



GEOCHEMISTRY OF THE GLÓRIA QUARTZ-MONZODIORITE: IMPLICATIONS FOR PALEOPROTEROZOIC EVOLUTION OF THE SOUTHERN SECTOR OF THE MINEIRO BELT, MINAS GERAIS STATE, BRAZIL ¹

(With 14 figures)

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ABSTRACT: The Glória quartz-monzodiorite originated at 2188 ± 29 Ma ago in the central segment of the Paleoproterozoic Mineiro belt is intrusive into the Rio das Mortes greenstone belt. Most of the major, minor and trace elements have not been extensively modified during the regional metamorphism. The Glória quartz-monzodiorite shows a calc-alkaline, metaluminous, arc-related geochemical signature, and displays major and minor trace element differences among the recognized fine, fine/medium and medium-grained facies. The medium-grained facies rocks show SiO_2 variation (from 58.2% to 64.3%) that allows subdivision into two sub-facies (medium I and II). The REE contents of the fine/medium and medium-grained sub-facies I show prominent LREE enrichment ($[\text{La}/\text{Yb}]_N$ between 29.7 and 38.0) and weak negative Eu anomalies. Geochemical modeling and trace element ratios support that the chemical differences resulted from progressive fractional crystallization of amphibole in fine, fine/medium and medium I sub-facies and plagioclase in medium II sub-facies. Overall field observations, geochemistry and age determinations of coeval Paleoproterozoic plutons in the region between Lavras and São João del Rei cities indicate that the Glória quartz-monzodiorite represents the old body of the pre-collisional phase of the Mineiro belt.

Key words: Glória quartz-monzodiorite. Geochemistry. Geochemical modeling. Paleoproterozoic. Mineiro belt.

RESUMO: Geoquímica do Quartzo Monzodiorito Glória: implicações para a evolução paleoproterozóica do setor sudeste do Cinturão Mineiro, Estado de Minas Gerais, Brasil.

O Quartzo Monzodiorito Glória é um corpo máfico associado à evolução paleoproterozóica do Cinturão Mineiro, porção sudeste do Cráton São Francisco, Estado de Minas Gerais, Brasil. Este é intrusivo nas rochas do *greenstone belt* Rio das Mortes e tem idade de cristalização de 2188 ± 29 Ma. Suas rochas podem ser subdivididas em fácies fina, fina/média e média, as quais apresentam assinatura geoquímica cálcio-alcálica, metaluminosa e de arco magmático. A variação do conteúdo de SiO_2 (de 58,2% a 64,3%) das rochas da fácies média permitiu a subdivisão da mesma em duas sub-fácies: média I e média II. O padrão de distribuição dos ETR da fácies fina/média e da sub-fácies média I apresenta pronunciado enriquecimento dos ETRL ($[\text{La}/\text{Yb}]_N$ entre 29,7 e 38,0) e sutil anomalia negativa de Eu. A caracterização geoquímica e as razões entre os elementos traços apontam que as diferenças observadas entre as fácies e sub-fácies devem-se ao fracionamento de anfibólio nas fácies fina, fina/média e sub-fácies média I e de plagioclásio na sub-fácies média II. Os dados geoquímicos, as observações de campo e os dados radiométricos de corpos plutônicos da região entre Lavras e São João del Rei apontam que o Quartzo Monzodiorito Glória é, até o presente momento, o representante mais antigo de composição diorítica gerado durante o estágio pré-colisional do Cinturão Mineiro.

Palavras-chave: Quartzo Monzodiorito Glória. Geoquímica. Modelagem geoquímica. Paleoproterozóico. Cinturão Mineiro.

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INTRODUCTION

The origin of dioritic magmas remains one of the outstanding problems in petrology. Several models have been proposed for the origin of andesites (RINGWOOD, 1974; CAWTHORN, STRONG & BROWN, 1976), but it is uncertain whether such models can be applied to dioritic complexes, which in many cases are considered to be derived from calc-alkaline magmas (GULSON *et al.*, 1972; WEAVER & TARNEY, 1982). Meanwhile, different types of magma are formed in island arcs, including calc-alkaline ones - with complex spatial relationships. Moreover the melts derived from mantle and crust seems to have been generated at the same time, making understanding the magma genesis of the associated volcanic and plutonic rocks a difficult task.

The southern portion of the São Francisco Craton, between Lavras and Conselheiro Lafaiete cities (Minas Gerais State), displays a polycyclic geological evolution, which is in part associated to the framework of the Paleoproterozoic Mineiro belt. The products of this belt includes felsic and mafic plutons related with distinct phases of the tectonic evolution (ÁVILA, 2000; TEIXEIRA *et al.*, 2000; NOCE *et al.*, 2000), thereby making up the area potentially important for investigating petrogenesis and tectonics.

The geology of the studied area has been recently revised by ÁVILA (2000), TOLEDO (2002), RIBEIRO *et al.* (2003), QUÉMÉNEUR *et al.* (2003), MELLO (2003), and CHERMAN (2004). In addition, petrographic, geochemical, and geochronological studies were carried out on several pyroxenitic - gabbroic - dioritic bodies, named: Brumado diorite (ÁVILA, 1992, 2000), São Sebastião da Vitória gabbro (SILVA, 1996), Rio Grande diorite (COUTO, 2000), Brito quartz-diorite (ÁVILA, 2000; ÁVILA *et al.*, 2005b), Rosário, Martins and Ibituruna diorites (QUÉMÉNEUR, NOCE & GARCIA, 1994; QUÉMÉNEUR & NOCE, 2000), Forro peridotite-pyroxenite, Manuel Inácio pyroxenite-gabbro, Rio dos Peixes and Rio Grande gabbros (TOLEDO, 2002), Vitoriano Veloso gabbro and Dores do Campo quartz-diorite (RIBEIRO *et al.*, 2003), and Glória quartz-monzodiorite (ÁVILA, TEIXEIRA & PEREIRA, 2004; ÁVILA *et al.*, 2005a). All of these plutons are intrusive into the metavolcanic and metasedimentary rocks of Rio das Mortes and/ or Nazareno greenstone belts - see figure 1.

This paper presents geochemical data of the Glória

quartz-monzodiorite that indicate its genetic relationship with the pre-collisional phase of the Mineiro belt, supported by the SHRIMP U-Pb age (2188 ± 29 Ma) (ÁVILA *et al.* 2005a).

REGIONAL GEOLOGY

The geology of the southern border of the São Francisco Craton comprises Archean and Paleoproterozoic rock units, the latter being genetically associated with the evolution of the Mineiro belt. As a summary, the country rocks consist predominantly of Archean TTG orthogneisses partially migmatized (Campo Belo, Bonfim, Passa Tempo complexes) and greenstone belt units (Rio das Velhas, Rio das Mortes and Nazareno) (Fig.1), partly covered by the Minas Supergroup and São João Del Rei, Carandaí and Andrelândia megasequences. On the other hand, the oldest terrane was intruded by mafic and felsic bodies, a part of which during the Paleoproterozoic (ÁVILA, 2000; TEIXEIRA *et al.*, 2000; NOCE *et al.*, 2000). In this regard, the mafic bodies of diorite composition represent a voluminous calc-alkaline plutonism, formed during the pre-collisional stage of the Mineiro belt.

The U-Pb and $^{207}\text{Pb}/^{206}\text{Pb}$ data in zircon available at regional scale in the central segment of the Mineiro belt indicate that the main period of magmatic activity took place between 2255 ± 6 Ma and 2101 ± 8 Ma ago (Fig.2). Therefore, the published Rb/Sr ages (2060-1860 Ma) in the Paleoproterozoic plutons are here interpreted as late isotopic resetting (Tab.1). Recent geological mapping carried out in the central part of the Mineiro belt, between Lavras and Conselheiro Lafaiete cities has shown that volcanic mafic and ultramafic rocks, associated with the Barbacena (PIRES, RIBEIRO & BARBOSA, 1990) and to the Itumirim-Nazareno greenstone belts (TEIXEIRA, 1992) comprise two distinct tectono-stratigraphic units (ÁVILA, 2000). These units are the Rio das Mortes and Nazareno greenstone belts, respectively (ÁVILA, TEIXEIRA & PEREIRA, 2004) - herein adopted afterward.

The Rio das Mortes greenstone belt is composed predominantly of amphibolites and amphibole-bearing schists, interbedded with thick packages of gondites, queluzites, metapelites and, subordinately, metaultramafic rocks and quartzites. Contrastingly, the Nazareno sequence exhibits abundant metaultramafic rocks (komatiites, serpentinites, talc-chlorite schists) but displays scarce interlayered lenses of metapelites and quartzites, as well as local mafic

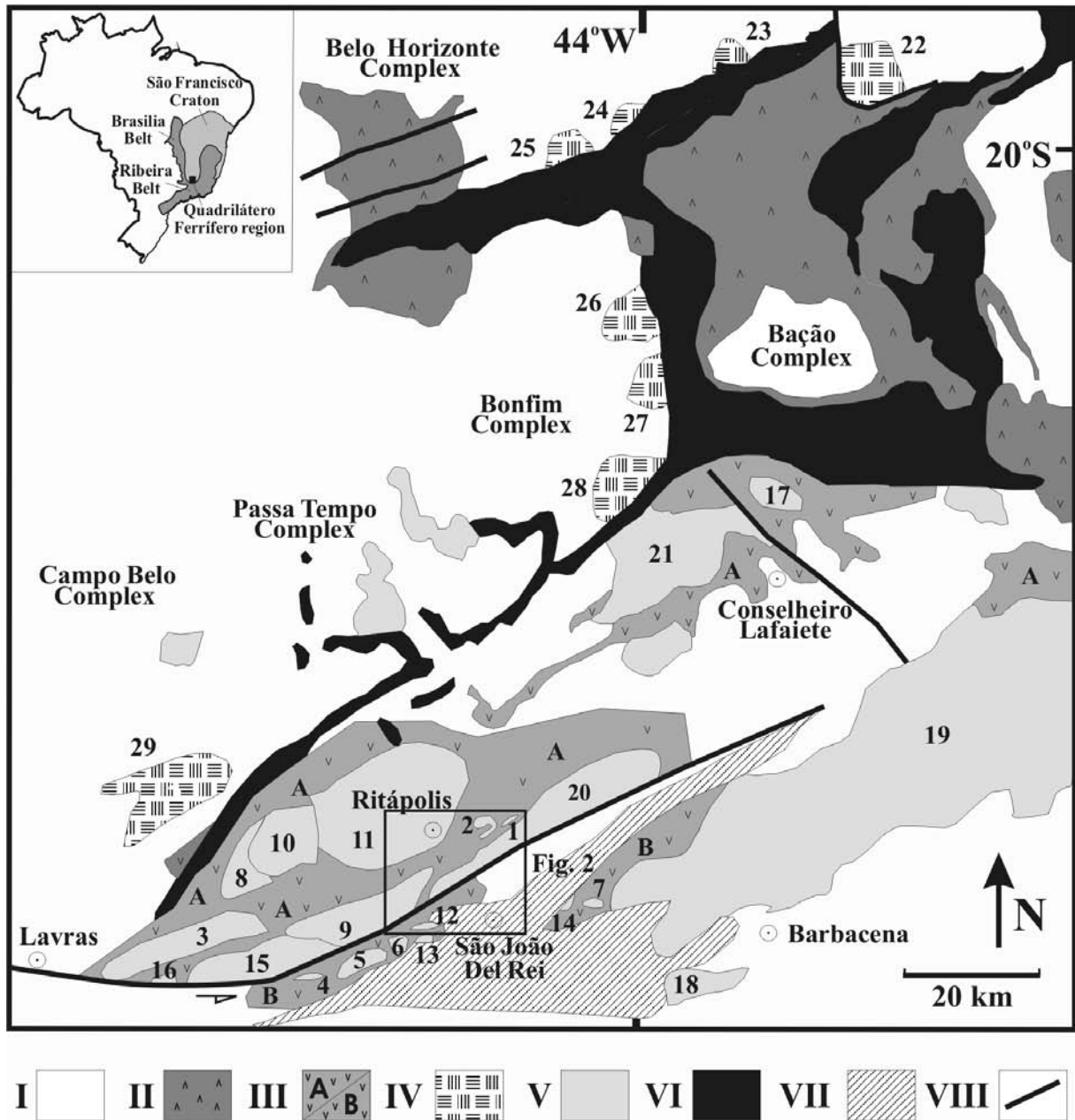


Fig.1- Archean and Paleoproterozoic plutons in the southern São Francisco Craton (adapted from ÁVILA *et al.*, 2003). I – Archean crust partly reworked during Paleoproterozoic times. II – Archean Rio das Velhas greenstone belt. III - Rio das Mortes (A) and Nazareno (B) greenstone belts. IV – Archean granitoids. V – Paleoproterozoic felsic and mafic plutons. VI – Minas Supergroup (Paleoproterozoic). VII – São João del Rei (Paleoproterozoic), Carandaí (Mesoproterozoic) and Andrelândia (Neoproterozoic) supracrustal sequences. VIII – Major structures. Keys: *Paleoproterozoic plutons*: 1 – Glória quartz-monzodiorite; 2 – Brumado diorite; 3 - Rio Grande diorite; 4 - Rio Grande gabbro; 5 - São Sebastião da Vitória gabbro; 6 – Brito quartz-diorite; 7 - Vitoriano Veloso gabbro; 8 – Ibituruna diorite; 9 – Cassiterita tonalite/trondhjemite; 10 – Tabuões trondhjemite; 11 – Ritópolis granitoid; 12 - Brumado de Baixo granodiorite; 13 - Brumado de Cima granodiorite and granophyric bodies; 14 – Tiradentes granitoid; 15 – Nazareno granite; 16 – Itumirim granitoid; 17 – Congonhas tonalite; 18 – Campolide granite; 19 – Ressaquinha complex; 20 – Fê granitic-gneiss; 21 - Alto Maranhão tonalite. *Archean plutons*: 22 – Caeté granodiorite; 23 - General Carneiro granite; 24 - Morro da Pedra granite; 25 - Ibirité granodiorite; 26 - Samambaia tonalite; 27 – Mamona granodiorite; 28 - Salto do Paraopeba granite; 29 – Bom Sucesso granite.

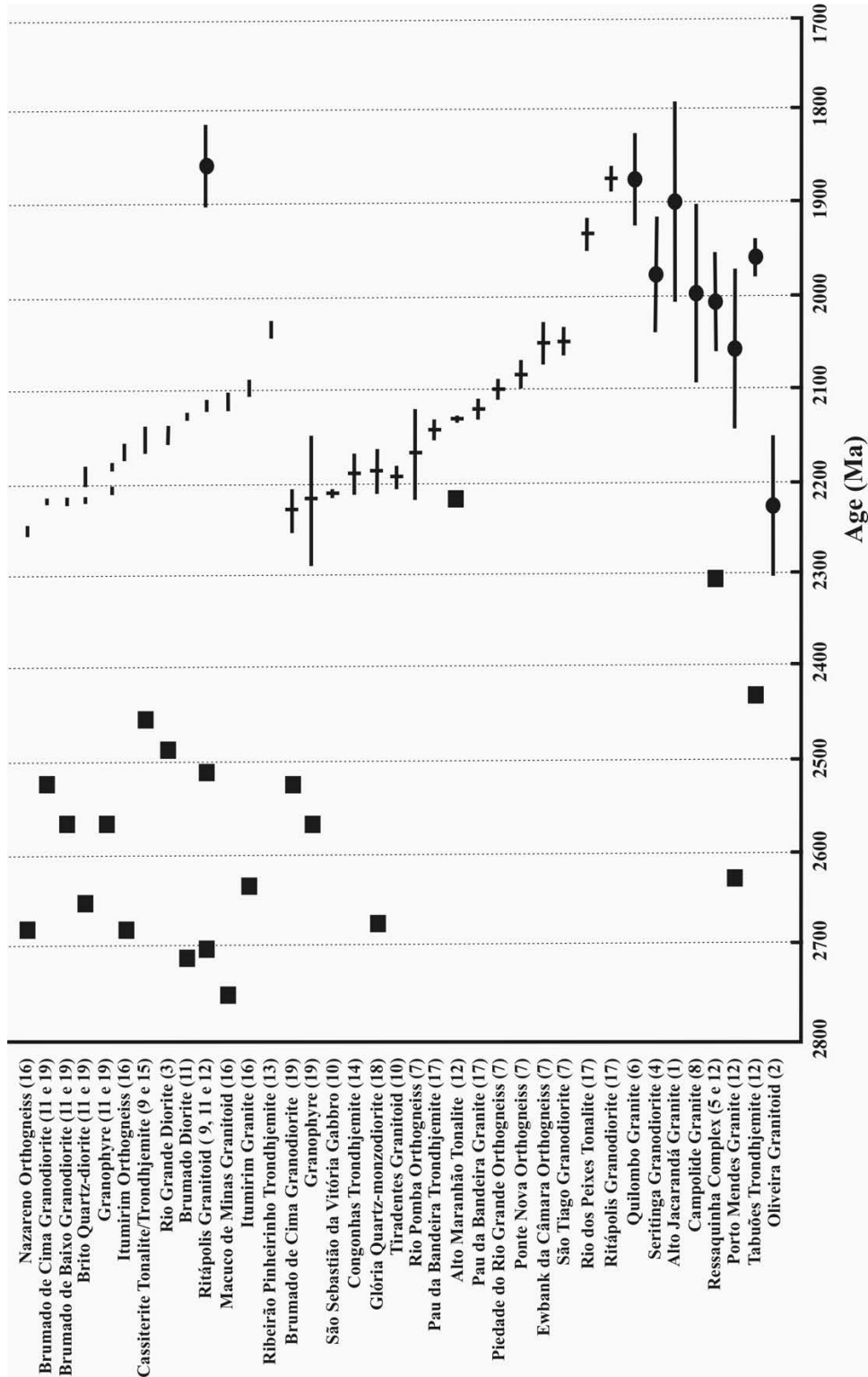


Fig.2- Crystallization age intervals of Paleoproterozoic mafic and felsic plutonic bodies in the southern border of the São Francisco Craton. Modified from ÁVILA *et al.* (2003). 1 - TEIXEIRA (1982); 2 - TEIXEIRA *et al.* (1987); 3 - CHERMAN (2002); 4 - HEILBRON *et al.* (1989); 5 - PADILHA, VASCONCELOS & GOMES (1991); 6 - CHOUDHURI *et al.* (1992); 7 - SILVA *et al.* (2000); 8 - TEIXEIRA *et al.* (2000); 9 - ÁVILA *et al.* (1998); 10 - VALENÇA *et al.* (2000); 11 - ÁVILA (2000); 12 - NOCE *et al.* (2000); 13 - EVANGELISTA, PERES & MACAMBIRA (2000); 14 - ROSA-SEIXAS *et al.* (2002); 15 - ÁVILA *et al.* (2003); 16 - CHERMAN (2004); 17 - CAMPOS (2004); 18 - ÁVILA *et al.* (2005a); 19 - ÁVILA *et al.* (2005b). Square - T_{DM} age; Circle - Rb/Sr age (whole-rock isochron); full line - $^{207}Pb/^{206}Pb$ age (Pb evaporation on zircon); fill-crossed line - U-Pb zircon age (SHRIMP and isotopic dilution). Ages in millions years (Ma), except for the T_{DM} ages, given in billion years (Ga). See table .

TABLE 1. Summary of the geochronological data of the plutonic bodies of the Mineiro belt.

PLUTON	LITHOLOGY	AGE (Ma)	METHOD	T _{DM} (Ma)	REF.
Nazareno orthogneiss *	Tonalite-trondhjemite	2255 ± 6	C	2.68	13
Brumado de Cima *	Granodiorite	2239 ± 25	A	2.52	16
Oliveira	Granitoid	2228 ± 76	D		2
Granophyre *	Granodiorite	2221 ± 70	B	2.56	8 e 16
Brito *	Quartz-diorite	2221 ± 2	C	2.64	8 e 16
São Sebastião da Vitória *	Gabbro	2220 ± 3	B		7
Brumado de Cima *	Granodiorite	2219 ± 2	C	2.52	8 e 16
Brumado de Baixo *	Granodiorite	2218 ± 3	C	2.56	8 e 16
Granophyre *	Granodiorite	2207 ± 4	C	2.56	8 e 16
Congonhas *	Trondhjemite	2195 ± 18	A		11
Brito *	Quartz-diorite	2196 ± 6	C	2.64	8 e 16
Tiradentes *	Granitoid	2194 ± 8	B		7
Granophyre *	Granodiorite	2192 ± 4	C	2.56	8 e 16
Glória *	Quartz-monzodiorite	2188 ± 29	A	2.68	15
Rio Pomba orthogneiss	Tonalite	2169 ± 44	A		6
Itumirim orthogneiss *	Tonalite-trondhjemite	2177 ± 4	C	2.68	13
Cassiterita *	Tonalite-trondhjemite	2162 ± 10	C	2.47	12
Rio Grande *	Diorite	2155 ± 3	C	2.49	3
Brumado *	Diorite	2131 ± 4	C	2.72	8
Pau da Bandeira	Trondhjemite	2127 ± 7	B		14
Alto Maranhão *	Tonalite	2124 ± 2	B	2.27	9
Ritápolis *	Granite	2122 ± 6	C	2.51	8
Ritápolis *	Granite	2121 ± 7	C	2.51	8
Pau da Bandeira	Granite	2118 ± 7	A		14
Macuco de Minas	Granitoid	2116 ± 9	C	2.75	13
Piedade do Rio Grande	Tonalite	2102 ± 8	A		6
Itumirim *	Granite	2101 ± 8	C	2.63	13
Ponte Nova orthogneiss	Tonalite	2079 ± 11	A		6
Porto Mendes	Granite	2061 ± 82	D	2.62	9
Ewbank da Câmara	Tonalite	2052 ± 26	A		6
São Tiago	Granodiorite	2050 ± 12	A		6
Ribeirão Pinheirinho	Trondhjemite	2036 ± 4	C		10
Ressaquinha *	Granite-tonalite	2010 ± 52	D	2.30	9
Campolide *	Granite	1998 ± 17	D		9
Seritinga	Granodiorite	1980 ± 62	D		4
Tabuões *	Trondhjemite	1962 ± 20	D	2.43	9
Rio dos Peixes	Tonalite	1937 ± 22	B		14
Alto Jacarandá	Granite	1900 ± 108	D	2.90	1
Ritápolis *	Granodiorite	1887 ± 19	B	2.71	14
Quilombo	Granitoid	1878 ± 50	D		5
Ritápolis *	Granite	1863 ± 44	D	2.71	9
Itutinga	Granite			2.77	9
Fé *	Granite			2.68	8

(A) U-Pb SHRIMP (zircon); (B) U-Pb isotopic dilution (zircon); (C) ²⁰⁷Pb/²⁰⁶Pb (Pb evaporation on zircon); (D) Rb/Sr (whole rock isochron); Ref.: references. 1 - TEIXEIRA (1982); 2 - TEIXEIRA *et al.* (1987); 3 - CHERMAN (2002); 4 - HEILBRON *et al.* (1989); 5 - CHOUDHURI *et al.* (1992); 6 - SILVA *et al.* (2002); 7 - VALENÇA *et al.* (2000); 8 - ÁVILA (2000); 9 - NOCE *et al.* (2000); 10 - EVANGELISTA, PERES & MACAMBIRA (2000); 11 - ROSA SEIXAS *et al.* (2002); 12 - ÁVILA *et al.* (2003); 13 - CHERMAN (2004); 14 - CAMPOS (2004); 15 - ÁVILA *et al.* (2005a); 16 - ÁVILA *et al.* (2005b). (*) Plutons in figure 1.

flows and sills (concordant-layered amphibolites). The studied region was affected by at least three distinct metamorphic-deformational events. The first one, of low- to medium grade amphibolite facies, affected the metaultramafic, metamafic, and metasedimentary rocks of the Nazareno and Rio das Mortes greenstone belts and give the association Mg-hornblende/Fe-hornblende + oligoclase/andesine ± chlorite ± epidote ± biotite ± sphene ± ilmenite in the metamafic rocks (TOLEDO, 2002). The second event developed under greenschist- and low- amphibolite facies, and affected regionally not only the Nazareno and Rio das Mortes greenstone belts, but also dunites, pyroxenites-gabbros and paleoproterozoic intrusions of the Mineiro belt. The metamorphic association of Paleoproterozoic diorites and gabbros is actinolite ± albite ± epidote ± biotite ± sphene (SILVA, 1996; ÁVILA, 2000). This event was coeval with deformation and folding of the greenstone belt

sequences, leading to subvertical foliation (NNE-SSW strike direction) and a regional scale orientation of most plutonic and volcanic units. The third event, of greenschist facies, is associated to the Neoproterozoic tectonic events that surrounded the southern extremity of the São Francisco Craton and developed NE-SW faults and shear zones (RIBEIRO *et al.*, 1995).

GEOLOGY OF THE GLÓRIA QUARTZ-MONZODIORITE

The Glória quartz-monzodiorite crops out between the cities of Ritápolis and Coronel Xavier Chaves, and exhibits a NNE-SSW regional foliation. It is intrusive into banded gneisses, amphibolites, schists, and metapelites of Rio das Mortes greenstone belt (Fig.3), according to the 2188 ± 29 Ma SHRIMP U-Pb zircon age (ÁVILA *et al.* 2005a).

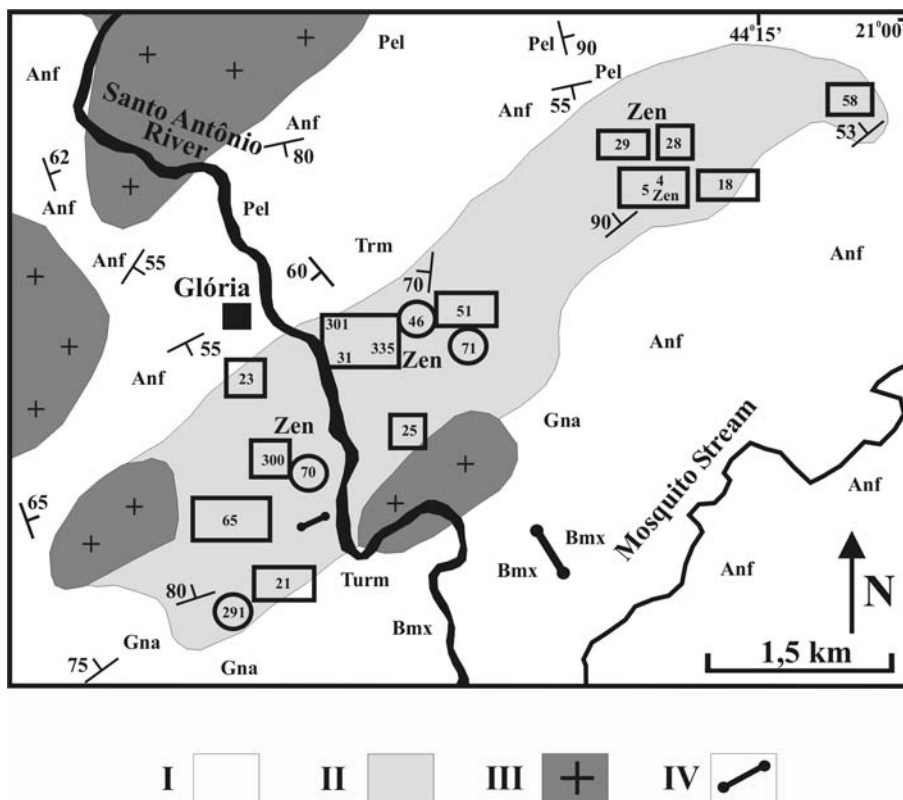


Fig.3- Geology of Glória quartz-monzodiorite and distribution of its mineral facies. Adapted from ÁVILA, TEIXEIRA & PEREIRA (2004). I - Rio das Mortes greenstone belt. II - Glória quartz-monzodiorite. III - Ritápolis granitoid. IV - Mafic dykes. (O) Fine fácies; (□) Fine/medium fácies; (▭) Medium fácies. Rocks: (Trm) tremolite, (Anf) amphibolite, (Bmx) biotite-muscovite schist, (Gna) banded gneiss, (Pel) pelite, (Turm) turmalinite, (Zen) enclave zones.

Major minerals of the intrusion comprise calcic plagioclase, green hornblende, brown biotite, quartz, and potassic feldspar. Metamorphic phases are actinolite, albite, sphene, light brown biotite, epidote, sericite, chlorite, and carbonate. The accessory minerals are apatite, zircon, allanite, and ilmenite. Primary textures are given by equigranular hypidiomorphic crystals and, subordinately, intergranular quartz grains.

The grain-size variation (between 0.1 and 4.0 mm) reported for the Glória quartz-monzodiorite made possible its petrographic subdivision into three different facies (ÁVILA, TEIXEIRA & PEREIRA, 2004). The fine-grained facies, which is the oldest, has a restricted occurrence and is commonly cross-cut by the most widespread fine/medium-grained facies. The youngest medium-grained facies occurs mainly as apophyses and tabular injections, and displays sharp contacts with the formers. Relicts of primary minerals are observed in all the recognized facies.

In general, the modal composition of the Glória quartz-monzodiorite (quartz-diorite, quartz-monzodiorite and tonalite, with rare quartz-

monzodioritic terms) is similar to those found in the Brumado (ÁVILA, 2000), Rio Grande (COUTO, 2000), and Ibitutinga diorites (QUÉMÊNEUR, NOCE & GARCIA, 1994) that occur in the vicinities. However, the Glória quartz-monzodiorite has potassic feldspar content up to 20% (Tab.2).

The mineral composition of the Glória quartz-monzodiorite is distinguished from that of the contemporary São Sebastião da Vitória (SILVA, 1996), Rio Grande and Rio dos Peixes gabbros (TOLEDO, 2002) by the lack of pyroxene and the presence of potassic feldspar. Compared to the Ritápolis, Cassiterita, Brumado de Cima, and Brumado de Baixo bodies (ÁVILA, 2000), the Glória quartz-monzodiorite has lesser quartz and potassic feldspar and higher amphibole as well as mafic minerals modal contents (Tab.2).

Quartz-feldspathic aplites, quartz- and epidote-bearing veins, granitic dykes and pegmatitic injections cross cut the Glória quartz-monzodiorite. The two latter injections are related to the Ritápolis granitoid (2121 ± 7 Ma; ÁVILA, 2000), as supported by field and petrographic relationships.

Table 2. Mineral distribution intervals of selected bodies of the Mineiro belt, southern portion of the São Francisco Craton.

PLUTON	Qz	Plag	Biot	K-feld	Amph	Pyrx	mafic	Ref
Glória quartz-monzodiorite	5.0-21.2	27.0-59.0	7.0-21.0	0-21.0	0-24.0	0	30.0-53.0	1
Brumado diorite (medium facies)	4.0-22.6	31.4-57.4	10.6-44.9	0-5.3	9.2-41.7	0	33.7-57.1	2
Rio Grande diorite	Tr-24.0	32.0-62.0	Tr-12.0	0	15.0-50.0	0	29.5-52.0	3
Ibituruna diorite	5.0-15.0	44.0-55.0	2.0-4.0	5.0-10.0	10.0-20.0	0	n.d.	4
São Sebastião da Vitória gabbro	0-2	48.4-61.8	0	0	0.2-17.2	28.4-45.4	39.2-51.6	5
Brumado de Baixo granodiorite	31.0-47.1	33.9-42.0	Tr-4.6	15.7-23.0	0	0	2.3-9.2	2
Brumado de Cima granodiorite	25.4-37.5	32.7-48.6	Tr-9.4	12.8-22.6	0-Tr	0	4.4-11.9	2
Cassiterita tonalite/trondhjemite	23.2-43.9	43.2-69.4	3.3-12.0	0-7.8	Tr-1.2	0	5.1-14.0	2
Brito quartz-diorite	8.0-13.0	65.0-82.0	3.0-15.0	0-3.0	0	0	5.0-19.0	2
Ritápolis granitoid	25.0-45.0	30.0-63.0	Tr-16.0	0-40.0	0	0	1.0-17.0	2

(Qz) quartz; (Plag) plagioclase; (Biot) biotite; (K-feld) potassic feldspar; (Amph) amphibole; (Pyrx) pyroxene; (Epid) epidote; (Op.M) opaque minerals; (Sph) sphene; (Apat) apatite; (Zr) zircon; (Allan) allanite; (Chlor) chlorite; (% maf.) mafic minerals percent. Ref: 1 - ÁVILA, TEIXEIRA & PEREIRA (2004); 2 - ÁVILA (2000); 3 - COUTO (2000); 4 - QUÉMÊNEUR, NOCE & GARCIA (1994); 5 - SILVA (1996).

Mineralogical transformations of the Glória primary assemblage were attributed to at least two different sub-solidus events (metamorphism and potassic metasomatism). The metamorphic event caused orientation of amphibole, development of sodic plagioclase, epidote and sphene, and forming crystal aligned parallel to the regional structural trend. This implies that the intrusion crystallized before crustal shortening of the Mineiro belt. The metasomatic minerals occur only at contact with granitic dykes related to the Ritópolis granitoid, during which amphibole in the Glória mineral assemblage was partially or completely replaced by biotite and/or chlorite.

METHODOLOGY

The analyzed samples were selected after petrography characterization. The chemical analyses of eleven samples were carried out in the laboratories of Lake-field Geosol and X-ray fluorescence of the Universidade Federal do Rio de Janeiro, Rio de Janeiro, Brazil. Data from the two laboratories are similar within the error. The analytical routines of the former laboratory comprise: X-ray spectrometry (Philips PW2400) for the analysis of the major and minor elements (SiO_2 , TiO_2 , Al_2O_3 , FeO_{Tot} , MnO , MgO , CaO , K_2O , P_2O_5) as well as Cr_2O_3 and NiO ; atomic absorption spectrometry, after dissolution with $\text{HF} + \text{HClO}_4$ for Na_2O ; decomposition with $\text{HF} + \text{H}_2\text{SO}_4$ in platinum crucible buffered for FeO with CO_2 evolution and FeO titulation with KMnO_4 ; electrode of specific ion in alkaline fusion for F; loss of ignition by calcination at 1000°C under constant weight; X-ray fluorescence spectrometry using pressed powder pellets, for Cl, S, Th, Ba, Nb, Cs, U, Rb, Hf, Sr, Y and Zr, and plasma spectrometry (ICP) of pre-concentrated in resin of ion exchange for the Rare Earth Elements (REE). In the Universidade Federal do Rio de Janeiro, the major elements (SiO_2 , TiO_2 , Al_2O_3 , $\text{Fe}_2\text{O}_{3\text{Tot}}$, MnO , MgO , CaO , K_2O , Na_2O and P_2O_5) were analyzed by X-ray fluorescence spectrometry (Phillips PW2400 with Rh-bearing tube) on samples fused with Li-tetraborate. Loss of ignition was obtained by heating rock powder at 950°C up to steady weight. Trace elements (Cr, Ni, V, Co, Zn, Rb, Ba, Sr, Nb, Ga, Y e Zr) were analyzed by X-ray fluorescence spectrometry, using one gram of powder pressed pellets.

WHOLE ROCK GEOCHEMISTRY – RESULTS AND DISCUSSION

Chemical data for the major and trace elements, excluding the REE, are presented in table 3. The Glória quartz-monzodiorite presents significant variations of major, minor, and trace element contents. The fine/medium facies samples have restrict variation of SiO_2 (from 57.20% to 58.81%), whereas one sample of the fine facies group presented SiO_2 , MgO , CaO , and Na_2O contents compatible with the typical range of the fine/medium facies group. The medium facies samples show large variation of SiO_2 contents (from 58.20% to 64.30%), which allowed its separation into two distinct sub-facies: medium I and medium II. Samples of medium I sub-facies have a narrow SiO_2 contents (58.20% to 59.22%), whereas samples of medium II sub-facies displays a wider range of SiO_2 , Al_2O_3 , MgO , and CaO contents, when compared to the fine and fine/medium facies samples (Tab.3). Modal compositions of the analysed samples are shown in figure 4.

The Harker's diagrams display distinct evolution trends, with positive correlations for Al_2O_3 and Na_2O with SiO_2 of the fine and fine/medium facies and medium I sub-facies samples and negative correlations for the same oxides of medium II sub-facies. The peculiar behavior of the medium II sub-facies is also corroborated by the negative correlation trends displayed for TiO_2 , CaO , and P_2O_5 with SiO_2 and positive trend displayed for K_2O (Fig.5).

The relationships among the major elements indicate that the studied samples are metaluminous (Fig.6), with sub-alkaline nature (Fig.7) and medium-K calc-alkaline filiation (Figs.8-9). However, samples PC-18B, CT-335A and BC-05N show contrasting high modal proportion of microcline and biotite, and thus higher K_2O content. These samples fit the typical evolved high-K calc-alkaline rocks.

The limited chemical variation observed among the fine, fine/medium, and medium I sub-facies samples in the Harker diagrams supports a common evolution under similar conditions. In addition, the presence of relicts of igneous phase and/or igneous textures in the fine/medium facies, medium I and medium II sub-facies co-existing with metamorphic mineral associations, suggest that these samples underwent metamorphic conditions from greenschist- to low- amphibolite facies (see preview section). Therefore, this precludes no substantial exchanges of major, minor, and trace elements. In contrast, the metasomatic episode (see above)

resulted in significant petrography changes in the Glória samples. However, the observed mineral changes appear to be restricted to contacts with the dyke apophysis related to the Ritópolis granitoid.

The scattered patterns displayed by Rb, Ba, Sr, Zr, and Y with SiO₂ (Fig. 10) do not agree with the strong Sr positive correlation observed in the fine and fine/medium facies and medium I sub-facies, as well as with negative correlations observed for the medium II sub-facies one. The positive correlations of Sr with SiO₂ displayed by the samples of the fine, fine/medium, and medium I sub-facies clearly contrasts with the negative correlation of Sr and CaO with SiO₂ shown by the medium II sub-facies samples (Fig. 11a). All these features are consistent with the idea that plagioclase doesn't played a significant role during fractionation of the fine and fine/medium facies and medium I sub-facies.

The increase of plagioclase modal percent in the

fine and fine/medium facies and medium I sub-facies, from 37% to 59% (Fig.11b) accompanies Al₂O₃ increase (from 14.02% to 15.07%), whilst CaO (5.82% and 6.16%) variation is restrict. Similarly, Sr content increases with the proportions of plagioclase for almost constant CaO (Fig.11a), whereas the negative correlation of MgO with SiO₂ accompanies decreasing of biotite and amphibole modal contents (Fig. 11c). This pattern points out the role of broad participation of amphibole during the formation of the fine and fine/medium facies and medium I sub-facies.

The fine/medium facies and medium I sub-facies are characterized by enrichment of the LREE ([La/Yb]_N between 29.7 and 38.0) and slight negative Eu anomalies (Fig.12; Tab.4). On the light of these data, the high concentrations of the LREE can be attributed either to the fractionation of allanite and/or to crustal contamination.

TABLE 3. Chemical results (wt %) of major, minor and trace elements for the samples of the different facies of Glória quartz-monzodiorite.

ROCK	PC-18B	CT-335A	BC-04A1	BC-05N	BC-04C	CT-300	BC-05G1	BC-05G	PC-18A	PC-18E	PC-18E1
CLASSIFICATION	QD	QMd	QMd	QMd	QD	QD	QD	QD	QD	QD	QD
Facies	○	◆	◆	◆	●	●	●	●	△	△	△
SiO ₂	57.5	57.2	58.81	57.78	58.64	58.2	59.14	59.22	64.3	60.9	59.4
TiO ₂	1.1	0.83	0.82	0.88	0.82	1.1	0.89	0.83	0.66	0.73	0.75
Al ₂ O ₃	13.6	14.2	14.72	14.37	14.67	14.6	15.07	14.57	14.6	15.9	16.6
Fe ₂ O _{3(t)}	7.08	7.3	6.58	6.83	6.59	8.41	6.34	6.35	5.65	6.21	6.29
MnO	0.13	0.1	0.1	0.11	0.1	0.1	0.1	0.11	0.09	0.11	0.12
MgO	5.5	6.4	4.77	5.48	4.84	5.0	4.04	5.29	3.0	3.4	3.2
CaO	6.0	6.0	5.96	6.16	5.82	5.9	5.98	5.95	4.2	4.8	5.3
Na ₂ O	3.4	3.5	4.65	4.05	4.79	3.2	5.26	4.73	3.8	4.5	5.0
K ₂ O	3.3	2.7	2.23	2.63	2.17	1.8	1.74	1.87	2.3	2.1	1.8
P ₂ O ₅	0.79	0.47	0.46	0.43	0.47	0.36	0.41	0.46	0.27	0.33	0.33
P.F.	1.59	1.2	0.33	0.68	0.64	1.8	0.7	0.67	1.31	1.32	1.42
TOTAL	99.54	99.4	99.43	99.4	99.55	99.86	99.67	100.05	99.83	99.93	99.82
Cr	205	225	197	262	131	300	137	233	137	137	68
Ni	157	65	117	159	77	115	77	162	79	79	79
Ba	2186	1040	1254	1106	919	1360	875	1137	1059	1365	888
Sr	834	518	1206	978	1342	813	1302	1429	674	987	1240
Rb	109	55	55	95	70	79	100	115	81	89	86
Nb	---	5	9	10	11	5	10	9	34	86	35
Zr	446	180	317	306	365	189	325	373	215	232	221
Y	25	19	24	29	26	25	28	30	16	26	25

(QD) quartz-diorite; (QMd) quartz-monzodiorite; (○) fine facies; (◆) fine/medium facies; (●) medium I sub-facies; (△) medium II sub-facies.

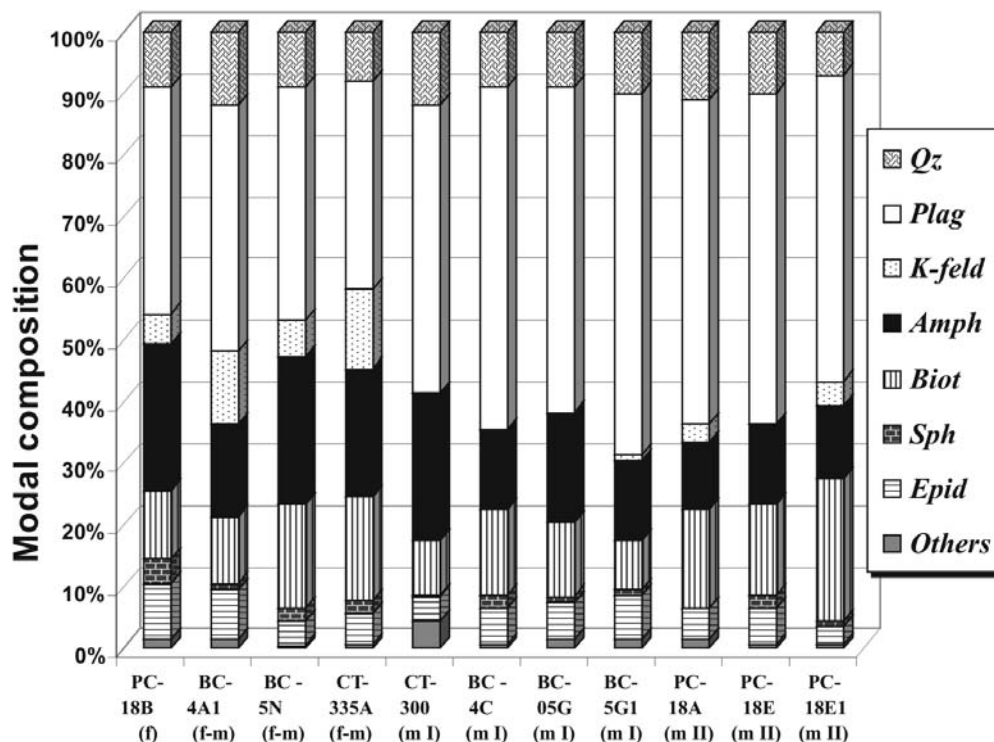


Fig.4- Bar diagram representing the modal composition (based on ÁVILA, TEIXEIRA & PEREIRA, 2004 data) for the samples of the different facies of the Glória quartz-monzodiorite. (m-I) – medium I sub-facies; (m-II) – medium II sub-facies; (f-m) – fine/medium facies; (f) – fine facies. (Qz) quartz; (Plag) plagioclase; (K-feld): potassic feldspar; (Amph) amphibole; (Biot) biotite; (Sph) sphene; (Epid) epidote; others includes: chlorite, zircon, apatite, opaque minerals, allanite, white mica and carbonate.

Table 4. Chemical analyses (ppm) of rare earth elements for the samples of the different facies of Glória quartz-monzodiorite.

ROCK	CT-335A	CT-300
CLASSIFICATION	QMd	QD
Facies	♦	●
La	84.9	92.9
Ce	179.9	121.9
Nd	87.93	65.16
Sm	14.43	9.45
Eu	2.99	1.97
Gd	8.13	5.58
Dy	5.8	4.11
Ho	1.1	0.81
Er	2.63	2.14
Yb	1.93	1.65
Lu	0.24	0.22

(QD) quartz-diorite; (QMd) quartz-monzodiorite. (♦) fine/medium facies; (●) medium I sub-facies.

The different behavior displayed by the medium II sub-facies is dependent on the plagioclase fractionation, since it controls the Al_2O_3 , CaO, Na_2O , and Sr contents. The limited variation of the MgO content (between 3.0% and 3.4%) reveals the absence of any significant differentiation process involving fractionation of amphibole and biotite. This agrees well with the closely modal concentration of the sum of both minerals (25% to 27%).

The HFSE (Zr, P, Nb, and Ti) and LILE (Ba and K) signature of the fine and fine/medium facies and medium I and II sub-facies is shown in figure 13. This is consistent with the typical geochemical pattern of volcanic arc-derived rocks, as given by the Nb and Ti negative anomalies and the low Y contents. Such features would result from the retention of opaque minerals (and also garnet) in the source region. All the facies show positive Zr anomalies and occasional small negative P peaks which suggest volcanic arc-derived rocks.

The overall geochemical characteristics of the trace

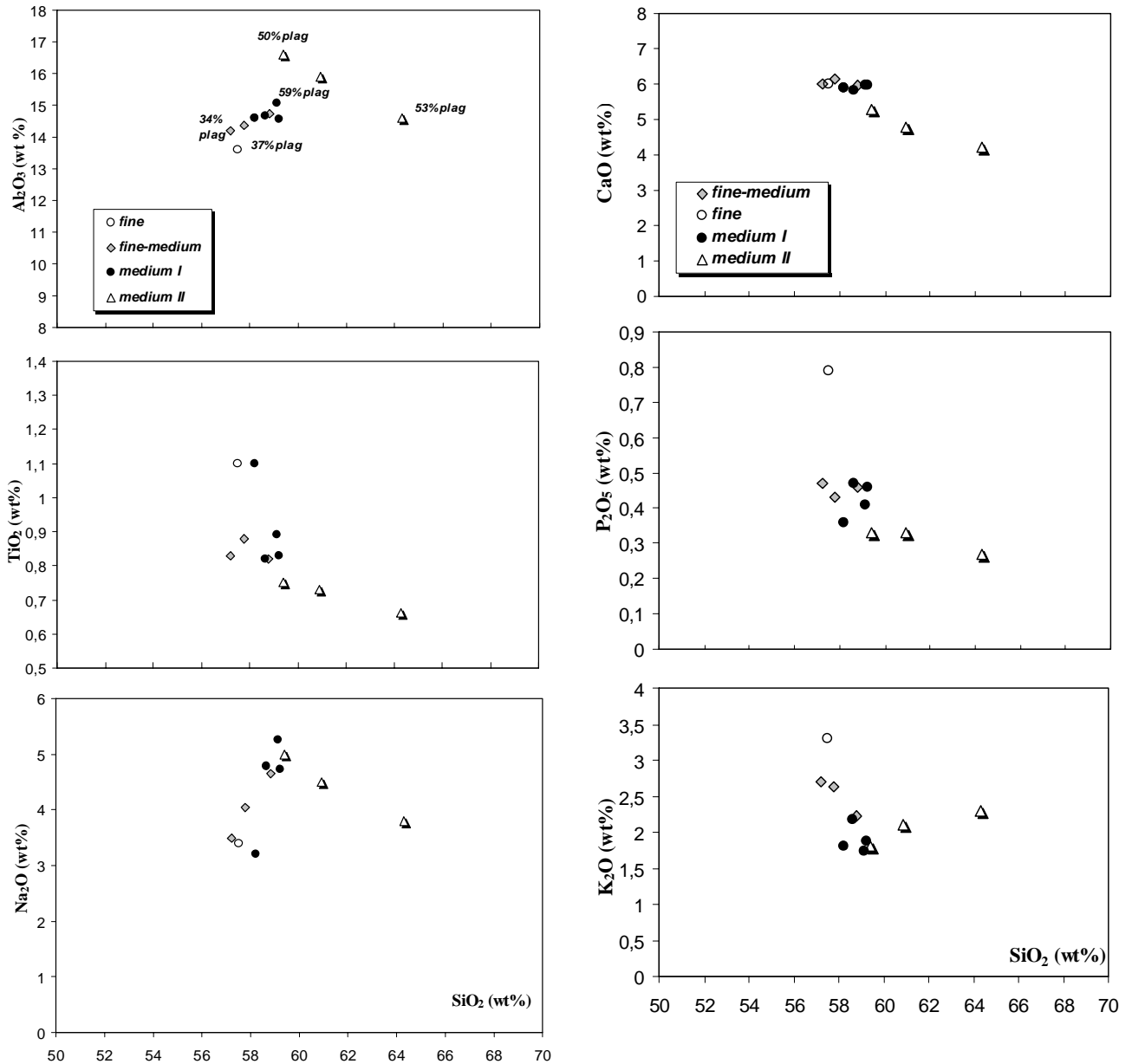
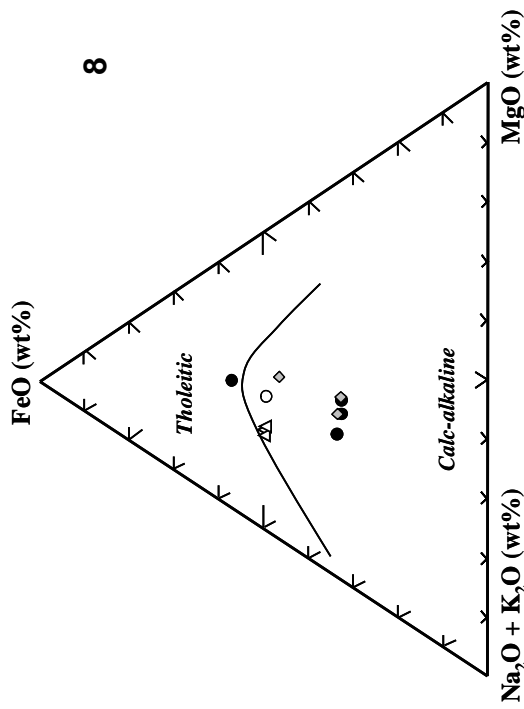
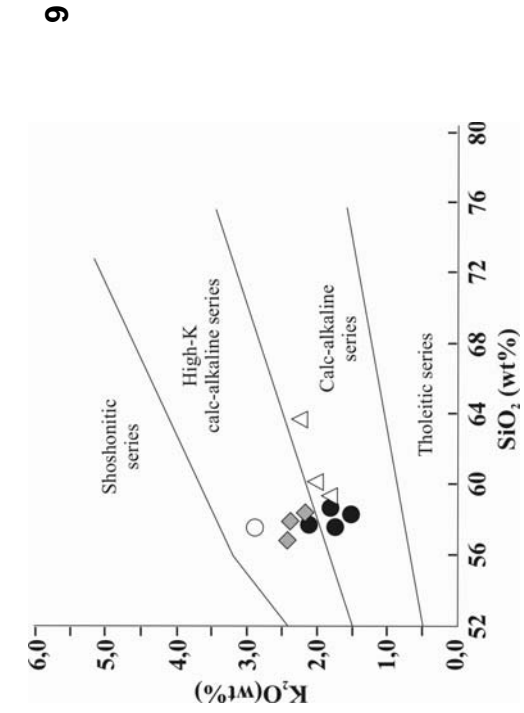
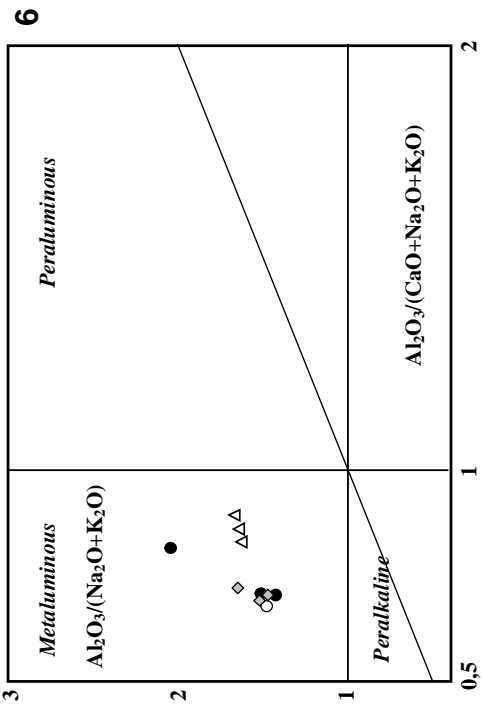
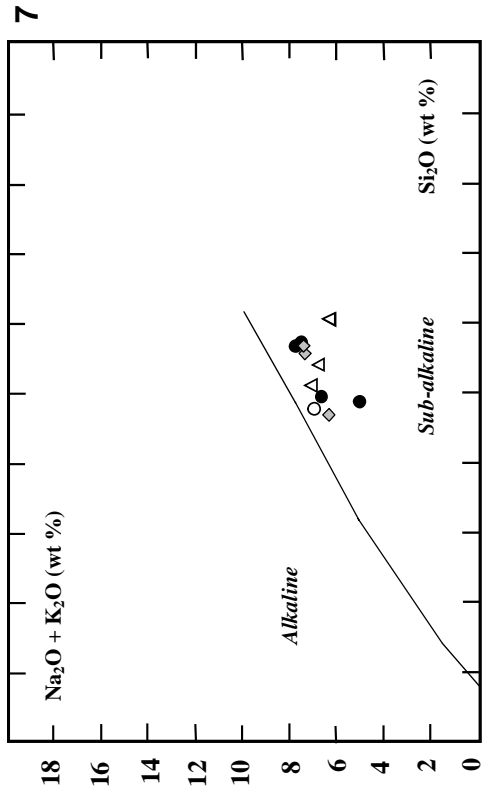


Fig.5- Harker diagrams (major elements) for the samples of the different facies of the Glória quartz-monzodiorite. (○) fine facies; (◊) fine/medium facies; (●) medium I sub-facies; (△) medium II sub-facies.

elements are consistent with magmatic evolution under low to medium pressure conditions. This conclusion is supported by: *i*) simultaneous depletion of Sr and HFSE; *ii*) P high concentrations; *iii*) variations of Ba/P ratios (0.47 to 0.87), K/Rb (135 to 407), Ba/Sr (0,67 to 2,62); *iv*) random variation of Ti/P vs. K/Rb ratios; and *v*) negative correlation of Ba/Rb vs. Rb ratios (see Tab.5).

Furthermore, the relations between Rb x (Y+Nb) are coherent with a volcanic arc environment signature (Fig. 14), as also suggested by the high Zr, Pb, Ba and K (see above). These geochemical features are comparable to that of contemporary pre-collisional intrusions of the Mineiro belt (e.g. Brumado diorite: 2131 ± 4 Ma – ÁVILA, 2000; and Cassiterita Trondhjemite/Tonalite: 2162 ± 10 Ma – ÁVILA *et al.*, 2003).



Figs. 6-9- Discriminant diagrams for the samples of the different facies of the Glória quartz-monzodiorite. Fig. 6- $[Al_2O_3 / (CaO + Na_2O + K_2O)]_{mol} \times [Al_2O_3 / (Na_2O + K_2O)]_{mol}$ (MANIAR & PICCOLI, 1989). Fig. 7- $SiO_2 \times Na_2O + K_2O$ (IRVINE & BARAGGAR, 1971). Fig. 8- $MgO-FeO^*-Na_2O + K_2O$ (IRVINE & BARAGGAR, 1971). Fig. 9- $SiO_2 \times Na_2O + K_2O$ (PECCEERILLO & TAYLOR, 1976). (○) fine facies; (◆) fine/medium facies; (●) medium I sub-facies; (△) medium II sub-facies.

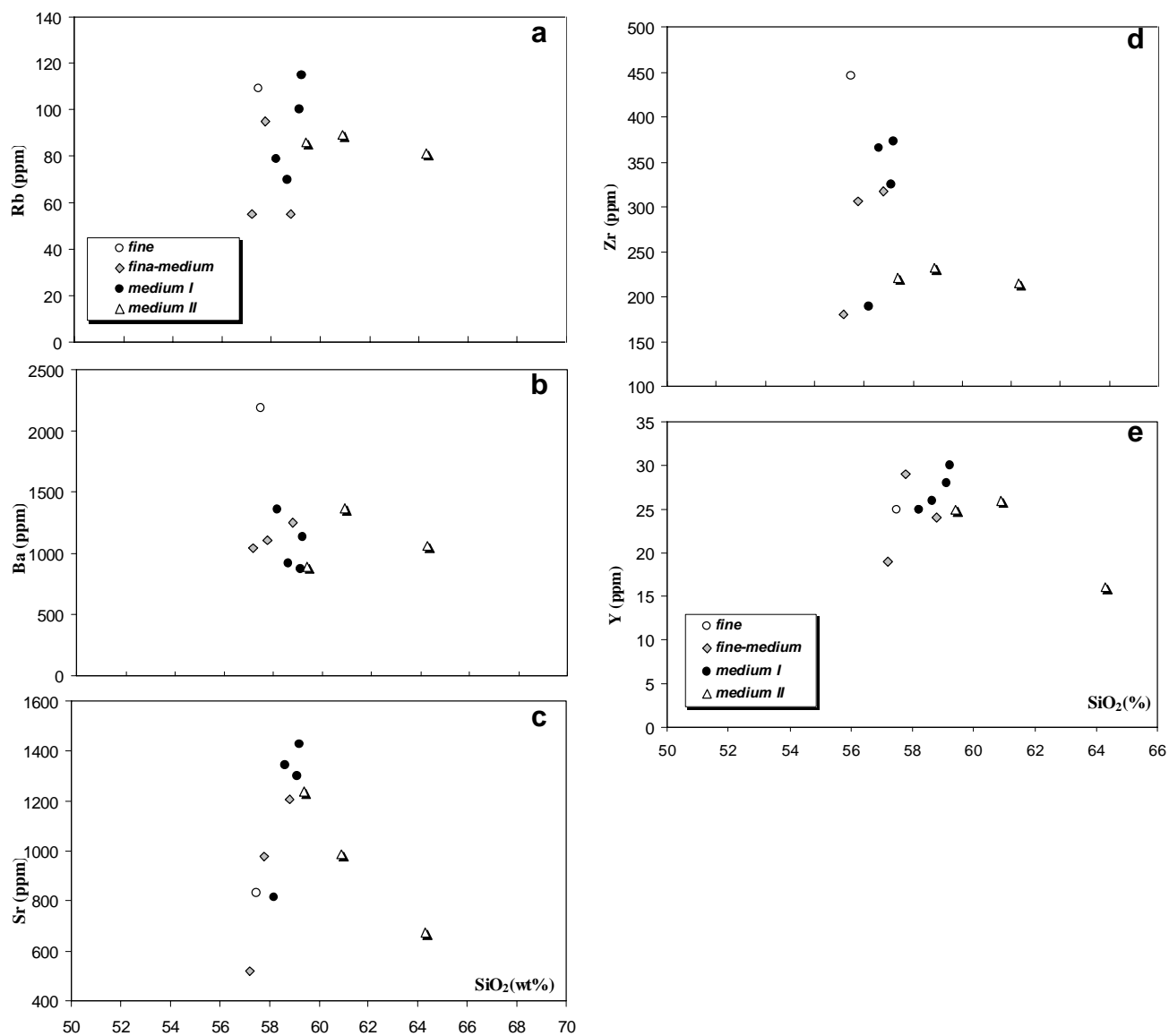


Fig. 10- Harker diagrams for trace elements for the samples of the different facies of the Glória quartz-monzodiorite. (○) fine facies; (◇) fine/medium facies; (●) medium I sub-facies; (△) medium II sub-facies.

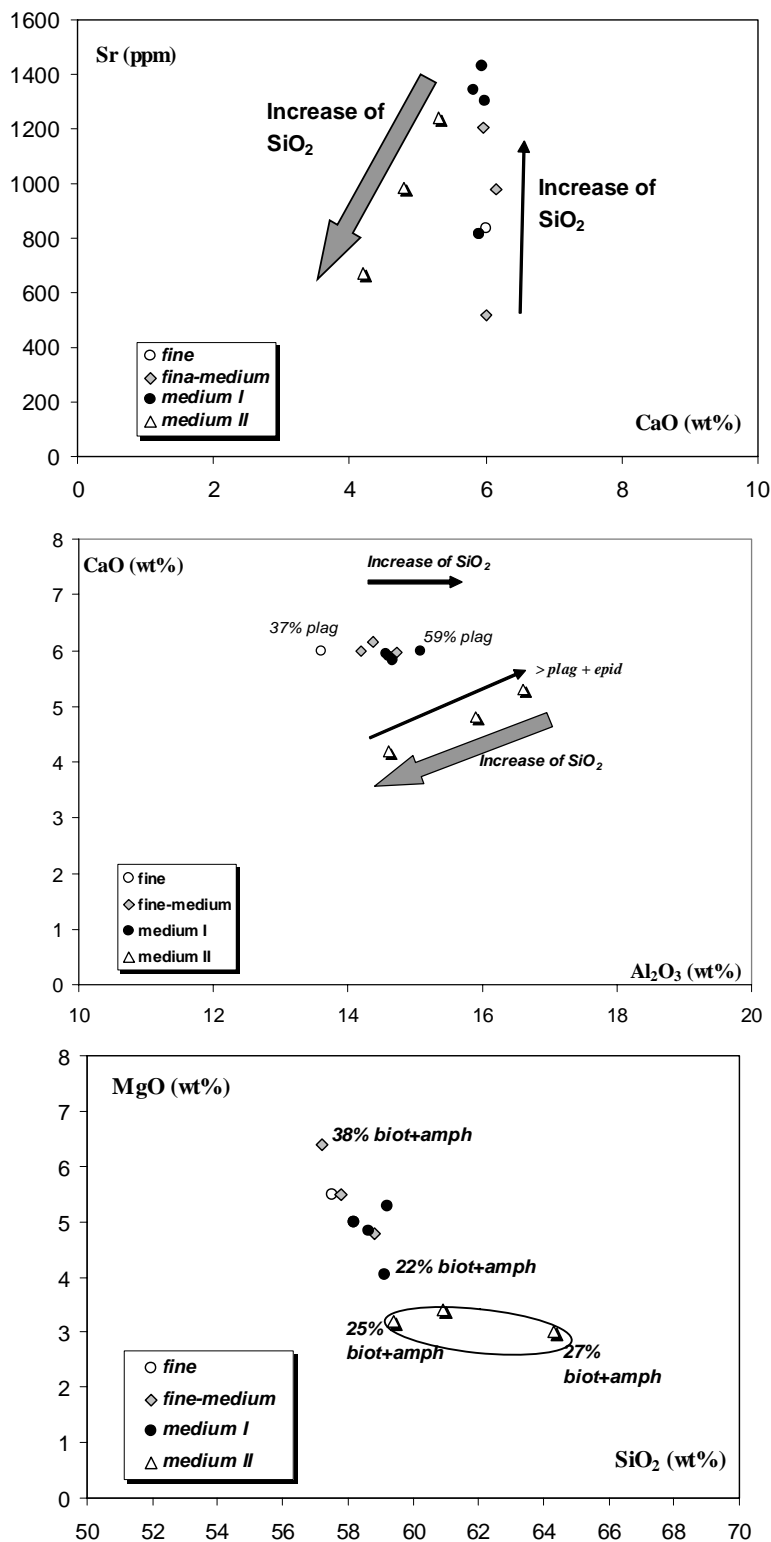


Fig.11- Diagram for the samples of the different facies of the Glória quartz-monzodiorite. (a) CaO x Sr; (b) Al₂O₃ x CaO; (c) SiO₂ x MgO. (○) fine facies; (◇) fine/medium facies; (●) medium I sub-facies; (△) medium II sub-facies.

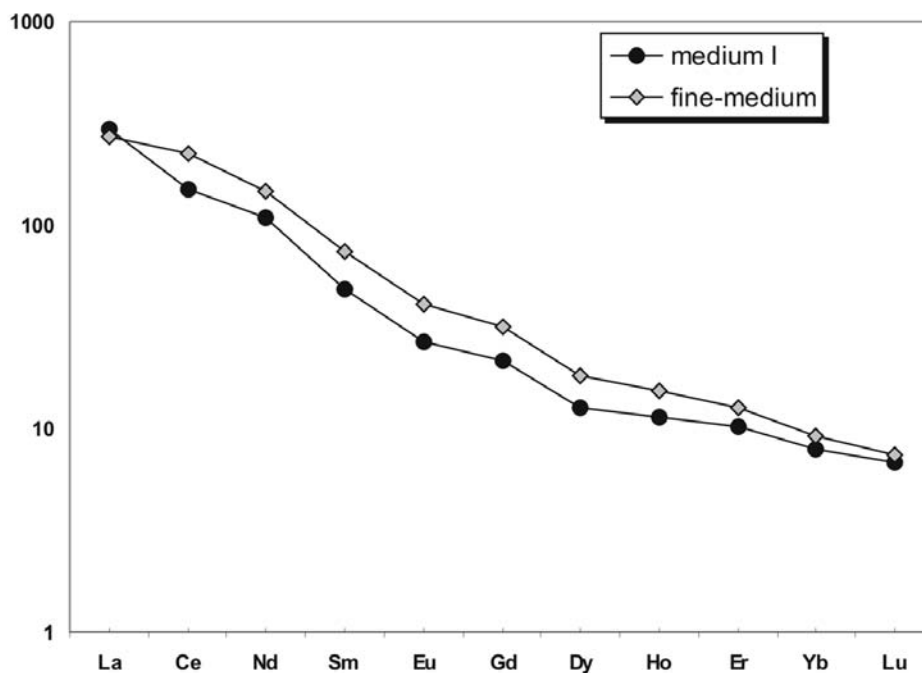


Fig.12- Distribution of the rare earth elements normalized to chondrite pattern of BOYNTON (1984). (◆) fine/medium facies; (●) medium I sub-facies.

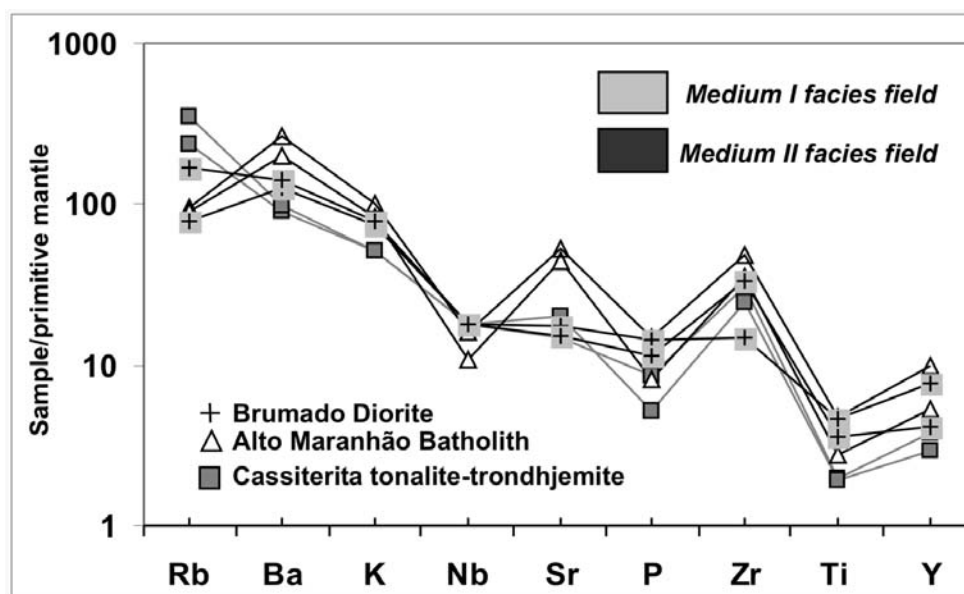


Fig.13- Spidergram of samples of medium I sub-facies and medium II sub-facies of the Glória quartz-monzodiorite. Values normalized to primitive mantle (TAYLOR & McLENNAN, 1985).

TABLE 5. Trace element ratios for the different facies samples of Glória quartz-monzodiorite.

ROCK	PC-18B	CT-335A	BC-04A1	BC-05N	BC-04C	CT-300	BC-05G1	BC-05G	PC-18A	PC-18E	PC-18E1
CLASSIFICATION	QD	QMd	QMd	QMd	QD	QD	QD	QD	QD	QD	QD
Facies	○	◆	◆	◆	●	●	●	●	△	△	△
SiO ₂	57,5	57,2	58,81	57,78	58,64	58,2	59,14	59,22	64,3	60,9	59,4
Zr/Y	17,84	9,47	13,21	10,55	14,04	7,56	11,61	12,43	13,44	8,92	8,84
Ba/Sr	2,62	2,01	1,04	1,13	0,68	1,67	0,67	0,80	1,57	1,38	0,72
Sr/Y	33,36	27,26	50,25	33,72	51,62	32,52	46,50	47,63	42,13	37,96	49,60
Ti/P	1,91	2,43	2,45	2,81	2,40	4,20	2,98	2,48	3,36	3,04	3,12
K/Rb	251,33	407,54	336,59	229,82	257,35	189,15	144,45	134,99	235,73	195,88	173,76
Ba/Rb	20,06	18,91	22,80	11,64	13,13	17,22	8,75	9,89	13,07	15,34	10,33
Ba/P	0,63	0,51	0,62	0,59	0,45	0,87	0,49	0,57	0,90	0,95	0,62

(QD) quartz-diorite; (QMd) quartz-monzodiorite. (○) fine facies; (◆) fine/medium facies; (●) medium I sub-facies; (△) medium II sub-facies.

TECTONIC IMPLICATIONS AND GEOCHEMICAL EVOLUTION

The evolution of the Mineiro belt is chiefly related to an extensive calc-alkaline plutonism, driven by complex mixture of mantle- and crustal derived end-members (ÁVILA, 2000; NOCE *et al.*, 2000; TEIXEIRA *et al.*, 2005). Particularly, the evolution of the dioritic magmatism in the Mineiro belt started with the Glória quartz-monzodiorite intrusion (2188 ± 29 Ma; ÁVILA *et al.*, 2005a) and continued with the less differentiated bodies (low K-feldspar proportions) of Rio Grande (2155 ± 3 Ma; CHERMAN, 2002), Brumado (2131 ± 4 Ma; ÁVILA, 2000), and Ibitutinga diorites.

In the Glória quartz-monzodiorite, the fine facies, fine/medium, and medium I sub-facies evolved by a combination of the fractionation of amphibole, whereas the medium II sub-facies displays different geochemical trends, here interpreted as the result of plagioclase fractionation, inasmuch as biotite and amphibole contents were well stabilized.

Moreover, the geochemical data indicate that the recognized facies (fine, fine/medium, medium I sub-facies, and medium II sub-facies) are probably co-genetic, evolved under low to medium pressure conditions (in volcanic arc - related setting), and originated at 2188 ± 29 Ma ago (SHRIMP U-Pb zircon age). The studied samples derived from a Paleoproterozoic juvenile magma slightly enriched in crustal components, as also supported by the negative $\epsilon_{Nd(T)}$ signature (-3.4) and T_{DM} model age (2.68 Ga) (ÁVILA *et al.*, 2005a).

The youngest Paleoproterozoic sin-tectonic intrusions found between Lavras and São João del Rei are pegmatites and granitic apophyses, which are ascribed to the late-magmatic activity of Ritápolis granitoid (2121 ± 7 Ma), Macucu de Minas granitoid (2116 ± 9 Ma), and Itumirim granite (2101 ± 8 Ma), respectively (ÁVILA, 2000; CHERMAN, 2004). In the São João Del Rei region, the Ritápolis granitoid caused replacement of metamorphic actinolite by metassomatic biotite along the margins of the Glória quartz-monzodiorite and Brumado diorite.

From the above geologic framework and according to the petrographic and geochemical characteristics, the Glória quartz-monzodiorite (2188 ± 29 Ma) can be related to the pre-collisional tectonic phase of the Mineiro belt. On-going isotopic and geochemical studies on adjacent Paleoproterozoic plutons will bring new insights on tectonic and magmatic aspects of the central part of the Mineiro belt.

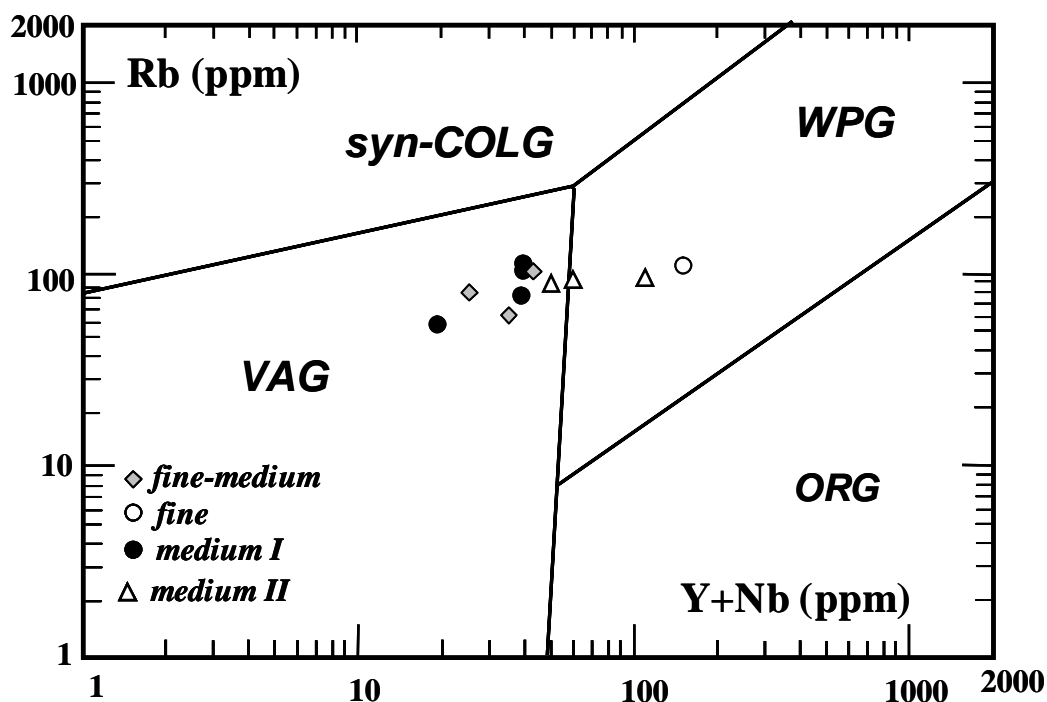


Fig. 14- Rb x (Y + Nb) tectonic discrimination diagram (PEARCE, HARRIS & TINDLE, 1984) for the samples of the different facies of the Glória quartz-monzodiorite. (○) fine facies; (◊) fine/medium facies; (●) medium I sub-facies; (△) medium II sub-facies.

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REFERENCES

- ÁVILA, C.A., 1992. **Geologia, petrografia e geoquímica das rochas pré-cambrianas (Unidade Metadiorítica Ibitutinga e Unidade Metatromhjemítica Caburu) intrusivas nas rochas do Greenstone Belt Barbacena, São João Del Rei, Minas Gerais**. Rio de Janeiro. 265p. Dissertação (Mestrado em Geologia), Programa de Pós-Graduação em Geologia, Departamento de Geologia, Universidade Federal do Rio de Janeiro.
- ÁVILA, C.A., 2000. **Geologia, petrografia e geocronologia de corpos plutônicos paleoproterozóicos da borda meridional do Cráton São Francisco, região de São João Del Rei, Minas Gerais**. Rio de Janeiro. 401p. Tese (Doutorado em Geologia), Programa de Pós-Graduação em Geologia, Departamento de Geologia, Universidade Federal do Rio de Janeiro.
- ÁVILA, C.A.; VALENÇA, J.G.; MOURA, C.A.V.; RIBEIRO, A. & PACIULLO, F.V., 1998. Idades $^{207}\text{Pb}/^{206}\text{Pb}$ em zircões de corpos metaplutônicos da região de São João Del Rei, borda sul do Cráton do São Francisco, Minas Gerais. In: CONGRESSO BRASILEIRO GEOLOGIA, 40., 1998, Belo Horizonte. **Boletim de Resumos...**, Belo Horizonte: Sociedade Brasileira de Geologia, p.75-78.

- ÁVILA, C.A.; VALENÇA, J.G.; MOURA, C.A.V.; KLEIN, V.C. & PEREIRA, R.M., 2003. Geoquímica e idade do Trondhjemito Cassiterita, borda meridional do Cráton São Francisco, Minas Gerais. **Arquivos do Museu Nacional**, Rio de Janeiro, **61**(4):267-284.
- ÁVILA, C.A.; TEIXEIRA, W. & PEREIRA, R.M., 2004. Geologia e petrografia do Quartzo Monzodiorito Glória, Cinturão Mineiro, porção sul do Cráton São Francisco, Minas Gerais. **Arquivos do Museu Nacional**, Rio de Janeiro, **62**(1):83-98.
- ÁVILA, C.A.; TEIXEIRA, W.; CORDANI, H.G.; BARRUETO, H.R.; PEREIRA, R.M.; MARTINS, V.T. & DUNYI, L., 2005a. Geoquímica e idade U/Pb do Quartzo Monzodiorito Glória: implicações na evolução paleoproterozóica do setor oriental do Cinturão Mineiro. In: CONGRESSO BRASILEIRO DE GEOQUÍMICA, 9., 2005, Porto de Galinhas. **Anais...**, Porto de Galinhas: Sociedade Brasileira de Geoquímica. (Published in CD ROM)
- ÁVILA, C.A.; VALENÇA, J.G.; TEIXEIRA, W.; BARRUETO, H.R.; MOURA, C.A.V.; CORDANI, H.G.; PEREIRA, R.M. & MARTINS, V.T., 2005b. Geocronologia U/Pb e Pb/Pb da Suíte Serrinha: implicações para a evolução paleoproterozóica da margem sul do Cráton São Francisco. In: SIMPÓSIO DE VULCANISMO E AMBIENTES ASSOCIADOS, 3., 2005, Cabo Frio. **Anais...**, Cabo Frio: Sociedade Brasileira de Geologia, p.357-361.
- BOYNTON, W.V., 1984. Cosmochemistry of the rare earth element: meteorite studies. In: HENDERSON, P. (Ed.). **Rare earth element geochemistry**. Amsterdam: Elsevier. p.63-114.
- CAMPOS, J.C.S., 2004. **O lineamento Jeceaba – Bom Sucesso como limite dos terrenos arqueanos e paleoproterozóicos do Cráton São Francisco meridional: evidências geológicas, geoquímicas (rocha total) e geocronológica (U-Pb)**. 161p. Tese (Doutorado em Geologia), Programa de Pós-Graduação em Geologia, Departamento de Geologia, Universidade Federal de Ouro Preto.
- CAWTHORN, R.G.; STRONG, D.F. & BROWN, P.A., 1976. Origin of corundum-normative intrusive and extrusive magmas. **Nature**, Hampshire, **259**(1):102-104.
- CHERMAN, A.F., 2002. **Geologia, petrografia, feições estruturais e geocronologia dos corpos metagranitóides intrusivos no Greenstone Belt Barbacena, na região entre Lavras e Nazareno, Minas Gerais**. Rio de Janeiro. 60p. Exame de Qualificação (Doutorado em Geologia), Programa de Pós-Graduação em Geologia, Departamento de Geologia, Universidade Federal do Rio de Janeiro.
- CHERMAN, A.F., 2004. **Geologia, petrografia e geocronologia de ortognaisses paleoproterozóicos da borda meridional do Cráton do São Francisco, na região entre Itumirim e Nazareno, Minas Gerais**. Rio de Janeiro. 259p. Tese (Doutorado em Geologia), Programa de Pós-Graduação em Geologia, Departamento de Geologia, Universidade Federal do Rio de Janeiro.
- CHOUDHURI, A.; CROSTA, A.P.; SCHRANK, A.; SZABÓ, G.A.J. & IYER, S.S., 1992. The Quilombo Granite in the Archean Morro do Ferro Greenstone belt, SW Minas Gerais, and character of the transamazonian event. **Revista da Escola de Minas**, Ouro Preto, **45**(1/2):152-153.
- COUTO, F.M., 2000. **Metadioritos, metaquartzo dioritos e metatonalitos (associação MDQT) e suas rochas encaixantes do Greenstone Belt Barbacena, na região de Lavras – Nazareno (sul do Estado de Minas Gerais)**. Rio de Janeiro. 75p. Dissertação (Mestrado em Geologia), Programa de Pós-Graduação em Geologia, Departamento de Geologia, Universidade Federal do Rio de Janeiro.
- EVANGELISTA, H.J.; PERES, G.G. & MACAMBIRA, M.J.B., 2000. Pb/Pb single-zircon dating of Paleoproterozoic calc-alkaline/alkaline magmatism in the southeastern São Francisco Craton region, Brazil. **Revista Brasileira de Geociências**, São Paulo, **30**(1):174-176.
- GULSON, B.L.; LOVERING, J.F.; TAYLOR, S.R. & WHITE, A.J.R., 1972. High-K diorites, their place in the calc-alkaline association and relationship to andesites. **Lithos**, Netherlands, **5**:269-279.
- HEILBRON, M.; GONÇALVES, M.L.; TEIXEIRA, W.; TROUW, R.A.J.; PADILHA, A.V. & KAWASHITA, K., 1989. Geocronologia da região entre Lavras, São João del Rei, Lima Duarte e Caxambú (MG). **Anais da Academia Brasileira de Ciências**, Rio de Janeiro, **61**(2):177-199.
- IRVINE, T.N. & BARAGAR, W.R.A., 1971. A guide to the chemical classification of common volcanic rocks. **Canadian Journal of Earth Sciences**, Ottawa, **8**(5):523-548.
- MANIAR, P.D. & PICOLLI, P.M., 1989. Tectonic discrimination of granitoids. **Geological Society of America Bulletin**, Bolder, **101**(5):635-643.
- MELLO, A.G., 2003. **Rochas metavulcânicas máficas e metacumuláticas máficas e ultramáficas do Greenstone Belt Barbacena e metagranitóides intrusivos, na área de Dores de Campos, sul do Estado de Minas Gerais**. 159p. Dissertação (Mestrado em Geologia), Programa de Pós-Graduação em Geologia, Departamento de Geologia, Universidade Federal do Rio de Janeiro.
- NOCE, C.M.; TEIXEIRA, W.; QUÉMÉNEUR, J.J.G.; MARTINS, V.T.S. & BOLZACHINI, E., 2000. Isotopic signatures of paleoproterozoic granitoids from the southern São Francisco Craton and implications for the evolution of the Transamazonian Orogeny. **Journal of South American Earth Sciences**, Oxford, **13**(2):225-239.
- PADILHA, A.V.; VASCONCELOS, R.M. & GOMES, R.A.A.D., 1991. Evolução geológica. In: **Barbacena. Folha SF.23-X-C-III, Estado do Minas Gerais**. Programa de Levantamentos Geológicos Básicos do Brasil, DNPM/CPRM, p.111-133.

- PEARCE, J.A.; HARRIS, N.B.W. & TINDLE, A.G., 1984. Trace element discrimination diagrams for the tectonic interpretation of granitic rocks. **Journal of Petrology**, Oxford, **25**(4):956-983.
- PECCERILLO, R. & TAYLOR, S.R., 1976. Geochemistry of Eocene calc-alkaline volcanic rocks from Kastamonu area, northern Turkey. **Contributions to Mineralogy and Petrology**, Berlin, **58**(1):63-81.
- PIRES, F.R.M.; RIBEIRO, A. & BARBOSA, M.I.M., 1990. Distribuição do "Greenstone Belt" Barbacena na região de São João Del Rei, Minas Gerais In: CONGRESSO BRASILEIRO GEOLOGIA, 36., 1990, Natal. **Anais...**, Natal: Sociedade Brasileira de Geologia. v.5, p.2941-2951.
- QUÉMÊNEUR, J.J.G. & NOCE, C.M., 2000. Geochemistry and petrology of felsic and mafic suites related to the Paleoproterozoic Transamazonian orogeny in Minas Gerais, Brazil. **Revista Brasileira de Geociências**, São Paulo, **30**(1):87-90.
- QUÉMÊNEUR, J.J.G.; NOCE, C.M. & GARCIA, D., 1994. Caracterização das suítes granitóides do arco magmático transamazônico na borda meridional do Cráton do São Francisco, Minas Gerais. In: CONGRESSO BRASILEIRO GEOLOGIA, 38., 1994, Camboriú. **Boletim de Resumos Expandidos...**, Camboriú: Sociedade Brasileira de Geologia. v.1, p.117-119.
- QUÉMÊNEUR, J.J.G.; RIBEIRO, A.; TROUW, R.A.J.; PACIULLO, F.V.P. & HEILBRON, M., 2003. Geologia da Folha Lavras (1:100.000). In: Companhia Mineradora de Minas Gerais – COMIG (Ed.) **Geologia e recursos minerais do sudeste brasileiro**. Vol.II, capítulo 7, p. 259-319.
- RIBEIRO, A.; TROUW, R.A.J.; ANDREIS, R.R.; PACIULLO, F.V.P. & VALENÇA, J.G., 1995. Evolução das bacias proterozóicas e o termo-tectonismo brasileiro na margem sul do Cráton do São Francisco. **Revista Brasileira de Geociências**, São Paulo, **25**(4):235-248.
- RIBEIRO, A.; ÁVILA, C.A.; VALENÇA, J.G.; PACIULLO, F.V.P. & TROUW, R.A.J., 2003. Geologia da Folha São João del Rei (1:100.000). In: Companhia Mineradora de Minas Gerais – COMIG (Ed.) **Geologia e recursos minerais do sudeste brasileiro**. Vol.III, Capítulo 11, pag. 521-622.
- RINGWOOD, A.E., 1974. The petrological evolution of island arc systems. **Journal of Geological Society**, London, **130**:183-204.
- ROSA-SEIXAS, L.A.; CARNEIRO, M.A.; NOCE, C.M.; BARDINTZEFF, J.M. & BONIN, B., 2002. Preliminary investigations about geodynamic of precambrian continental crust differentiation in the Quadrilátero Ferrífero region deduced from Archaean and Paleoproterozoic felsic plutonic rocks, Brazil – Part II: trondhjemitic rocks. In: CONGRESSO BRASILEIRO DE GEOLOGIA, 42., 2002, João Pessoa. **Boletim de Resumos...**, João Pessoa: Sociedade Brasileira de Geologia, v.1, p.528.
- SILVA, M.A., 1996. **Geologia e petrografia do corpo metagabroico pré-cambriano de São Sebastião da Vitória, Minas Gerais**. 125p. Dissertação (Mestrado em Geologia), Programa de Pós-Graduação em Geologia, Departamento de Geologia, Universidade Federal do Rio de Janeiro.
- SILVA, L.C.; ARMSTRONG, R.; NOCE, C.M.; CARNEIRO, M.A.; PIMENTEL, M.; PEDROSA-SOARES, A.C.; LEITE, C.A.; VIEIRA, V.S.; SILVA, M.A.; PAES, V.J.C. & CARDOSO FILHO, J.M., 2002. Reavaliação da evolução geológica em terrenos pré-cambrianos brasileiros com base em novos dados U-Pb Shrimp, Parte II: Orógeno Araçuaí, Cinturão Mineiro e Cráton São Francisco meridional. **Revista Brasileira de Geociências**, São Paulo, **32**(4):513-528.
- TAYLOR, S.R. & MCLENNAN, S.M., 1985. **The continental crust: its composition and evolution**. Oxford: Blackwell.
- TEIXEIRA, N.A., 1992. Contribuição à geologia do "Greenstone Belt" Itumirim-Nazareno (MG). In: CONGRESSO BRASILEIRO GEOLOGIA, 37., 1992, São Paulo. **Boletim Resumos Expandidos...**, São Paulo: Sociedade Brasileira de Geologia. v.1, p.476-477.
- TEIXEIRA, W., 1982. Geochronology of Southern Part of the São Francisco Cráton. **Revista Brasileira de Geociências**, São Paulo, **12**(1/3):268-277.
- TEIXEIRA, W.; CORDANI, U.G.; KAWASHITA, K.; TAYLOR, P.N. & VAN SCHMUS, W.R., 1987. Archean and early proterozoic crustal evolution in the southern part of the São Francisco Craton. In: INTERNATIONAL SYMPOSIUM ON GRANITES AND ASSOCIATED MINERALIZATIONS, I., 1987, Salvador. **Extended abstracts...**, Salvador: Sociedade Brasileira de Geologia, Brazil. v.1, p.37-40.
- TEIXEIRA, W.; SABATÉ, P.; BARBOSA, J.; NOCE, C.M. & CARNEIRO, M.A., 2000. Archean and Paleoproterozoic evolution of the São Francisco Craton. In: CORDANI, U.G.; MILLANI, E.J.; THOMAZ FILHO, A. & CAMPOS, D.A. (Eds.) **Tectonic evolution of South America**. Rio de Janeiro: Departamento Nacional da Produção Mineral. p.101-138.
- TEIXEIRA, W.; ÁVILA, C.A.; CORDANI, U.G.; MARTINS, V.T.S. & VALENÇA, J.G., 2005. Dados isotópicos (U/Pb, Pb/Pb, Sm/Nd, Rb/Sr) do plutonismo paleoproterozóico do Cinturão Mineiro, porção meridional do Cráton São Francisco: implicações tectônicas. In: SIMPÓSIO DO CRÁTON DO SÃO FRANCISCO, 3., 2005, Salvador. **Anais...**, Salvador: Sociedade Brasileira de Geologia, p.174-177.
- TOLEDO, C.L.B., 2002. **Evolução geológica das rochas máficas e ultramáficas no Greenstone Belt Barbacena, na região de Nazareno, MG**. 307p. Tese (Doutorado em Geologia), Programa de Pós-Graduação em Geociências, Departamento de Metalogênese e Geoquímica, Universidade Estadual de Campinas.

- VALENÇA, J.G.; SILVA, M.A.; SCHIMITT, R.S.; TROUW, R.A.J. & NOCE, C.M., 2000. Transamazonian gabbro-noritic intrusive rocks from the southernmost São Francisco Craton (Brazil). In: INTERNATIONAL GEOLOGICAL CONGRESS, 31., 2000, Rio de Janeiro, Brazil. **Abstracts...**, Rio de Janeiro: Sociedade Brasileira de Geologia (Published in CD-ROM).
- WEAVER, B.L. & TARNEY, J., 1982. Andesitic magmatism and continental growth. In: THORPE, R.S. (Ed.) **Andesites**. Nova York: John Wiley & Sons. p.639-661.