

## Petrology of metabasaltic dykes in the Diamantina region, Minas Gerais, Brazil

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**ABSTRACT.** — A sequence of mafic dykes is found in the Diamantina region (Minas Gerais, Brazil) at the eastern border of the southern São Francisco Craton. The dykes have been distinguished into four groups on the basis of petrography and geochemical characteristics. Groups 1 to 3 cut the rock sequence older than Meso-Proterozoic, but do not cut the Neo-Proterozoic rocks, thus constraining their emplacement age. Group 1 is constituted by fine grained, sometimes foliated metabasites, which only exceptionally preserve relics of the primary mineral assemblage, and are located only in the lowest stratigraphic units of the Espinhaço Supergroup, suggesting an older emplacement age with respect to the other groups. Group 2 and 3 metabasites are better preserved than those of Group 1. Group 4 represents a single igneous body virtually non metamorphic. Its age is not constrained, but it is similar to Mesozoic dykes occurring further south in this region.

In all groups, composition is basaltic with tholeiitic affinity. Metamorphic element mobility substantially affected only the LILE, whereas igneous variation trends are preserved for all the other elements. The various groups differ for their incompatible trace element composition and ratios. These ratios are more similar to OIB (Ocean Island Basalt) values rather than to any other magma type.

Geochemical evidence rules out any important influence of crustal contamination, fractional crystallisation, or variable degrees of melting of a common source material as an explanation for the inter-group variability. It is inferred that the geochemistry of the different groups reflects complementary characteristics and differences of their mantle sources. These latter are attributed either to a metasomatic enrichment of a variably depleted premetasomatic mantle by a component with OIB characteristics, or, alternatively (our preferred interpretation), to the melting of the metasomatised mantle at different depths. The metasomatised sources underwent extensive melting, producing tholeiitic melts retaining OIB-like geochemical characteristics. By analogy with OIB, the metasomatic component may be plume-related. Dyke emplacement may be controlled by passive crustal rifting induced by plume-related mantle diapirs. In such a scenario, the Group 1 samples could be related to the initial rifting phase and plume impingement in the lithosphere, whereas Groups 2 and 3 could represent advanced stages of crustal thinning and melting of the plume head source. The youngest Group 4 dykes presumably represent a limited and local occurrence of the Mesozoic mafic magmatism which affects the area of the Serra do Espinhaço.

**RIASSUNTO.** — È stata studiata una sequenza di dicchi metabasaltici affioranti nella regione di

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Diamantina (Minas Gerais, Brasile), al bordo orientale della porzione meridionale del cratone São Francisco. I dicchi sono stati distinti in 4 gruppi sulla base delle loro caratteristiche petrografiche e geochimiche. I dicchi appartenenti ai gruppi da 1 a 3 affiorano nelle sequenze di rocce più antiche del Meso-Proterozoico, ma non si rinvennero in quelle più recenti, fornendo così il limite superiore alla loro età di messa in posto. Il gruppo 1 è costituito da dicchi metabasaltici a grana fine, talvolta foliati, che soltanto in casi molto rari preservano relitti della loro paragenesi primaria. Essi affiorano soltanto nelle unità stratigrafiche più basse del Supergruppo Espinhaço, suggerendo un'età di messa in posto più antica rispetto a quella degli altri gruppi. Le metabasiti dei gruppi 2 e 3 sono meglio conservate rispetto a quelle del gruppo 1. Il gruppo 4 rappresenta un singolo corpo igneo non metamorfico. Al momento non esistono indicazioni certe sulla sua età di messa in posto, tuttavia tale corpo mostra forti somiglianze con dicchi Mesozoici che affiorano a Sud della zona studiata.

I dicchi di tutti i gruppi hanno composizione basaltica con affinità tholeiitica. I diagrammi di variazione sono consistenti con processi ignei per tutti gli elementi ad eccezione dei LILE, che sono stati interessati da mobilità metamorfica. I 4 gruppi mostrano differenze tra di loro per quanto riguarda la concentrazione e i rapporti degli elementi in tracce incompatibili. Tali rapporti assomigliano di più a quelli dei basalti di isole oceaniche (OIB), piuttosto che a quelli di ogni altro tipo di magma. Le caratteristiche geochimiche escludono che le differenze tra i 4 gruppi dipendano in maniera significativa da processi di contaminazione crostale, cristallizzazione frazionata o da differenti gradi di fusione parziale della stessa sorgente. Tali differenze vengono attribuite a caratteristiche complementari di sorgenti di mantello diverse, dovute ad arricchimento metasomatico di un mantello premetasomatico variamente impoverito, oppure (nostra interpretazione preferita) alla fusione di mantello metasomatizzato a profondità differenti. Le sorgenti metasomatizzate subirono un esteso processo di fusione, tale da produrre fusi tholeiitici con caratteristiche geochimiche simili a quelle di OIB. Il componente metasomatico potrebbe essere collegato all'esistenza di un «plume» di mantello, analogamente a quanto viene invocato per la genesi di OIB. La messa in posto dei dicchi potrebbe essere controllata da «rifting» passivo crostale indotto da diapiri di mantello, legati alla presenza di «plume». In questo scenario i dicchi del gruppo 1 potrebbero essere collegati alle fasi iniziali del «rifting» e all'interferenza del «plume» con la litosfera, mentre i gruppi 2 e 3 potrebbero rappresentare stadi

avanzati di assottigliamento crostale e di fusione della testa del «plume». I dicchi più giovani del gruppo 4 rappresentano presumibilmente una occorrenza limitata e locale del magmatismo basico Mesozoico che ha interessato l'area della Serra do Espinhaço.

KEY WORDS: *Mafic Dykes, Diamantina, Serra do Espinhaço, Proterozoic Mantle.*

## INTRODUCTION

Abundant literature and specific international symposia have stressed the bearing of the mafic dyke swarms in continental areas as indicators of petrological processes in their mantle sources and of crustal emplacement and the potential petrological and geochemical constraints on the geotectonic environment. We pursued these objectives by studying a sequence of Meso- to Early Neo-Proterozoic metamorphic dykes in the Diamantina region (Minas Gerais, Brazil). The Diamantina region is a part of the southern Serra do Espinhaço, which belongs to the external zone of the West-Congo - Araçuaí fold-thrust belt, along the southeastern margin of the Neo-Proterozoic São Francisco Craton (see also Cordani and Sato, 1999; Almeida *et al.*, 2000, Martins-Neto, 2000). The West-Congo - Araçuaí belt records a complicated geological evolution during the Proterozoic (e.g., Pedrosa Soares *et al.*, 1998). In the southern Serra do Espinhaço, the Espinhaço Supergroup is the predominant unit. It represents an intracontinental sequence developed in a rift-sag basin mainly during the Paleo- and Meso-Proterozoic (Almeida *et al.*, 2000, Martins-Neto, 2000). This sequence is dominantly constituted by continental to shallow marine, sedimentary protholiths in greenschist metamorphic grade, with acid volcanism and granitic suites emplaced into the edges of the rift. The sedimentologic, petrographic, stratigraphic, structural and tectonic characteristics of this sequence are reported in Martins-Neto (2000). It overlaps a basement of Transamazonian age (The Archean

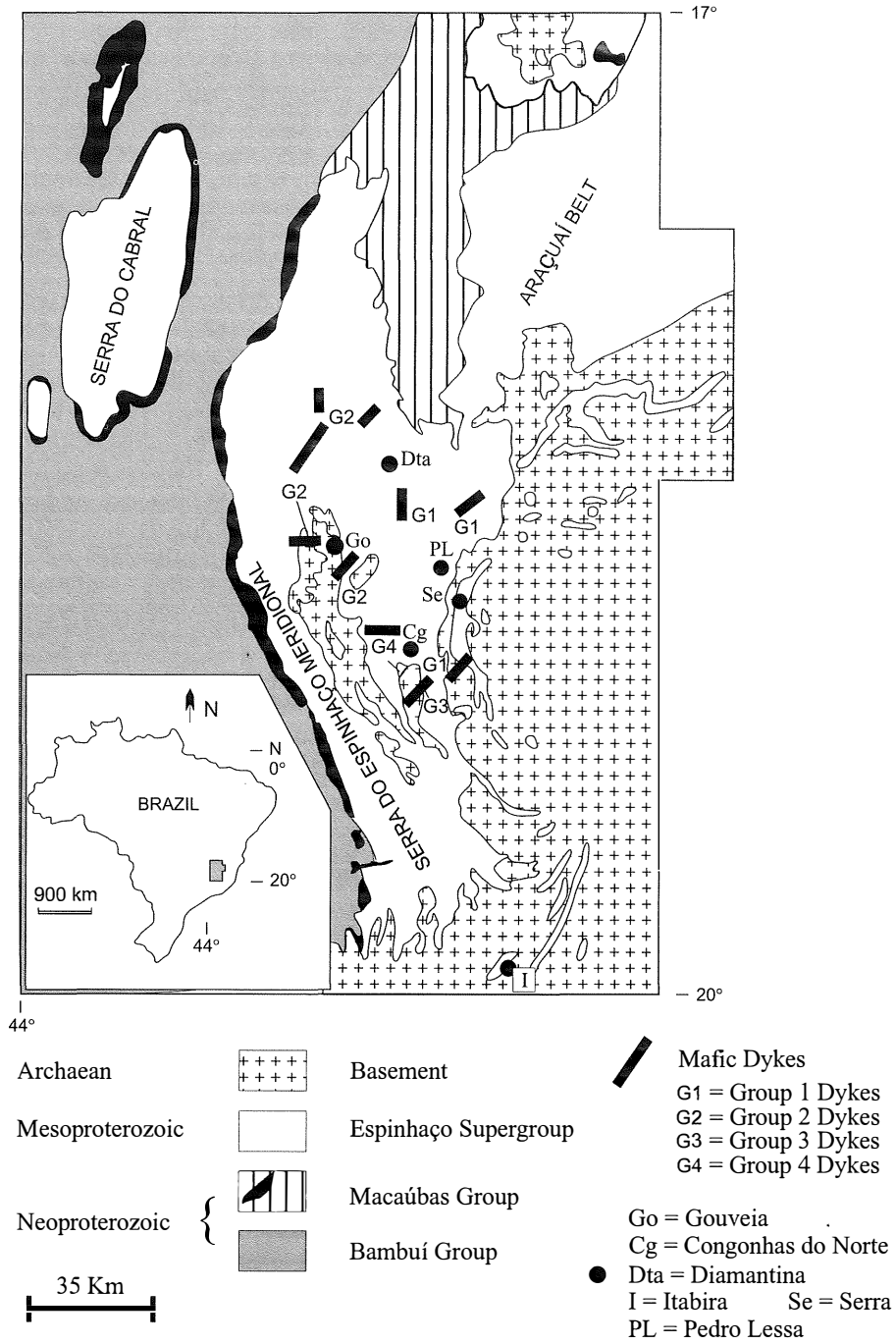


Fig. 1 – Geological Sketch Map with the Diamantina dyke occurrences.

to Paleo-Proterozoic Rio Paraúna Supergroup, Pflug, 1965), and is in turn unconformably overlain by the Neo-Proterozoic São Francisco Supergroup (Pflug and Renger, 1973; Dupont, 1996; Martins-Neto *et al.*, 2000). Its actual extension is  $1000 \times 400$  km, but it was at least twice before deformation (e.g., Machado *et al.*, 1989; Cordani *et al.*, 1992; Babinski *et al.*, 1994). At the end of Mesoproterozoic, the Espinhaço megasequence was part of the Rodinia supercontinent (Hoffman, 1991), whose relics are recognised both in Africa and Brazil (see for review, Teixeira *et al.*, 1999). Geological evidence indicates that the Rodinia supercontinent was disrupted by extension between Meso- and Neo-Proterozoic (Porada, 1989; Brito Neves *et al.* 1995). Several mafic dyke swarms formed due to the extensional regime which disrupted Rodinia, as suggested by U-Pb and  $^{40}\text{Ar}/^{39}\text{Ar}$  ages on individual dykes occurring in various localities along the eastern sector of the São Francisco Craton: Salvador (1003 – 926 Ma); Olivença-Itaju do Colônia (1078 – 1035 Ma), Ilhéus (1012 Ma), Pedro Lessa in the southern Espinhaço (906 Ma) – (e.g., Machado *et al.*, 1989; Renne *et al.*, 1990; Heaman, 1991; Dossin, 1994; Dossin *et al.*, 1995; Almeida Abreu, 1995). In Pedro Lessa (located 36 Km Southeast of Diamantina) intrusive field relations reveal that the dykes post-date the Espinhaço rocks, and pre-date the overlying Neoproterozoic sedimentary sequences (Bambuú and Macaubas) which formed around between 900 and 700 Ma, due to the development of the Araçuaí belt. The studied Diamantina dyke swarm or swarms filled extensional NS, EW and NE fractures and are intrusive into the Espinhaço Supergroup and the underlying crystalline basement. Therefore, their emplacement took place probably during the Meso- to early Neo-Proterozoic time as the other dykes mentioned above. Finally, the rocks of the southern Serra do Espinhaço were deformed and metamorphosed during the PanAfrican-Brasiliano event (around 600 Ma, Brito Neves *et al.*, 1979, Marshak and Alkmin, 1989).

#### LOCATION AND PETROGRAPHY

Because of intense weathering, the mafic bodies are poorly exposed and contacts are invariably hidden. The presumed thickness of the individual bodies exceed 10 m. They appear as dykes or sills in the outcropping areas of the Mesoproterozoic formations and the crystalline basement (fig. 1). As shown later, they will be distinguished into four groups on the basis of their geochemistry. These groups also correspond with different geographic distributions (fig. 1). Group 1 (8 dykes sampled) is constituted by fine grained, sometimes foliated metabasites which only exceptionally preserve relics of the primary mineral assemblage. They currently consist of actinolite-chlorite schists and amphibolites, where, besides amphibole and chlorite, the other metamorphic minerals are epidote, quartz, sodic plagioclase and leucoxene. Ophitic texture is preserved only in a few samples, where plagioclase is only partially altered and clinopyroxene is largely chloritized. The Group 1 mafic bodies occur only in the lowest stratigraphic units of the Espinhaço Supergroup, occurring in the western part of the study area (São João da Chapada and Sopa Brumadinho formations see Menezes Leal *et al.*, 1999 and Martins-Neto, 2000, for reference).

Group 2 and 3 metabasites (13 and 4 dykes sampled, respectively), occur in the terrains of the western part of the study area. The dominant texture is ophitic. Primary igneous minerals are plagioclase and clinopyroxene, partially transformed into the metamorphic mineral assemblage described in the Group 1 metabasites. Relics of the primary mineral assemblage are more abundant than in Group 1.

Group 4, represents a single igneous body virtually non metamorphic and, therefore, probably the youngest in age. Similar non metamorphic dykes, yielding a K/Ar whole rock age of 120Ma, are found in the Quadrilátero Ferrífero, 150 Km south of Diamantina (Moreira Silva *et al.*, 1995). The dominant texture in Group 4 rocks is porphyric,

where large euhedral or subeuhedral clinopyroxene crystals contain poikilitically inclusions of euhedral plagioclase. Transformation into tremolitic amphibole of the clinopyroxene rim is common. Epidote is a frequent secondary phase from plagioclase. Quartz occurs with plagioclase in the groundmass.

#### ANALYTICAL TECHNIQUES

We analysed 64 whole rock samples for major and trace elements (representative analyses are reported in Table 1) by X-Ray Fluorescence Spectrometry (XRF). 18 of these samples were analysed for Y and REE (Table 1) by Inductively Coupled Plasma - Mass Spectrometry (ICP-MS) and 13 samples for Nd and Sr isotopes (Table 2) by Mass Spectrometry (MS).

XRF analyses were carried out at the Dipartimento di Scienze della Terra dell'Università degli Studi di Modena e Reggio Emilia, Italy, by wavelength dispersive X-Ray fluorescence (Philips PW1480) on pressed powder pellets, using the methods of Franzini *et al.* (1975) and Leoni and Saitta (1976). Analyses are considered accurate to within 2-5% for major elements and less than 10% for trace elements. FeO was determined as total iron oxide.

ICP-MS analyses were carried out at the XRAL Laboratories (a Division of SGS - Société Générale de Surveillance S.A. - Canada Inc.) with Na<sub>2</sub>O<sub>2</sub> fusion technique. Detection limits are: 0.05 ppm for Eu and Ho, 0.2 ppm for Pr, 0.1 ppm for the other REE and 1 ppm for Y.

The Rb-Sr and Sm-Nd whole rock isotope analyses (Table 2) were carried out at the Geochronological Research Center (CPGeo) of the University of São Paulo, Brazil. The <sup>87</sup>Sr/<sup>86</sup>Sr values determined by isotope dilution are listed with absolute errors, and have been corrected to the mean value of the NBS-987 standard [0.710254 ± 0.000022]. The measured <sup>87</sup>Sr/<sup>86</sup>Sr values were normalised to <sup>87</sup>Sr/<sup>86</sup>Sr =

0.1194. The overall blank for the chemical procedure was 4 ng for Sr. A two column technique was used for the Sm-Nd analyses: firstly and ion exchange resin was employed for separation of the REE, and a second, HDEHP-coated Teflon powder column for separation of Sm and Nd. Details of the analytical procedures are given in Sato *et al.* (1995). The laboratory blanks for Nd and Sm during the period of analysis yield maximum values of 70 and 30 pg, respectively. Isotopic ratios for Rb-Sr and Sm-Nd were measured on the VG-354 multi- and single-collector mass spectrometer of the CPGeo.

#### GEOCHEMISTRY

Because of the metamorphic overprint of the studied rocks, element mobility should preliminarily be considered. There are, however, no definite criteria for assessing element behaviour during metamorphism. An example of contrasting conclusions reached by different authors, and the present lack of unequivocal tools for defining metamorphic element mobility, is provided by Grauch (1989) for REE. Verma (1992) sustains substantial changes in element concentration and ratios during sea-water alteration of ocean-ridge basalts, whereas Rollinson and Windley (1980) infer substantial element immobility.

A possible way for establishing metamorphic element mobility has been proposed by Beswick (1982) who indicates that in MPR (molecular proportion ratio, Pearce, 1968) plots elements which suffered metamorphic redistribution produce fan-like point spreading or correlations passing through the origin of the diagram (zero intercept). These types of diagrams have been variably criticised in the literature (e.g. Rollinson, 1993). Applied to the present case they show metamorphic mobility for K, Rb and Sr, but not for the other incompatible elements. This result may be consistent with the fact that metamorphism is open to water circulation and LILE have the highest solubility in hydrous fluids.

TABLE 1  
*Selected whole rock major and trace element analyses for Group 1 to 4 Diamantina dykes.*

Sample	Group 1					Group 2					Group 3			Group 4				
	DI-2	DI-3	DI-5	DI-6	DI-25	DI-26	DI-21	DI-30	DI-32	DI-55	DI-58	DI-59	DI-41	DI-44	DI-48	DI-49	DI-35	DI-36
<i>XRF (Wt%)</i>																		
SiO <sub>2</sub>	47.77	47.41	48.12	48.16	49.42	49.21	49.97	48.91	49.06	47.87	48.13	47.07	48.40	48.87	48.12	48.30	48.12	48.21
TiO <sub>2</sub>	1.06	0.91	1.02	1.08	1.12	1.90	2.02	1.63	1.64	1.41	1.40	1.20	2.17	2.42	1.81	2.02	3.16	3.28
Al <sub>2</sub> O <sub>3</sub>	13.11	13.31	15.30	14.90	15.84	12.25	14.35	15.26	13.97	14.18	14.53	14.10	13.71	12.64	12.05	13.99	14.56	13.87
Fe <sub>2</sub> O <sub>3</sub>	1.52	1.57	1.34	1.41	1.39	1.93	1.69	1.54	1.53	1.42	1.37	1.44	1.81	1.94	1.77	1.76	1.56	1.60
FeO	10.15	10.44	8.96	9.39	9.24	12.88	11.24	10.27	10.18	9.45	9.16	9.57	12.04	12.91	11.77	11.72	10.39	10.66
MnO	0.17	0.17	0.16	0.16	0.16	0.20	0.17	0.16	0.16	0.16	0.16	0.16	0.18	0.18	0.18	0.18	0.16	0.16
MgO	12.32	12.48	10.00	10.55	7.95	8.15	6.03	7.85	9.21	10.39	10.28	11.98	6.81	6.56	9.50	7.04	7.80	8.25
CaO	10.55	10.42	11.33	10.78	10.31	9.74	9.59	9.98	9.88	11.25	11.05	11.19	9.24	9.25	10.22	9.53	8.61	9.05
Na <sub>2</sub> O	1.80	1.67	1.99	2.11	3.04	1.88	2.99	2.75	2.67	2.20	1.98	1.59	2.98	2.76	2.33	3.05	3.24	2.78
K <sub>2</sub> O	0.33	0.33	0.67	0.29	0.37	0.23	0.44	0.24	0.28	0.43	0.75	0.50	0.84	0.47	0.64	0.72	0.52	0.28
P <sub>2</sub> O <sub>5</sub>	0.10	0.13	0.11	0.12	0.14	0.19	0.27	0.26	0.28	0.17	0.18	0.13	0.47	0.54	0.31	0.41	0.72	0.68
L.O.I.	2.69	2.66	2.02	2.02	2.33	2.53	2.00	2.26	2.43	1.80	2.02	2.19	1.17	1.55	1.38	1.19	1.37	1.94
Mg#	65.59	65.24	63.67	63.83	57.45	49.83	45.72	54.54	58.69	63.32	63.80	66.28	47.03	44.37	55.89	48.54	54.09	54.85
<i>XRF (ppm)</i>																		
Sc	40	38	40	37	35	41	37	35	37	42	40	42	35	36	42	34	31	32
V	260	243	242	249	243	389	364	272	296	293	289	266	417	447	391	382	392	401
Cr	360	334	269	307	55	31	87	187	256	458	492	707	127	92	230	123	167	177
Co	69	73	53	58	45	72	41	46	46	44	50	56	45	45	56	46	41	42
Ni	157	167	112	123	65	60	59	83	104	151	163	197	84	69	135	93	106	108
Cu	48	55	58	67	76	141	168	49	93	109	99	79	147	161	96	122	83	85
Zn	94	94	85	91	85	144	125	116	108	103	101	100	157	139	126	138	126	118
Rb	<3	<3	10	<3	<3	<3	18	<3	6	8	15	3	19	8	18	16	3	<3
Sr	339	398	381	363	426	430	314	352	319	276	311	217	396	444	321	418	859	911
Zr	90	85	88	96	114	145	221	180	186	124	128	104	204	230	153	180	177	170
Nb	12	13	13	11	15	22	20	19	18	12	11	11	16	17	12	15	27	27
Ba	140	138	188	123	121	107	174	118	92	121	172	131	403	217	256	348	490	365
Pb	12	9	6	8	5	10	14	13	11	9	4	6	15	16	9	15	10	7

Fe<sub>2</sub>O<sub>3</sub> and FeO were calculated from FeO<sub>tot</sub> (total iron oxide), assuming a ratio Fe<sub>2</sub>O<sub>3</sub>/FeO = 0.15.

TABLE 1: *continued*

Sample	Group 1					Group 2					Group 3				Group 4			
	DI-2	DI-3	DI-5	DI-6	DI-25	DI-26	DI-21	DI-30	DI-32	DI-55	DI-58	DI-59	DI-41	DI-44	DI-48	DI-49	DI-35	DI-36
<i>ICP-MS (ppm)</i>																		
Y	14	13	12	13	16	23	30	23	22	18	19	16	29	32	22	24	25	22
La	11	12	11	11.5	14.5	18	18.5	18	18	12	13	11.5	20.5	22	14	18	30	27
Ce	22.5	25.5	23.5	25.5	29.5	39	41	37.5	39	24	26	22.5	46	51.5	32.5	40.5	67.5	60
Pr	3.1	3.4	3.2	3.4	4	5.3	5.8	5.1	5.2	3.6	3.8	3.2	6.1	7.1	4.3	5.5	9.2	8.2
Nd	13	14.5	14.5	14	17	22.5	25	21	24	15.5	16.5	15	29	32	22	25.5	44.5	36
Sm	2.8	2.8	3.4	3.1	3.2	5	5.4	4.3	4.5	3.8	4.2	3.7	6.4	7.1	4.9	5.7	9	7.2
Eu	1	1.1	1.1	1.4	1.1	1.7	1.9	1.6	1.8	1.2	1.3	1	2.4	2.6	1.8	2.2	3.4	3.3
Gd	2.9	3	2.6	2.8	3.3	4.5	6.2	5.1	4.5	4	4.6	4	6.7	7.8	5.3	6.8	7.6	6.3
Tb	0.5	0.5	0.4	0.5	0.6	0.7	1.1	0.8	0.9	0.6	0.6	0.5	1.1	1.2	0.8	1.1	1.1	1.1
Dy	2.5	2.3	2.6	2.6	2.7	4.1	5.7	4.1	3.9	3.3	3.6	3.2	5.4	6.2	4.1	5.2	4.6	4.2
Ho	0.6	0.5	0.4	0.5	0.6	0.9	1.3	1	0.9	0.8	0.8	0.7	1.2	1.3	1	1	1.1	0.9
Er	1.5	1.3	1.3	1.5	1.6	2.2	3.5	2.5	2.7	2.5	2.2	1.5	3.7	3.1	2.4	3.2	2.4	2.3
Tm	0.1	0.2	0.1	0.1	0.2	0.3	0.4	0.4	0.3	0.3	0.3	0.3	0.5	0.5	0.3	0.4	0.4	0.3
Yb	1.6	1.3	1	1.1	1.6	2.1	3	1.9	1.9	2	2.1	1.5	2.7	3	2.2	2.6	1.9	1.7
Lu	0.2	0.2	0.2	0.2	0.2	0.3	0.5	0.3	0.3	0.3	0.3	0.3	0.5	0.5	0.3	0.3	0.3	0.1

TABLE 2  
*Rb-Sr and Sm-Nd isotope compositions of selected samples of Group 1 to 4.*

Group	Rb	Sr	$^{87}\text{Rb}/^{86}\text{Sr}$	$^{87}\text{Sr}/^{86}\text{Sr}$	error	Sm	$\text{Nd}^{147}\text{Sm}/^{144}\text{Nd}$	error $^{143}\text{Nd}/^{144}\text{Nd}$	error			
DI-2	1	<3	339	<0.0171		<b>2.908</b>	<b>12.283</b>	<b>0.1432</b>	<b>0.00005</b>	0.512220	0.000011	
DI-5	1	10	381	0.0759	0.70737	0.00012	3.4	14.5	0.1411			
DI-25	1	<3	426	<0.0136		<b>3.505</b>	<b>15.921</b>	<b>0.1331</b>	<b>0.00004</b>	0.512164	0.000010	
DI-26	1	<3	430	<0.0135	0.70651	0.00007	5	22.5	0.1338	0.512168	0.000009	
DI-11	2	<3	248	<0.0233	0.70657	0.00012	<b>3.689</b>	<b>14.498</b>	<b>0.1539</b>	<b>0.00005</b>	0.512337	0.000017
DI-21	2	18	314	0.1659	0.71478	0.00009	5.4	25	0.1300	0.512272	0.000011	
DI-30	2	<3	352	<0.0164	0.70708	0.00025	<b>4.788</b>	<b>20.506</b>	<b>0.1412</b>	<b>0.00005</b>	0.512314	0.000020
DI-55	2	8	276	0.0839	0.71430	0.00014	<b>3.665</b>	<b>14.427</b>	<b>0.1536</b>	<b>0.00005</b>	0.512358	0.000022
DI-59	2	3	217	0.0400	0.70720	0.00012	3.7	15	0.1485	0.512237	0.000011	
DI-44	3	8	444	0.0521	0.71333	0.00009	7.1	32	0.1335	0.512273	0.000011	
DI-48	3	18	321	0.1623	0.70803	0.00008	4.9	22	0.1341	0.512281	0.000007	
DI-50	3	17	416	0.1182	0.70805	0.00017	<b>5.645</b>	<b>22.778</b>	<b>0.1499</b>	<b>0.00005</b>	0.512254	0.000010
DI-35	4	3	859	0.0101	0.70680	0.00009	9	44.5	0.1217	0.512163	0.000012	

Data for Rb and Sr is by XRF determination. Data for Sm and Nd is by ICP-MS or IDMS (in bold) determination. Errors are at 1s level. The average values measured for the La Jolla Nd and BCR-1 standards are  $0.511849 \pm 0.000025$  and  $0.512662 \pm 0.000027$ , respectively, with errors at 1s level.



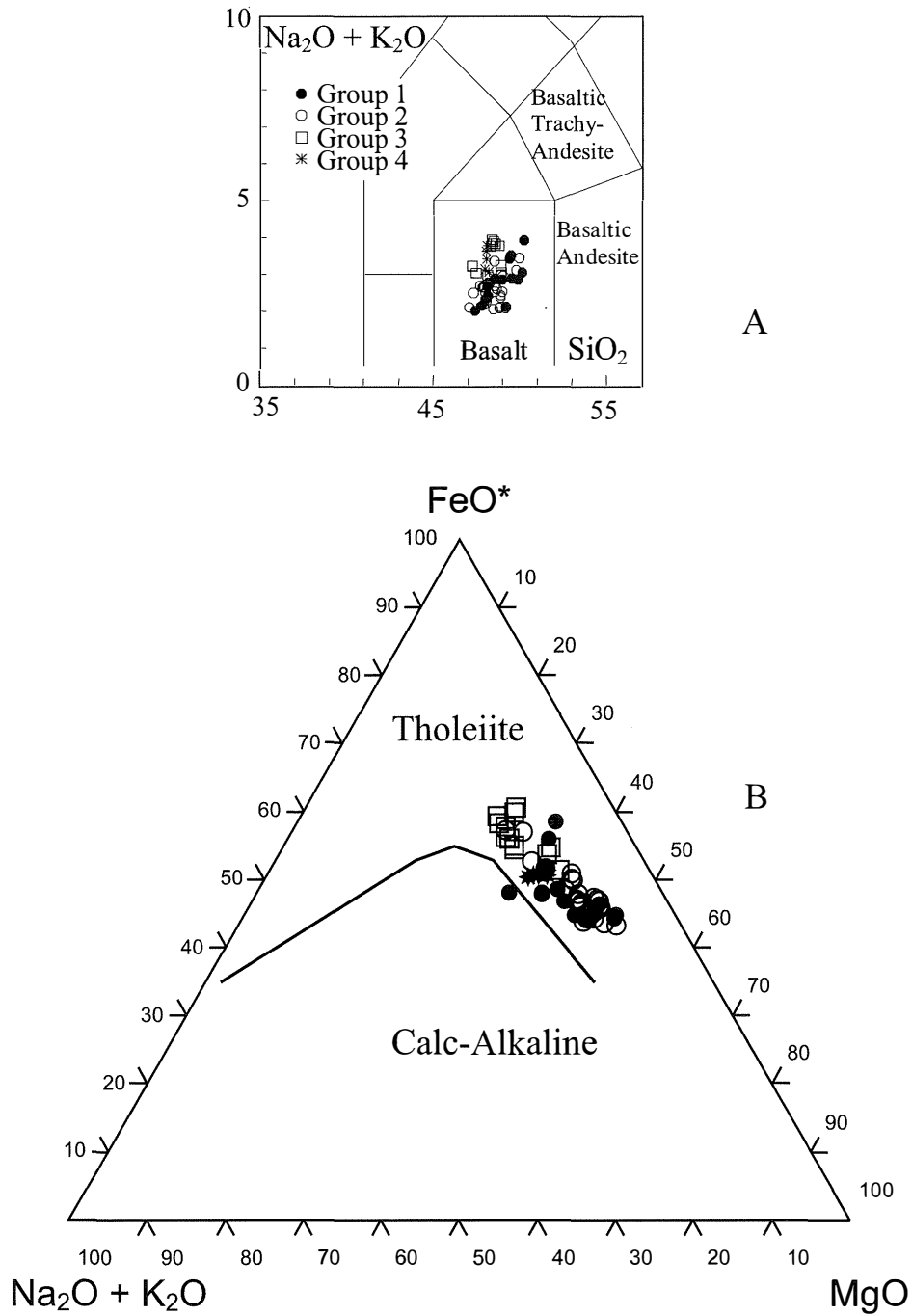


Fig. 2 – A = Total alkalies vs  $\text{SiO}_2$  and B = AFM diagram for Group 1 to 4 Diamantina dykes.

In view of the uncertainties on element mobility, we assume that chemical variation trends consistent with igneous processes (either fractional crystallisation or different melting degrees of the source) are relatively unaffected by metamorphism and can be used to infer

premetamorphic characteristics of the rock suite.

The Diamantina dykes are basalts with tholeiitic affinity, according to the AFM diagram (fig. 2). Inter-element variations of REE and HFSE display good correlation and

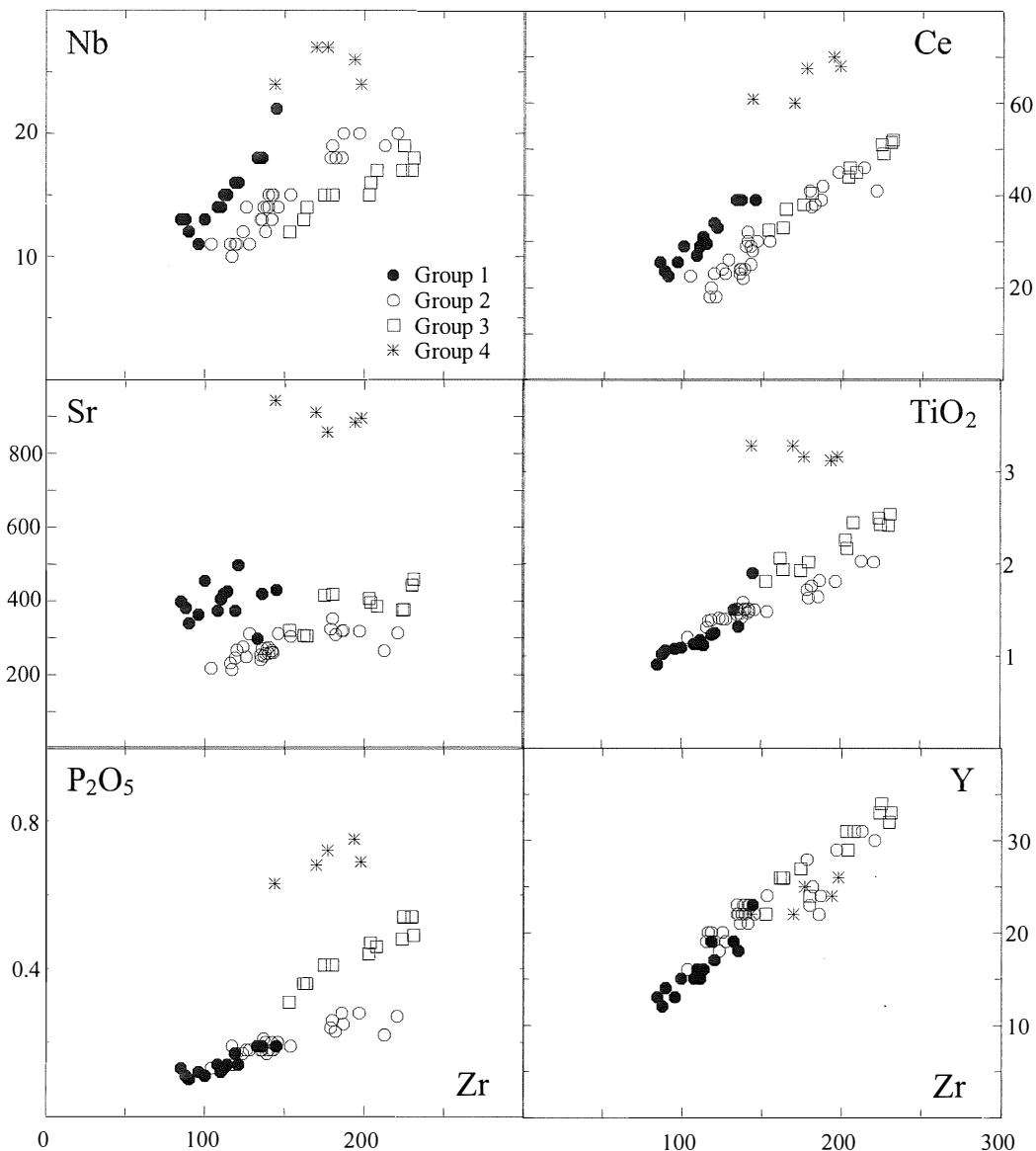


Fig. 3 – Selected trace element vs Zr for Group 1 to 4 Diamantina dykes.

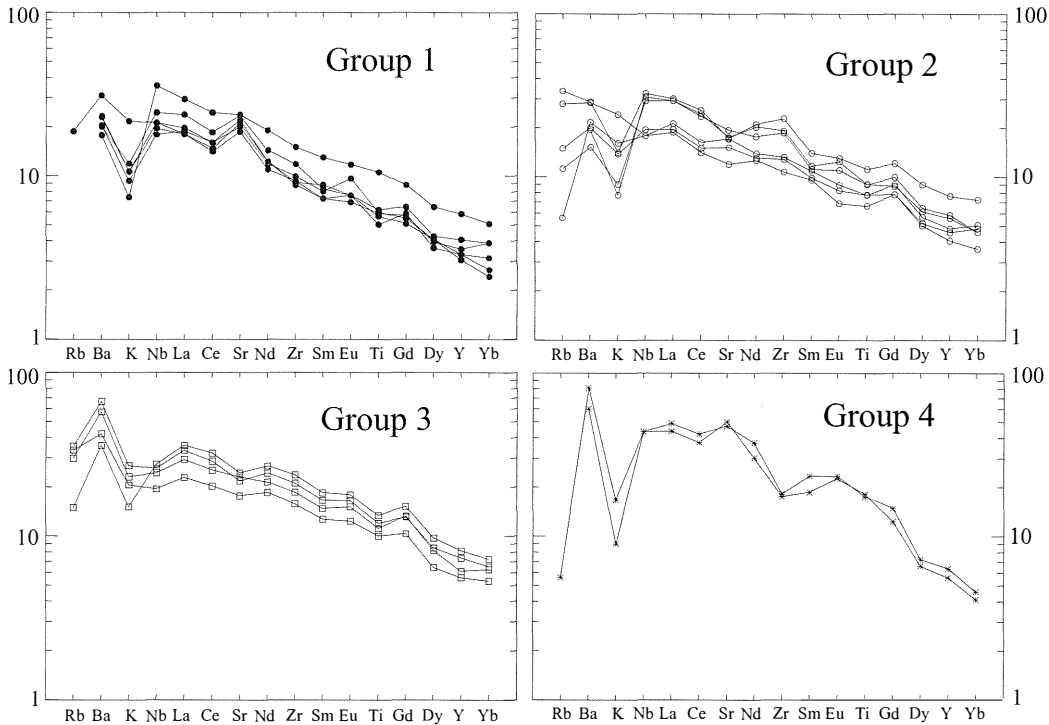


Fig. 4 – Incompatible trace element variation pattern normalized to the Primitive Mantle (Hofmann, 1988) for Group 1 to 4 Diamantina dykes.

discriminate the samples into four groups (fig. 3). Group 1 has a Zr concentration range between 80 and 150ppm. In this range Zr directly correlates with all the other incompatible elements except LILE, which show sample spreading, and Sr, which displays little variation between 300 and 500 ppm. With respect to Group 2, Group 1 rocks have higher concentration of LREE, MREE and Nb, slightly lower concentration of Ti and similar P concentration. Group 2 has a comparatively wider Zr concentration range than Group 1. Group 3 parallels, and in some cases overlaps, the variation trends of Group 2 at higher incompatible element concentrations. Group 4 is constituted by samples of only one igneous body, which, at a given Zr concentration, have markedly higher concentrations of all other incompatible elements, except Y. The four groups also differ for their REE patterns (more

steep in Group 4 and progressively smoother from 1 to 3, fig. 4 and Table 3) and for a large number of additional characteristics summarised in Table 3.

The four groups defined on the basis of incompatible trace elements have also distinct major element variation trends as show in the Mg# [ $100 \times \text{MgO}/(\text{MgO} + \text{FeO}_{\text{tot}})$  molar ratio] diagrams in figs. 5a and 5b. Variation trends suggest that Group 1 was dominated by fractional crystallisation of olivine in the Mg# range 65.2 – 57.5, followed or accompanied by plagioclase and clinopyroxene in more advanced crystallisation stages. Unlike Group 1, in Group 2 and 3 fractional crystallisation is dominated by plagioclase and clinopyroxene in all the Mg# range observed. This fractionation scheme is supported by the bulk  $D_{\text{Ni}}$  calculated from the Ni-incompatible element relationships, which results higher in Group 1

TABLE 3

Average and Standard Deviations ( $1\sigma$ ) of incompatible element ratios for Group 1 to 4 Diamantina dykes and for other localities.

		Rb/Sr	La/Nb	Ba/Nb	Zr/Nb	Ti/Nb	Ti/Zr	P/Zr	Zr/Y	Ti/Y	(La/Yb) <sub>n</sub>	(Sm/Yb) <sub>n</sub>	(Ce/Y) <sub>n</sub>	
Diamantina	Group 1	<b>Average</b>	<b>0.03</b>	<b>0.92</b>	<b>10.5</b>	<b>7.5</b>	<b>484</b>	<b>65.1</b>	<b>5.5</b>	<b>6.6</b>	<b>428</b>	<b>6.2</b>	<b>2.6</b>	<b>4.0</b>
		<i>St. Dev.</i>	0.01	0.08	3.7	0.5	41	5.2	0.6	0.6	30	0.9	0.6	0.2
	Group 2	<b>Average</b>	<b>0.04</b>	<b>1.02</b>	<b>9.9</b>	<b>10.3</b>	<b>644</b>	<b>62.6</b>	<b>5.8</b>	<b>6.4</b>	<b>401</b>	<b>5.1</b>	<b>2.3</b>	<b>3.3</b>
		<i>St. Dev.</i>	0.01	0.08	3.0	0.7	72	5.0	0.5	0.6	18	1.0	0.3	0.5
Diamantina	Group 3	<b>Average</b>	<b>0.05</b>	<b>1.24</b>	<b>21.6</b>	<b>12.5</b>	<b>849</b>	<b>67.8</b>	<b>9.7</b>	<b>6.6</b>	<b>447</b>	<b>4.8</b>	<b>2.5</b>	<b>3.6</b>
		<i>St. Dev.</i>	0.01	0.05	4.5	0.6	53	3.6	0.5	0.2	16	0.3	0.1	0.2
	Group 4	<b>Average</b>	<b>0.004</b>	<b>1.06</b>	<b>16.6</b>	<b>6.9</b>	<b>752</b>	<b>110.3</b>	<b>17.3</b>	<b>7.2</b>	<b>783</b>	<b>10.7</b>	<b>4.8</b>	<b>6.2</b>
		<i>St. Dev.</i>	0.000	0.06	2.5	0.8	45	15.1	1.3	0.6	60	0.0	0.3	0.2
São Francisco. Rio de La Plata and Rodinia Proterozoic Dykes	Uauá	<b>Average</b>	<b>0.10</b>	<b>1.93</b>	<b>82.8</b>	<b>10.5</b>	<b>1430</b>	<b>135.3</b>	<b>11.5</b>	<b>1.9</b>	<b>255</b>		<b>1.8</b>	
		<i>St. Dev.</i>	0.03	0.95	108.4	3.3	488	21.7	2.1	0.6	52		1.0	
	Salvador	<b>Average</b>	<b>0.09</b>	<b>1.71</b>	<b>31.0</b>	<b>9.3</b>	<b>972</b>	<b>103.3</b>	<b>13.6</b>	<b>3.7</b>	<b>386</b>		<b>2.8</b>	
		<i>St. Dev.</i>	0.02	0.26	10.4	1.9	258	9.2	4.0	0.4	42		1.1	
	Itajú do Colônia	<b>Average</b>	<b>0.08</b>	<b>1.25</b>	<b>18.6</b>	<b>13.0</b>	<b>1128</b>	<b>88.0</b>	<b>9.4</b>	<b>4.2</b>	<b>361</b>		<b>2.6</b>	
		<i>St. Dev.</i>	0.03	0.21	4.3	1.7	105	12.6	2.2	0.6	26		0.4	
	Oliveira Ilheus	<b>Average</b>	<b>0.08</b>	<b>1.33</b>	<b>21.2</b>	<b>12.7</b>	<b>1150</b>	<b>91.0</b>	<b>9.1</b>	<b>4.1</b>	<b>366</b>		<b>2.7</b>	
		<i>St. Dev.</i>	0.03	0.32	6.9	1.7	219	15.7	1.9	0.6	46		0.7	
	R. das Neves	<b>Average</b>	<b>0.16</b>	<b>1.89</b>	<b>35.0</b>	<b>14.6</b>	<b>1364</b>	<b>95.3</b>	<b>8.0</b>	<b>4.0</b>	<b>354</b>	<b>3.9</b>	<b>1.9</b>	<b>2.8</b>
		<i>St. Dev.</i>	0.08	0.29	17.7	1.5	244	25.9	0.9	1.4	77	1.8	0.5	1.1
S Espi- naço	<b>Average</b>						<b>208.8</b>	<b>18.0</b>	<b>3.8</b>	<b>490</b>				
	<i>St. Dev.</i>						141.0	10.3	3.6	228				
Uruguay	<b>Average</b>	<b>0.02</b>	<b>1.30</b>	<b>21.9</b>	<b>16.9</b>	<b>1133</b>	<b>68.3</b>	<b>9.0</b>	<b>7.1</b>	<b>478</b>		<b>0.9</b>		
	<i>St. Dev.</i>	0.01	0.30	6.5	3.5	191	10.7	2.1	0.9	60		1.6		

TABLE 3: *continued*

		Rb/Sr	La/Nb	Ba/Nb	Zr/Nb	Ti/Nb	Ti/Zr	P/Zr	Zr/Y	Ti/Y	(La/Yb) <sub>n</sub>	(Sm/Yb) <sub>n</sub>	(Ce/Y) <sub>n</sub>	
OIB	Gough	<b>Average</b>	<b>0.06</b>	<b>0.97</b>	<b>16.1</b>	<b>6.8</b>	<b>445</b>	<b>60.2</b>	<b>9.1</b>	<b>12.7</b>	<b>762</b>		<b>8</b>	
		<i>St. Dev.</i>	<i>0.01</i>	<i>0.13</i>	<i>2.8</i>	<i>0.8</i>	<i>37</i>	<i>0.8</i>	<i>0.7</i>	<i>1.2</i>	<i>66</i>		<i>0.9</i>	
	Tristan da Cunha	<b>Average</b>	<b>0.04</b>	<b>0.86</b>	<b>11.4</b>	<b>4.2</b>	<b>282</b>	<b>61.2</b>	<b>10.7</b>	<b>10.7</b>	<b>651</b>		<b>10.8</b>	
		<i>St. Dev.</i>	<i>0.01</i>	<i>0.06</i>	<i>0.8</i>	<i>0.4</i>	<i>43</i>	<i>5.2</i>	<i>2.6</i>	<i>0.6</i>	<i>27</i>		<i>1.2</i>	
	St. Helena	<b>Average</b>	<b>0.03</b>	<b>0.69</b>	<b>5.9</b>	<b>4.5</b>	<b>312</b>	<b>70.5</b>	<b>10.4</b>	<b>9.3</b>	<b>642</b>		<b>7.3</b>	
	<i>St. Dev.</i>	<i>0.01</i>	<i>0.03</i>	<i>0.2</i>	<i>0.2</i>	<i>53</i>	<i>13.2</i>	<i>0.7</i>	<i>1.0</i>	<i>65</i>		<i>0.9</i>		
	Ascension	<b>Average</b>	<b>0.07</b>	<b>0.65</b>	<b>6.8</b>	<b>5.3</b>	<b>374</b>	<b>69.9</b>	<b>12.8</b>	<b>7.4</b>	<b>486</b>		<b>4.6</b>	
		<i>St. Dev.</i>	<i>0.04</i>	<i>0.04</i>	<i>0.5</i>	<i>0.4</i>	<i>90</i>	<i>16.7</i>	<i>2.8</i>	<i>2.4</i>	<i>85</i>		<i>0.5</i>	
	Bouvet	<b>Average</b>	<b>0.05</b>	<b>0.68</b>	<b>6.0</b>	<b>6.9</b>	<b>507</b>	<b>73.1</b>	<b>8.8</b>	<b>7.1</b>	<b>520</b>		<b>3.9</b>	
		<i>St. Dev.</i>	<i>0.01</i>	<i>0.04</i>	<i>0.3</i>	<i>0.3</i>	<i>32</i>	<i>6.4</i>	<i>0.2</i>	<i>0.2</i>	<i>40</i>		<i>0.1</i>	
OIT	Hawaii	<b>Average</b>	<b>0.03</b>	<b>0.83</b>	<b>6.8</b>	<b>12.1</b>	<b>926</b>	<b>86.3</b>	<b>6.5</b>	<b>6.4</b>	<b>488</b>	<b>3.8</b>	<b>2.9</b>	<b>2.9</b>
		<i>St. Dev.</i>	<i>0.01</i>	<i>0.03</i>	<i>0.3</i>	<i>0.3</i>	<i>56</i>	<i>21.7</i>	<i>0.1</i>	<i>0.3</i>	<i>18</i>	<i>1.0</i>	<i>0.4</i>	<i>0.1</i>
	Iceland	<b>Average</b>	<b>0.04</b>	<b>0.92</b>	<b>5.5</b>	<b>9.4</b>	<b>986</b>	<b>102.0</b>	<b>8.1</b>	<b>3.7</b>	<b>366</b>	<b>2.4</b>	<b>1.5</b>	<b>1.8</b>
		<i>St. Dev.</i>	<i>0.01</i>	<i>0.22</i>	<i>1.1</i>	<i>2.1</i>	<i>414</i>	<i>19.7</i>	<i>2.2</i>	<i>0.5</i>	<i>23</i>	<i>0.4</i>	<i>0.1</i>	<i>0.4</i>

Data Sources: Uauá = Bellieni *et al.* (1995); Salvador = Moraes Brito *et al.* (1989), Bellieni *et al.* (1998); Itajú do Colonia = Tanner de Oliveira (1989), Araujo *et al.* (1992); Olivença Ilheus = Bellieni *et al.* (1991); Ribeirão das Neves = Chaves *et al.*, (1996); Southern Espinhaço = Moreira Silva *et al.*, (1995), Uruguay = Mazzucchelli *et al.*, (1995); Gough, Tristan da Cunha, St. Helena, Ascension and Bouvet = Weaver *et al.* (1987); Hawaii = Budahn and Schmitt (1985), Yang *et al.* (1994); Iceland = Macdonald *et al.* (1990)

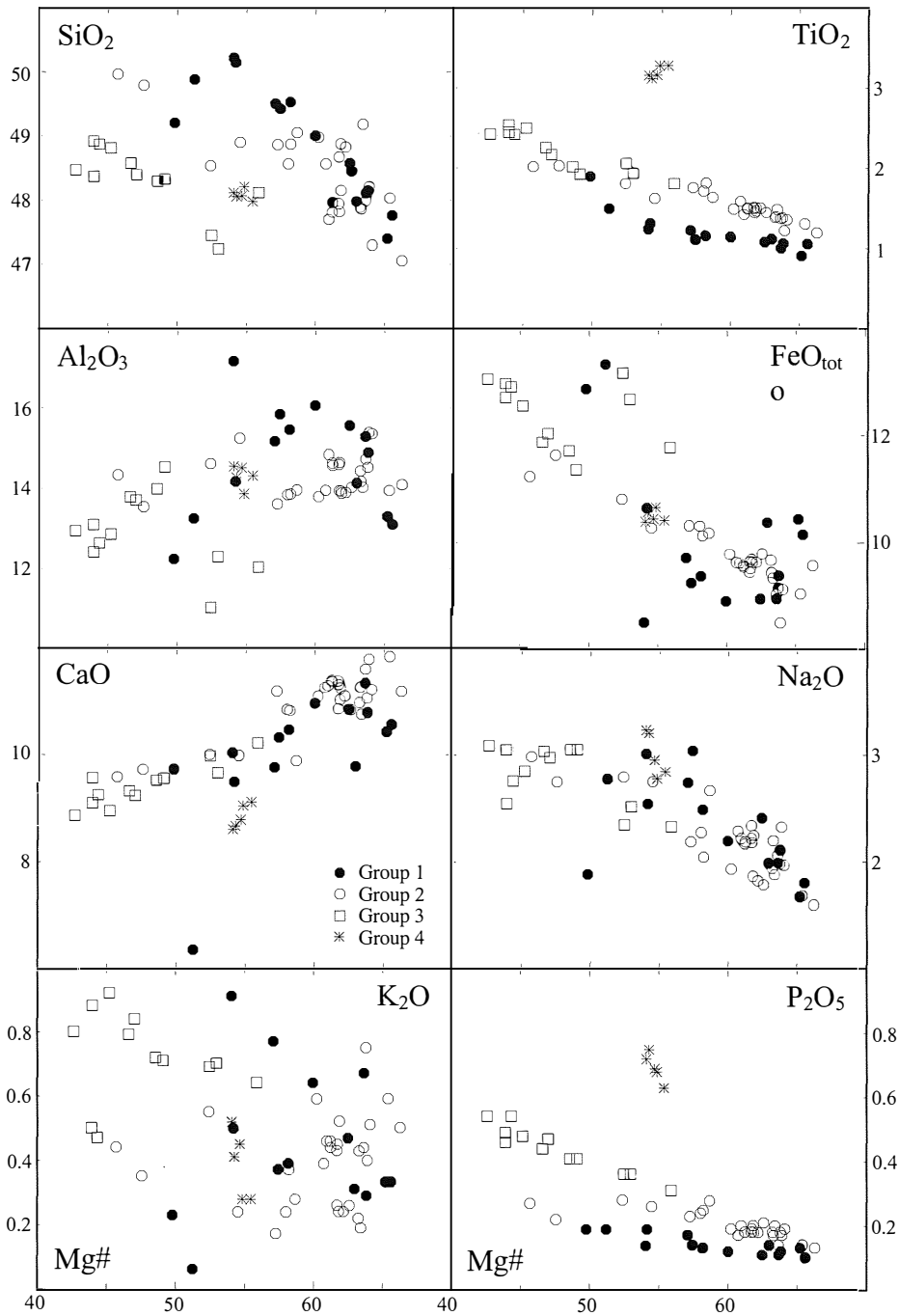


Fig. 5A – Major element vs Mg# [ $\text{MgO}/(\text{MgO}+\text{FeO}_{\text{tot}})$  molar ratio] for Group 1 to 4 Diamantina dykes.

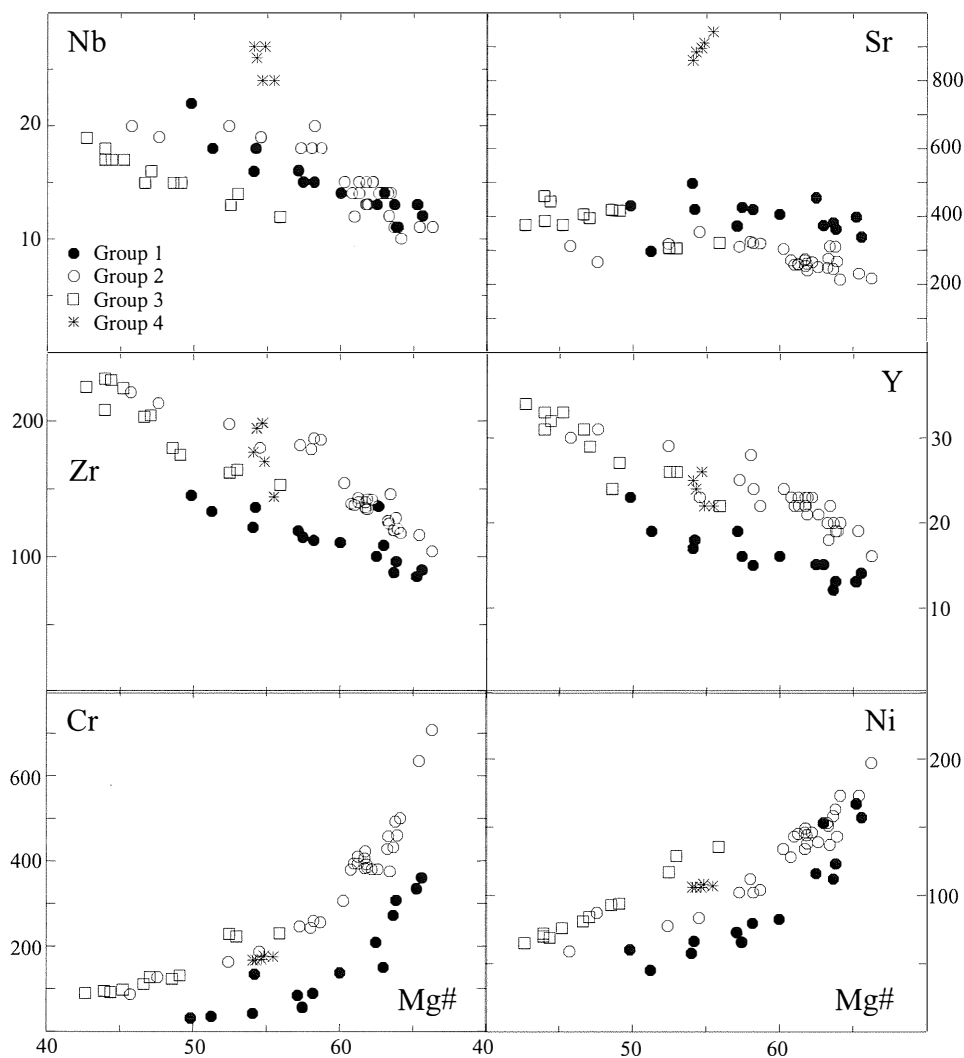


Fig. 5B – Selected trace element vs Mg# [ $MgO/(MgO+FeO_{tot})$  molar ratio] for Group 1 to 4 Diamantina dykes.

with respect to Group 2 and 3 (fig. 6). By considering the incompatible element Nb, Ce, Zr and P, bulk  $D_{Ni}$  varies as follows: Group 1 = 2.4 - 3.2, Group 2 = 2.1 - 2.3, Group 3 = 2.0 - 2.7, respectively. Early olivine-dominated fractional crystallisation in Group 1 is also supported by mass balance calculations, which show that by subtraction from sample Di-3 ( $Mg\# = 65.2$ ) 15 wt% of its equilibrium olivine

(Fo 87), the composition of Di-25 ( $Mg\# = 57.5$ ) is obtained.

#### ND AND SR ISOTOPES

Isotope determinations on selected samples are reported in Table 2. The Sr isotopes do not provide any age indication, as expected due to

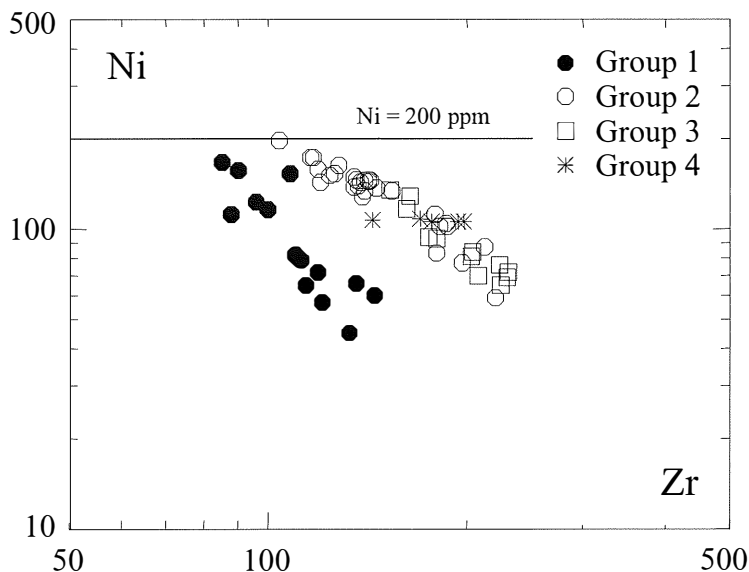


Fig. 6 – Plot of Ni vs Zr for Group 1 to 4 Diamantina dykes. The trend slope ( $m$ ) for each group is proportional to the bulk  $D_{Ni}$  of the fractionating mineral assemblage by the relation:  $D_{Ni} = 1 - m$ .

the metamorphic mobility of Rb (and probably Sr). Thirteen Sm/Nd analyses yielded two isotopic trends in a  $^{143}\text{Nd}/^{144}\text{Nd} - ^{147}\text{Sm}/^{144}\text{Nd}$  diagram (fig. 7a). The steeper slope trend is defined by all the Group 1 samples and by two other samples of Group 2 and Group 3. The other trend is defined by the remaining Group 2 and Group 3 samples. Because of the narrow isotope variation range, no reliable age can be calculated from these arrays, although the samples with the steeper slope may be older than the others. CHUR model ages of the samples with the steeper slope are in the range 1131 – 1258 Ma, with the others in the range 832 – 1064 Ma (fig. 8). Model ages with respect to a depleted source are in the ranges 1646 – 1862 and 1391 – 1779 Ma respectively, with positive  $\epsilon\text{Nd}$  (3.8 – 4.0 and 4.0 – 4.8, respectively).  $\epsilon\text{Nd}$  values were also recalculated according to the emplacement ages (1100 - 900 Ma) defined for the Meso- and Early Neo-Proterozoic dykes of the eastern São Francisco Craton and generally considered reliable for the dykes in the Espinhaço Supergroup (see

Almeida *et al.*, 2000). At 900 Ma, most Group 2 and Group 3 samples have  $\epsilon\text{Nd}$  values close to those of the CHUR, whereas the single Group 1 sample has negative  $\epsilon\text{Nd}$  values at about  $-2$  (fig. 7b). This negative value moves close to CHUR values by recalculating  $\epsilon\text{Nd}$  at 1100 Ma (fig. 7c), whilst most of the other samples yield values at  $+1.5$  at this age.

#### REASONS FOR THE INTER-GROUP VARIABILITY

The data presented so far indicates that Group 1 has significant geochemical differences with respect to the other groups, whereas minor differences distinguish Groups 2 and 3. Group 4 is also geochemically distinct, but the few samples constituting this Group are collected in only one body and have, therefore, doubtful regional significance. The characteristics of the various groups are summarised by the incompatible element ratios



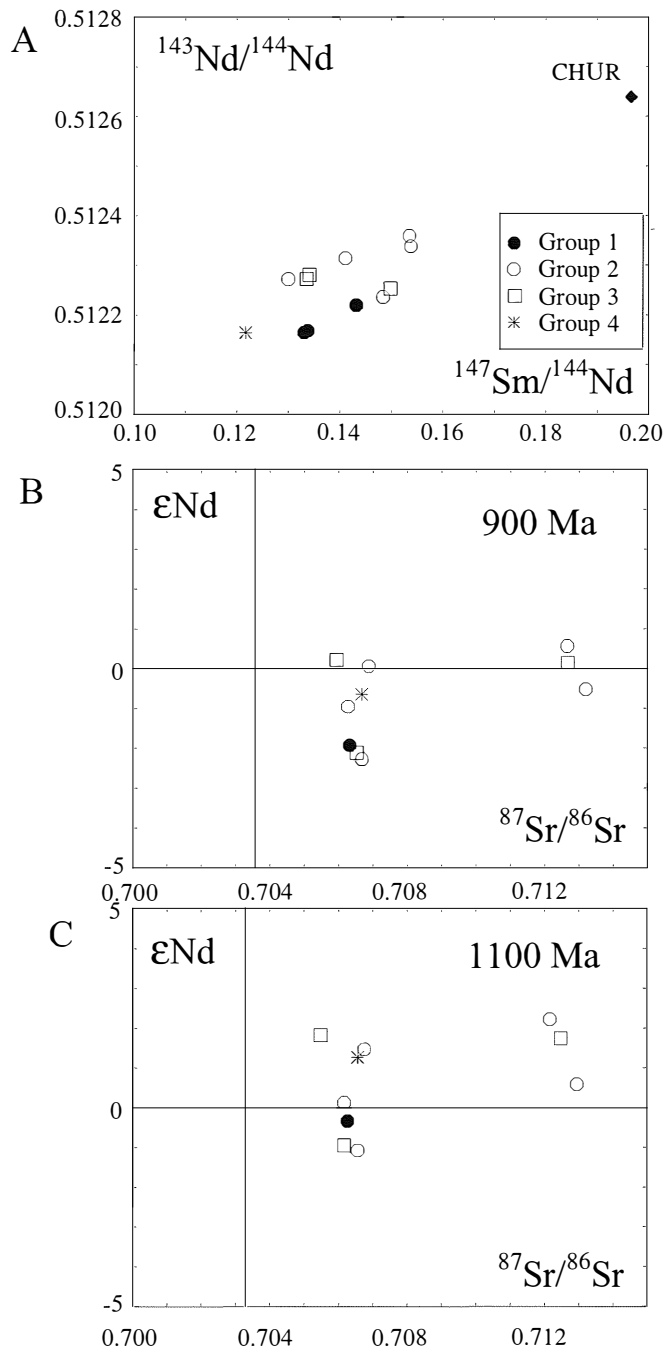


Fig. 7 – A) =  $^{143}\text{Nd}/^{144}\text{Nd}$  vs  $^{147}\text{Sm}/^{144}\text{Nd}$ ; B) =  $\epsilon\text{Nd}$  vs  $^{87}\text{Sr}/^{86}\text{Sr}$  at the assumed age of 900 Ma; C) =  $\epsilon\text{Nd}$  vs  $^{87}\text{Sr}/^{86}\text{Sr}$  at the assumed age of 1100 Ma for Group 1 to 4 Diamantina dykes.

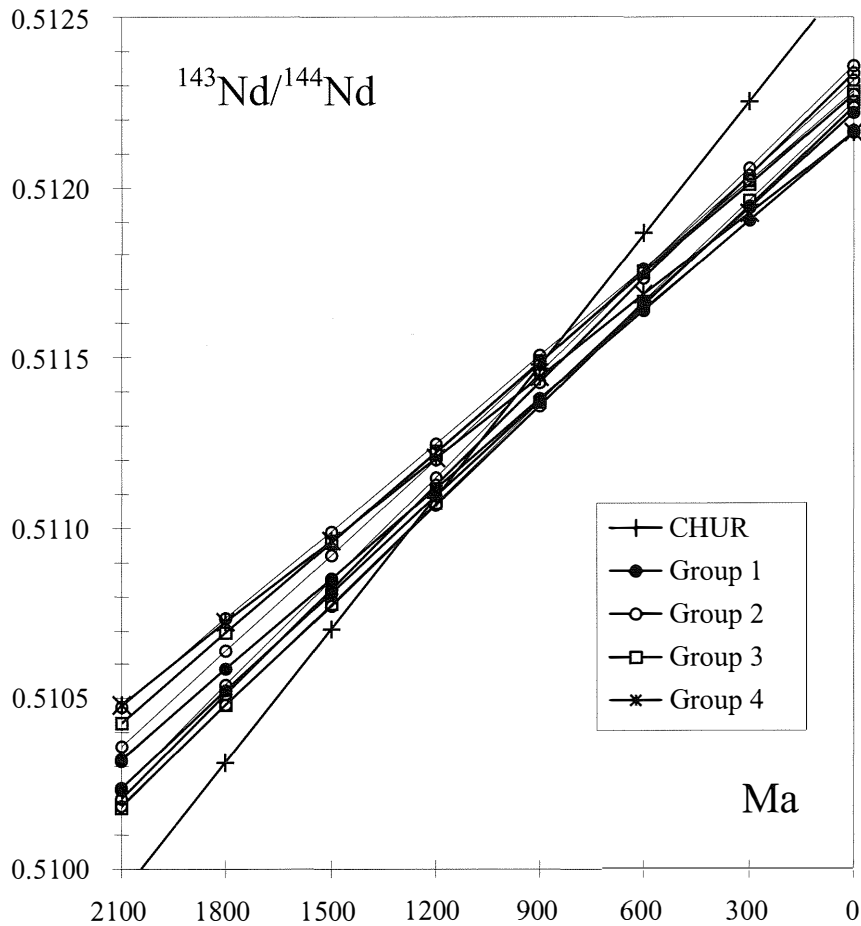


Fig. 8 – Sm/Nd model ages for Group 1 to 4 Diamantina dykes. CHUR present values:  $^{143}\text{Nd}/^{144}\text{Nd} = 0.512638$ ;  $^{147}\text{Sm}/^{144}\text{Nd} = 0.1967$ .

reported in Table 3, supporting the geochemical distinction of the groups. When compared with ratio values of basalts of different geological settings, those of the Diamantina dykes are more similar to OIB (Ocean Island Basalts) or OIT (Ocean Island Tholeiites) values rather than any other magma type. The inter-group geochemical variation, may depend on variable crustal contamination during crustal emplacement, or on different

fractionation assemblages, or finally, on different composition and/or degrees of melting of their respective mantle sources.

#### *Crustal contamination*

Interaction of mafic melts with a crustal component is documented by the variation in the hybrid melt of the elements which are enriched, like LILE, or depleted, like Ti and

Nb, in the crust with respect to mantle-derived melts. Because of their metamorphic mobility, LILE cannot provide firm indications in the present case, although the very low K<sub>2</sub>O and Rb concentrations in Group 1 rocks do not suggest any important crustal interaction. Sizeable negative Ti and Nb anomalies, typical of crustally contaminated rocks, are absent in Groups 1, 2 and 4, and are only weak in Group 3. The <sup>87</sup>Sr/<sup>86</sup>Sr is high, and remains such even recalculated at Paleo-Proterozoic ages (>0.704, fig. 7). However, in view of the Rb and Sr metamorphic mobility, the use of the Sr isotope is probably pointless, as already seen. We conclude that geochemical evidence rules out any important influence of crustal contamination.

#### *Fractional crystallisation*

Fractional crystallisation can only negligibly change the ratio value of incompatible trace elements because in Rayleigh fractionation the variation of the ratio is proportional to  $F^{(D_a - D_b)}$  (where F is the fraction of remaining liquid and D<sub>a</sub> and D<sub>b</sub> are the bulk partition coefficients of element a and b, respectively). Calculations of the fractionation degree necessary to account for the incompatible element ratio variation between Group 1 and 2 gives inconsistent results.

#### *Variable degrees of melting of a common source material*

An alternative possibility is that the various groups derive from different degrees of melting of a source of similar composition. During melting, all the ratios having the more incompatible element as the denominator will increase with increasing partial melting (and vice-versa if it is the numerator). From Table 3, it therefore results that, if the source is of constant composition, in most cases the degree of melting should decrease from Group 3 to Group 1. Possible exceptions are Ti/Zr and P/Zr, but the inter-group variation is within the error of each group. Group 4 gives contrasting

indications, because ratios such as Ti/Nb, Ti/Zr would indicate the highest degree of melting and Zr/Nb, Ti/Y, P/Zr, and La/Yb the lowest. However, estimates of the parent melt composition of the various groups indicates that different melting degrees can hardly explain the inter-group differences. The incompatible element contents of parent melts for Groups 1-3 have been estimated by calculating the incompatible element intercept at Ni = 200 ppm in logarithmic diagrams of incompatible elements versus Ni (see an example in fig. 6). The results (Table 4 and fig. 9) qualitatively indicate that the incompatible trace element concentration in the parent melt of Group 1 is lower than that of the parent melts of the Groups 2 and 3, and not higher as would be expected from a lower melting degree. Furthermore, Group 1 depletion is more marked for the moderately incompatible elements (Ti to Y) than for the more incompatible ones (Nb to Zr) and this is the opposite of what would be expected if Group 1 parent magma corresponds with the lowest degree of melting.

TABLE 4  
*Estimated parent melts for Group 1 to 3.*

	Group 1	Group 2	Group 3
La	9.15	11.13	10.57
Ce	19.07	21.76	24.36
Nd	11.20	14.20	17.05
Sm	2.22	3.58	3.83
Gd	2.12	3.77	4.21
Dy	1.88	2.98	3.22
Er	1.06	1.64	1.58
Yb	0.68	1.41	1.83
Zr	76	105	116
Ti	4460	7278	8585
Nb	9.47	9.70	9.70
Y	11.12	17.73	19.81

Estimates were made assuming Ni = 200 ppm in the parent melt.

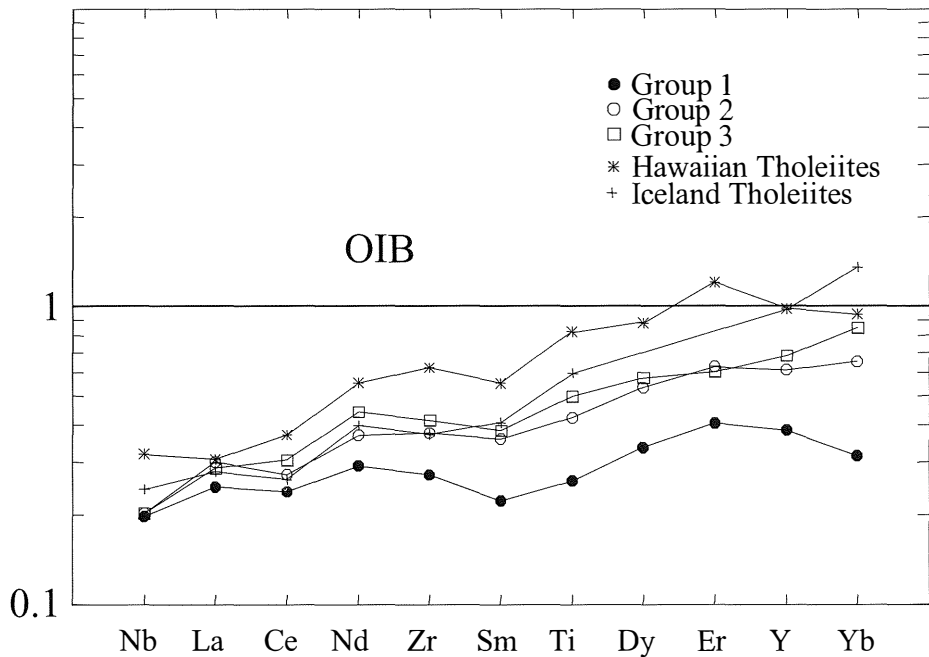


Fig. 9 – Incompatible trace element variation patterns normalised to the OIB composition (Sun and McDonough, 1989) showing the estimated parent melt of the Group 1 to 3 Diamantina dykes and the average Hawaiian (Budahn and Schmitt, 1985; Yang *et al.*, 1994) and Iceland (Macdonald *et al.*, 1990) Tholeiite composition. See text for further explanations. S. Paulo, Brazil.

#### Source composition

The points discussed above suggest that the geochemistry of the mafic rocks reflects that of their mantle sources, which had varying compositions from Group 1 to the others. The Diamantina dykes have tholeiitic affinity, like most of the Proterozoic dyke swarms from the São Francisco, Rio de La Plata and Rodinia cratons (e.g. Uauá, Salvador, Olivença-Ilhéus, Itaju do Colônia, Ribeirão das Neves, Southern Espinhaço, Uruguay, see references in Table 3 caption). Nevertheless, the element ratios of all four Diamantina groups (Table 3) have in common their similarity with those of OIB, rather than with those of the above mentioned other Proterozoic dyke swarms in the eastern part of the South America continent, or with any other magma-type. The composition of the calculated parent melts of Groups 1 to 3, normalised to OIB is plotted in fig. 9 together

with OIB compositions. Groups 2 and 3 have trace element patterns similar to those of OIB whereas Group 1 has a slightly fractionated patterns roughly paralleling OIB at lower trace element concentrations. The difference between Group 1 and the others is small for the most incompatible elements (from Nb to Ce) and it is very large from Sm to Yb. It is therefore obvious that Group 1 and the others cannot be related by different melting degrees of the same source, as already concluded in the preceding paragraph, because variable melting would affect more the concentration of the most incompatible elements with respect to the moderately incompatible ones. The observed differences suggest that the metasomatic agent (OIB-like) affected a mantle which recorded previous variable depletion degrees, being the highest premetasomatic depletion that of the Group 1 source. Alternatively, and more

probably, Group 1 and the others may derive from a metasomatised garnet- and spinel-facies peridotite, respectively.

#### GEODYNAMIC INDICATIONS FROM THE MAFIC ROCKS

The geochemical features discussed above indicate that a depleted mantle source was metasomatically enriched by a component having OIB characteristics, and underwent extensive melting producing tholeiitic melts retaining OIB-like geochemical characteristics. We suggest that, by analogy with OIB, the component which enriched the depleted mantle is likely to be plume-related. In such a case, the potential scenario envisaged from the present samples is that of passive crustal rifting induced by plume-related mantle diapirs (Anderson *et al.*, 1992; Saunders *et al.*, 1992). In this case, the Group 1 samples could be related with the initial rifting phase and plume impingement in the lithosphere, and, if the Group 1 source was in garnet facies, these melts could represent asthenospheric products with little or absent contribution from the lithospheric mantle. The other two groups could represent advanced stages of crustal thinning, lithosphere erosion and melting of the plume head source. Such a scenario requires, however, isotopic constraints on the relative age of the dyke groups. The isotope indications are at present equivocal. Model ages point to at least two distinct melting and melt intrusion episodes, of which the older is represented dominantly by Group 1 samples. The difference between the two episodes is about 200 Ma, which appears to be too long a time span for maintaining a fixed plume interference on continental crust. The older age of the Group 1 samples is, on the other hand, supported by other qualitative indications, such as the fact that Group 1 rocks have a stronger metamorphic imprint with respect to the others, and the observation that these mafic magmas affect only the older Espinhaço units (São João da Chapada and Sopa Brumadinho), whereas the other mafic bodies affect all the formations.

Further speculations suggest that Group 1 and Groups 2 + 3 mafic rocks could, respectively, represent mantle melting products arising during the early and late stages of the breaking of the Rodinia Supercontinent at the limit between Meso and Neo-Proterozoic. If such is the case, then the various groups cannot be related to the same plume effect. However, the inferred age differences of the various groups are poorly constrained. Alternatively, if the three groups of mafic rocks were synchronous, the isotope data could indicate metasomatism of a plume component on a variably depleted mantle, thus reconciling their characteristics with the effects of only one plume which acted possibly at the end of the Mesoproterozoic.

#### CONCLUSIONS

In the Diamantina area basaltic dykes intruded the Espinhaço Supergroup belonging to the Neoproterozoic Araçuaí-West Congo fold belt. The geochemical features of the dykes allow the discrimination of the samples into four groups, with Group 1 comparatively enriched in the most incompatible elements with respect to Group 2 and 3. Group 4 is represented by a single igneous body. All the Diamantina dykes show a tholeiitic affinity (indicated by major element composition), like most of the Proterozoic dyke swarms from the Rodinia Supercontinent. In spite of this, the element ratios of the Diamantina dykes are quite similar to those of OIB. The geochemical characteristics of the Diamantina dykes are consistent with the derivation of primary melts from a mantle metasomatised by an OIB component. The differences between Group 1 and the others require either a higher depletion of the Group 1 premetasomatic source or a difference in the depths of the metasomatised mantle (garnet-facies for Group 1 and spinel-facies for the others). The tholeiitic character suggests a relatively high degree of melting. It is possible that the OIB trace element signature is related to a plume component which impinged the «Espinhaço» lithospheric mantle

and triggered its melting during the Meso and Neo-Proterozoic. However, the age of dyke emplacement is poorly constrained by the present data. It is possible that Group 1 dykes are about 200 Ma older with respect to Group 2 and 3 dykes (1100 Ma and 900 Ma, respectively), as suggested by the stronger metamorphic imprint of the Group 1 dykes and the field relationships with the country rocks. If true, the Group 1 rocks and those of Groups 2 and 3 could, respectively, be connected with mantle melting episodes related to early and late stages of the breaking of the Rodinia supercontinent. Group 4 dykes are virtually non metamorphic and, therefore, the youngest in age. Presumably they represent a limited and local occurrence of the Mesozoic mafic magmatism which affected the area of the Serra do Espinhaço (Almeida *et al.*, 2000), with isotopic ages ranging from 220 up to 170 Ma in the southern part (Dossin *et al.*, 1995, Moreira Silva *et al.*, 1995).

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