

LREE-ENRICHED KOMATIITES FROM CRIXÁS, CENTRAL BRAZIL

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The Crixás greenstone belt is located in the central portion of Goiás State, Central Brazil, and is made up of three volcano-sedimentary belts: the Crixás, Guarinos and Pilar de Goiás belts. The basal portion of the greenstone belt is characterized by spinifex-textured metaperidotites (STPK), metapyroxenites (STPYK) and pillowed metabasalts (BK with subordinate tholeiites) with occasional lenses of metacherts and iron-formations. Sm/Nd unpublished data (U.G. Cordani, personal communication) indicates an age of 2.6 Ga for the Crixás mafic-ultramafic rocks.

The lower mafic-ultramafic volcanic unit is overlain by chemical and pelitic metasediments represented by graphite- and chlorite-schists, iron-formations, metacherts and calc-silicate rocks. Gold mineralization associated with the iron-formations and metacherts appears mainly along the axial zones of isoclinal folds.

The volcano-sedimentary belts are surrounded by granite-gneiss domes of the Goiano Complex, which consists of hornblende and biotite granitoid-gneiss-migmatites with tonalitic-granodioritic-granitic compositions.

Geochronological information on the Goiano Complex (Tassinari & Montalvão, 1980; Montalvão, 1985) indicates, using a Rb/Sr reference isochron, an age of 2.47 Ga and a  $^{87}\text{Sr}/^{86}\text{Sr}$  initial ratio of 0.701. A  $^{207}\text{Pb}/^{204}\text{Pb}$  isochron yielded an age of 2.48 Ga with a  $\mu_1$  value of 7.7 suggesting a mantle origin. Another Rb/Sr reference isochron indicates an age of 2.93 Ga with a  $^{87}\text{Sr}/^{86}\text{Sr}$  initial ratio of 0.700 leading to the idea that the Goiano Complex might be an

Archean multi-intrusive unit. The Hidrolina dome which appears to be intrusive into the greenstone belt lithologies is made up of granitoid-gneiss-migmatites with mafic-ultramafic enclaves and is composed of diorite-quartz diorite-quartz monzonite-granites with a Rb/Sr reference isochron age of 2.12 Ga and a  $^{87}\text{Sr}/^{86}\text{Sr}$  initial ratio of 0.702, also consistent with a mantle origin (Montalvão, 1985).

The mafic-ultramafic rocks of the Crixás greestone belt have undergone a series of mineralogical changes either during late-magmatic and metamorphic stages, or due to seawater interaction. Rocks preserving primary features such as porphyritic, cumulitic, skeletal and spinifex textures, and lacking orientation, possibly have been altered during seawater interaction or during late-magmatic transformations. Serpentinization, talcification, carbonization, amphibolitization, chloritization and tourmalinization are considered to be the most important types of alteration in the Crixás rocks (Montalvão et al., 1982). The formation of opaque minerals, mainly magnetite, is also related to some of the alteration stages.

Major and trace element data (Montalvão et al., 1982; Kuyumjian & Dardenne, 1982; Montalvão, 1985) indicate that the mafic-ultramafic rocks of the Crixás greenstone belt have a komatiitic-tholeiitic trend with peridotitic, pyroxenitic and basaltic komatiites and subordinate tholeiites (Table 1).

In terms of major and trace element contents the Crixás komatiites are quite similar to typical komatiites from other regions of the world. One anomalous feature for the ultramafic komatiites from Crixás is the low  $\text{CaO}/\text{Al}_2\text{O}_3$  ratio of 0.66. Also, the Crixás ultramafic rocks have higher levels of Rb and Ba and lower Sr contents (averages: 12 ppm for Rb, 28 ppm for Ba and 16 ppm for Sr) compared to typical komatiites (averages: 2.2 ppm for Rb, 7.5 ppm for Ba and 20 ppm for Sr - Nesbitt & Sun, 1976).

Table 1. Average compositions of peridotitic komatiites from Africa, Canada and Australia (Condie, 1981), and Crixás peridotitic and basaltic komatiites (Kuyumjian & Dardenne, 1982; Montalvão, 1985).

	Komati	Abitibi	W-Australia	Crixás	Crixás
	STPK	STPK	STPK	STPK	BK
SiO <sub>2</sub> %	42.52	42.9	41.9	43.2	48.8
TiO <sub>2</sub>	0.18	0.36	0.23	0.32	0.80
Al <sub>2</sub> O <sub>3</sub>	3.44	7.46	5.22	5.33	12.60
Fe <sub>2</sub> O <sub>3</sub>	4.92	2.9	3.62	5.60	6.06
FeO	5.87	6.50	5.21	4.70	6.70
MgO	30.27	24.0	29.86	28.73	8.77
CaO	4.96	7.21	4.69	3.51	10.70
Na <sub>2</sub> O	0.41	0.13	0.22	0.25	1.97
K <sub>2</sub> O	0.16	0.06	0.02	0.03	0.16
P <sub>2</sub> O <sub>5</sub>	0.02	0.02	0.02	0.06	0.09
MnO	0.19	0.22	0.18	0.19	0.22
Cr ppm	2200	2700	3000	2650	148
Ni	2000	1300	1600	1560	85
V	90	170	120	120	200
Co	60	110	105	125	39
Cu	45	89	95	45	64
Zn	102	90	130	75	35
Zr	34	35	15	25	55

The Crixás komatiites show LREE enrichment and relatively flat HREE (Table 2; Fig. 1). The degree of LREE enrichment ( $La_N/Sm_N$ ) varies from 1.4 to 2.7 with an average of 1.8. The LREE enrichment relative to HREE can be seen by the  $La_N/Yb_N$  ratio which averages 4.8 and ranges from 3.8 to 6.8. Sample 6 which has much higher contents of total REE is composed essentially of chlorite.

Table 2. REE abundances ( $\mu g g^{-1}$ ) in Crixás komatiites. Data were obtained by ICP-MS (Bolton et al., 1983). Total analytical errors are estimated to be  $\approx 10\%$ . Numbers correspond to following samples: 1 - spinifex-textured serpentine-tremolite schist (STPYK); 2 - spinifex-textured serpentine-tremolite schist (STPK); 3 - spinifex-textured serpentinite (STPK); 4 - spinifex-textured serpentinite (STPK); 5 - spinifex-textured chlorite-tremolite schist (STPK); 6 - chlorite schist; 7 - spinifex-textured tremolite-serpentinite (STPK); 8 -

spinifex-textured tremolite-serpentinite (STPYK); 9 - spinifex-textured serpentinite (STPK); 10 - spinifex-textured serpentinite (metadunite).

	1	2	3	4	5	6	7	8	9	10	Duplicate analysis	
											2	7
La	27	8	18	13	12	131	11	17	16	16	7	5
Ce	32	16	26	15	26	63	15	30	28	27	13	10
Nd	30	16	27	15	23	177	11	24	24	24	10	10
Sm	6	3	6	1	5	44	3	6	7	6	2	2
Eu	2.8	1.2	1.9	1.3	1.7	14.3	1.1	2.1	1.9	1.8	0.9	0.8
Gd	-	-	-	-	-	54	-	-	-	-	-	-
Dy	3.6	1.5	2.3	1.4	2.1	37	2.2	3.1	3.2	3.0	1.4	1.1
Yb	2.6	1.1	1.8	1.5	1.6	12	1.3	3.0	2.4	2.3	1.0	0.8
Y	12	5	8	5	8	207	10	18	16	14	6	4

Many authors have suggested that peridotitic komatiites could be produced by large degrees (over 50%) of melting of upper mantle peridotites and that the komatiitic liquids would have compositions simulating that of their source peridotites. Green (1975) has proposed a model in which PK is produced and extracted from mantle plumes (diapirs) at shallow levels by melting only a small degree of residual solid phases in the plume. In this model the komatiitic liquids would not closely reflect the composition of the mantle source, but rather the composition of residue-rich plumes.

Most komatiites have either flat REE patterns or show slight LREE depletion (Fig. 2). For instance, the Komati (Sun & Nesbitt, 1978), Suomussalmi (Jahn et al., 1980) and Qingyuan (Zhai et al., 1985) komatiites have flat REE patterns with total REE contents ranging from 2 to 8 times chondrites, while the Tipasjarvi (Jahn et al., 1980), Abitibi and Western Australia (Sun & Nesbitt, 1978) komatiites have slight LREE depletion.

On the other hand, South American komatiites appear to be LREE enriched.

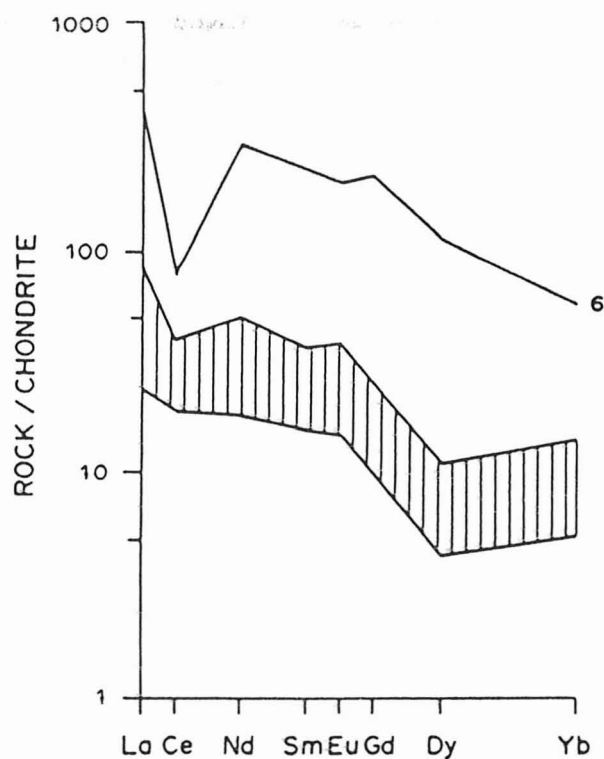


Figure 1 -- Field of REE distribution patterns of Crixás komatiites (striped) and REE patterns of chlorite schist (sample 6).

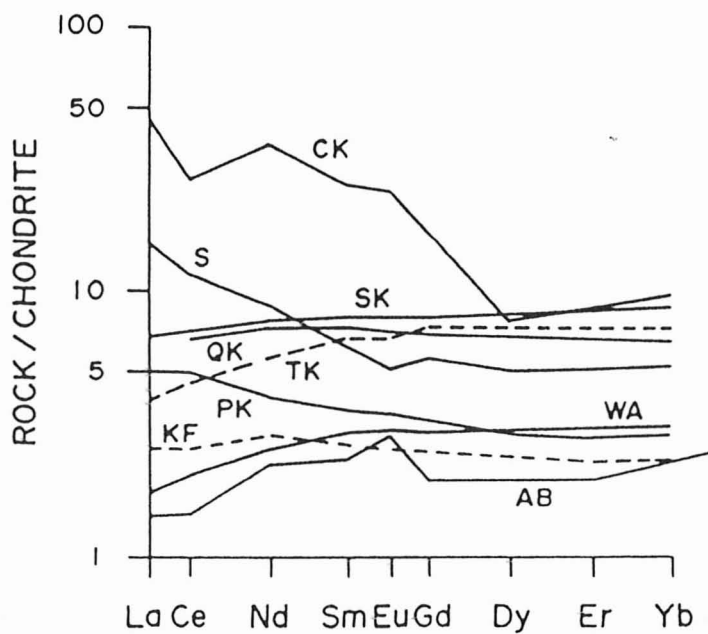


Figure 2 -- Average REE patterns of komatiites from: CK - Crixás; S - Seringa; SK - Suomussalmi; TK - Tipasjarvi; QK - Quingyan; PK - Piumhi; KF - Komati Fm.; AB - Abitibi; WA - Western Australia. See text for data sources.

The Piumhi komatiites (Jahn & Schrank, 1983) from south-eastern Brazil have  $\text{La}_N/\text{Yb}_N$  ratios of about 1.8 and LREE contents varying from 5 to 20 times chondrite values; the komatiites from French Guiana (Gruau et al., 1985) have  $\text{La}_N/\text{Yb}_N$  ratios of 2 to 6 with LREE contents ranging from 10 to 30 times those of chondrites; the Seringa komatiites (Huhn et al., 1986) from northern Brazil show a flat HREE pattern and enriched LREE ( $\text{La}_N/\text{Sm}_N=1.7$ ) with LREE contents ranging from 10 to 30 times chondrite values. Basaltic komatiites from the Australian Negri volcanics (Sun & Nesbitt, 1978) also have LREE enrichment, with  $\text{La}_N$  ranging from 25 to 40 times chondrite. These LREE enriched peridotitic and basaltic komatiites have been interpreted as derived from a LREE enriched source (Sun & Nesbitt, 1978, Jahn & Schrank, 1983).

Secondary processes, such as the alterations commonly found in komatiitic rocks, may change LREE concentrations causing slight enrichment of LREE (Condie et al., 1977; Sun & Nesbitt, 1978). LREE mobility has been detected during hydrothermal alteration associated with seawater interaction, spilitisation, and hydrous low-grade metamorphism (Hellman & Henderson, 1977; Floyd, 1977; Ludden & Thompson, 1978; Hellman et al., 1979). Considering that LREE enrichment during alteration is generally very small it is probable that the Crixás komatiites were originally LREE enriched, although some of the enrichment may be due to alteration. Another reason to suspect that the LREE enrichment may reflect mantle source characteristics is that other South American komatiites, such as those from Seringa, Piumhi and French Guiana are also LREE enriched.

The only fresh komatiites known are the Cretaceous rocks from Gorgona (Gansser et al., 1979; Aitken & Echeverria, 1984) and drill hole samples of the Archean Belingwe komatiites (Nisbet et al., 1987). Virtually all other komatiites, even those that show flat or LREE depleted patterns, have been altered.

Both the Crixás and Piumhi komatiites have low  $\text{CaO}/\text{Al}_2\text{O}_3$  ratios (0.6 - 0.7) suggesting that these rocks may have lost Ca by alteration or that the liquids were fractionated by clinopyroxene separation. Clinopyroxene fractionation may cause very slight LREE enrichment, but it appears to be insufficient to explain the LREE enriched character of the Piumhi rocks (Jahn & Schrank, 1983). In the Crixás komatiites it is especially difficult to explain the low  $\text{CaO}/\text{Al}_2\text{O}_3$  ratios by clinopyroxene fractionation since the basaltic komatiites have slightly higher ratios (0.8) than the peridotitic komatiites.

The LREE enrichment of all known South American komatiites suggest that either we have a very special type of alteration in this continent or else that this enrichment reflects upper mantle source characteristics. In this case it is possible that it reflects deeper source areas in the mantle, analogous to intraplate basalts.

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