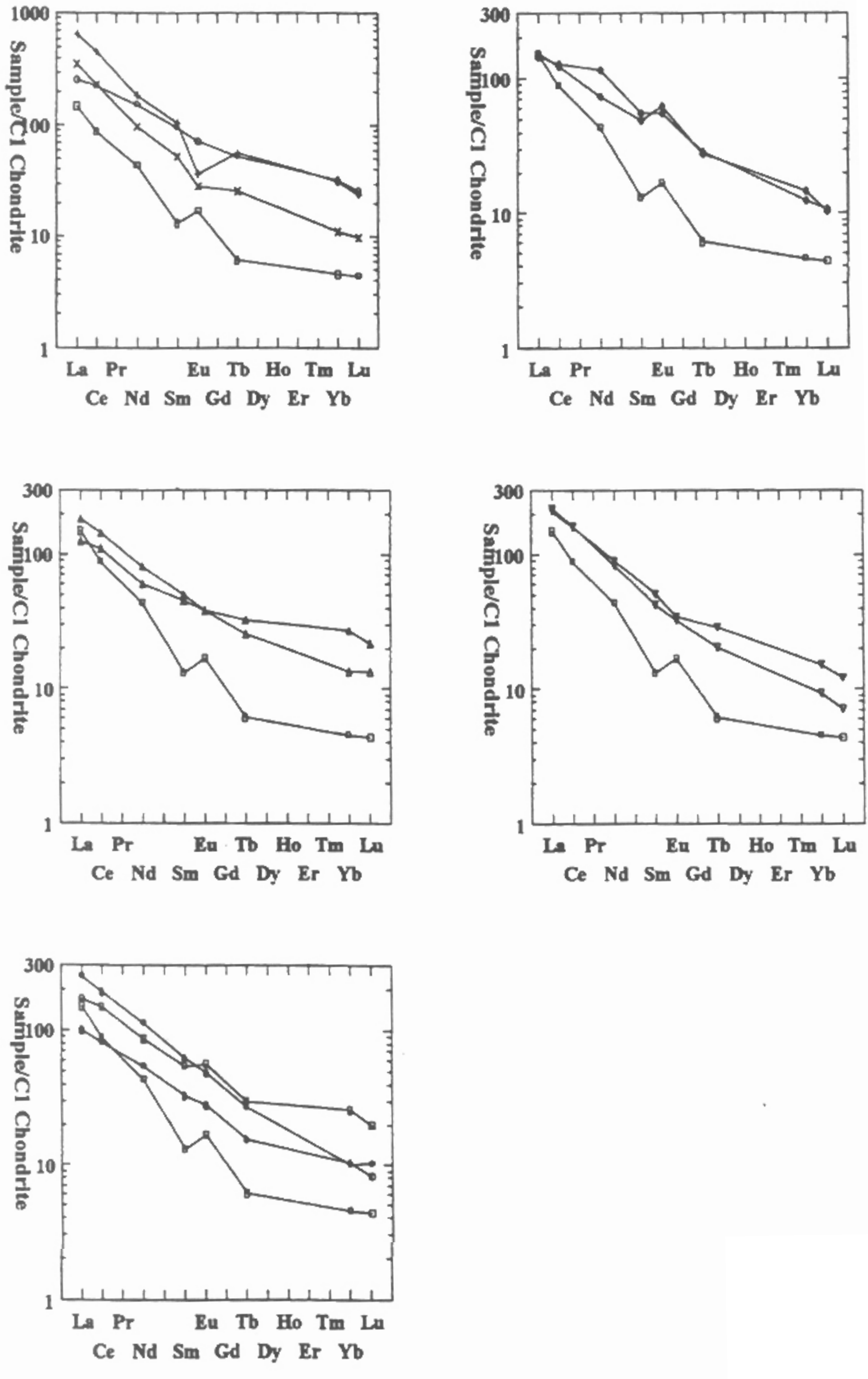
CHOUDHURI, A. & ENZWEILER, J. (1992) Enderbitic gneisses and charnockite massifs in the Varginha-Guaxupé Complex: A question of melt generation during granulite facies metamorphism. II Simp.Cráton do São Francisco, Slavador, BA, Anais: 26-29.

CHOUDHURI, A .; MEDEIROS, R.M.; CARVALHO, E.D.R.; SZABÓ, G.A.J. (1992) High-grade mafic migmatite from SW Minas Gerais: Na example of amphibolite melting. 37° Congr. Bras. Geol., São Paulo, SP, **1**: 423-424.

JANASI, V.A (1995) Neoproterozoic mangerite-"rapakivi"granite magmatism in southeastern Brazil: The São Pedro de Caldas Massif. Symp. Rapakivi Grani9tes and Related Rocks, Belém, Brazil. Abstracts, 44-45.

OLIVEIRA, M.A F. (1984) Considerações sobre a evolução do Complexo Varginha. 33° Congr. Bras. Geol., Rio de Janeiro. Anais **5**:2302-2304.

FIG. 1 REE IN FELSIC AND MAFIC GRANULITES FROM GUAXUPÉ, MG



Sequence of figures: A, B, C, D, E

NB. see Table for sample symbols. No. 226 is repeated for comparison.