# PRELIMINARY Sm-Nd AND Pb-Pb ISOTOPIC DATA OF THE Fe-Cu-Au-BEARING SERROTE DA LAJE COMPLEX, ARAPIRACA, ALAGOAS, BRAZIL

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**Post-morten*

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## INTRODUCTION

Magnetic iron ore-hosted copper deposit occurs in layered mafic-ultramafic intrusions in the low Rio São Francisco River valley, in the States of Bahia, Sergipe and Alagoas in Northeastern Brazil. They are nested in metavolcano-sedimentary sequences, which are considered as part of the South Alagoas Zone, Amorim (1995). Two layered mafic-ultramafic complexes are recognized in this part of the Sergipano Belt: the Canindé and the Serrote da Laje complexes.

The age of the Serrote da Laje is uncertain, but it is roughly inferred to be older than 1,400 Ma, which was obtained via Rb-Sr dating of the younger Bela Aurora-type granites (Amorim et al., 1990).

This study is an exercise geared to assess the age relationships between the Serrote da Laje Complex and its metasedimentary host rocks using the Sm-Nd and Pb-Pb systematics. The preliminary age determinations of the deformed and polimetamorphosed rocks of this fragment of the South Alagoas Zone also aim to contribute to the understanding of the geological history of this part of the Borborema Province.

## GEOLOGICAL SETTING

The Serrote da Lage Complex is a layered intrusion, lying within the South Alagoas Zone of the Sergipano Belt, as an intrusive body into the Rio Coruripe Domain of Jaramataia Group, (Amorim et al., 1995). The Jaramataia Group is a 120 km long bow-shaped folded belt, which crops out between the cities of Belo Monte and Igaci in the central part of the State of Alagoas, Brazil. It consists of plutonic, volcanic and sedimentary rocks, which were metamorphosed under the greenschist to granulite facies conditions (Fig. 1).

## THE SERROTE DA LAGE COMPLEX

The Serrote da Lage Complex crops out between the cities of Craíbas and Arapiraca in the State of Alagoas (Fig. 1). It is composed of a sequence of gabbro, norite, hyperstenite and magnetite, hosted by clastic and chemical sediments (Horbach & Marimon, 1988).

The differentiates are mingled with fine- to medium-grained gabbroic rocks, which were interpreted as younger crosscutting diabase and gabbro (Fig. 2). The complex is highly deformed and recrystallized within the granulite facies condicions, which has produced a metamorphic paragenesis composed of hypersthene, sillimanite, cordierite and garnet. The sequence was later intruded by granite and pegmatite dykes. The granulites have been retrometamorphosed within the greenschist facies conditions in zones of britle deformation, which exhibit biotite, chlorite, talc and carbonate.

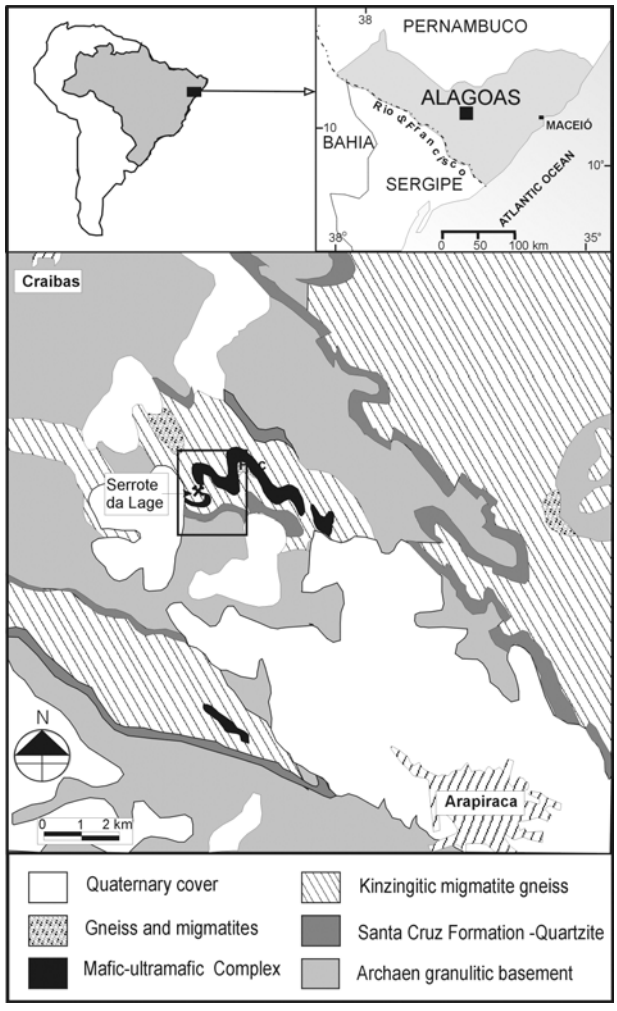


**Figure 1.** Geologic map of the Arapiraca and Craíbas area. (After Amorim , 1995).

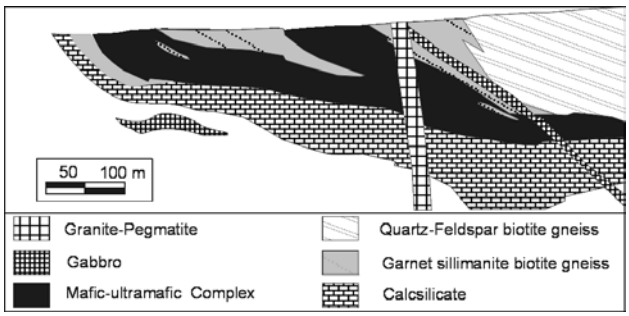


**Figure 2.** Geological section of the Serrote da Laje Complex (After Leal, 2002).

The Serrote da Lage Complex hosts a copper ore deposit, confined to the iron-rich differentiates which was evaluated by CVRD as large as 74 million tons of ore, bearing 0,62% Cu. An epigenetic gold mineralization, related to fractured zones of the copper ores, is also observed and the ore-grade is of the order of 0.17 ppm Au, (Figueiredo & Xavier, 1992).

## GEOCHRONOLOGY

A reconnaissance isotopic research exercise was carried out in this complex in order to tentatively assess the age relationships between the mafic-ultramafic rocks and their host lythological units of the Rio Coruripe Domain. The meta igneous rocks of the Cu-Au deposits were studied via the Sm-Nd method and the enclosing metasedimentary rocks were indirectly dated through the Pb-Pb zircon evaporation method on detrital grains.

### Sm-Nd SYSTEMATICS

The Sm-Nd isotopic study was carried out on nine samples of drill cores, which were kindly provided by CVRD – Companhia Vale do Rio Doce. Sampling aimed to cover the lythological spectra from leucocratic to ultramafic in order to obtain a whole-rock isochron. This procedure also aimed to distinguish, from the isotopic point of view, rocks that might have generated from different types of magma within the complex.

Sm and Nd were separated by standard ion-exchange techniques. Sr and Nd isotopic analyses were performed at the Geochronology Laboratory of the University of Brasília in static mode using a multi-collector Finnigan MAT-262 mass spectrometer. Total blanks were: Sr = 0.2 ng, and Nd < 0.2ng. 2σ uncertainties for the $^{87}Sr/^{86}Sr$ and $^{143}Nd/^{144}Nd$ ratios are smaller than 0.01% and 0.005%, respectively. Analytical procedures are those reported by (Gioia & Pimentel, 2000)

Decay constants are those recommended by Steiger and Jäger (1977), and ages are reported at the 95% confidence interval. Analysis of the NBS-987 Sr standard gave values between 0.71024 and 0.71029, and the LaJolla Nd standard yielded values between 0.511830 and 0.511848.

Samples taken from different drill holes are listed in Table 1. The rock specimens are metamorphic rocks, which still preserve some primary features, such as cumulus textures, rhythmic layering, and typical diabasic textures.

**Table 1.** Mineralogical composition of the samples. Opx - hyperstene; Pl - plagioclase; Cpx - diopside; Hb – hornblende; Gr - garnet; Bt - biotite; Cd - cordierite; Cl - chlorite; Qz - quartz; Mt - magnetite; Sulf - sulphide.

| Sample Id | Rock Type | Mineralogy | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Opx | Cpx | Pl | Hb | Gr | Bt | Cd | Cl | Qz | Mt | Sulf |
| FD37-25.20 | Diabase | | x | x | x | | | | | | x | x |
| FD48-24 | Meta leucogabbro | | x | x | x | x | x | | | | x | x |
| FD37-38 | Meta gabbro | | x | x | x | x | x | | | | x | x |
| FD02-40.80 | Meta norite | x | | x | x | x | x | x | | x | x | x |
| FD02-67-40 | Meta norite | x | | x | x | x | x | x | | x | x | x |
| FD51-4.5 | Magnetite chloritite | x | | | | | x | x | x | | x | x |
| FD46-66-35 | Metadunite | x | | | | | x | | x | | x | x |
| FD46-66-90 | Meta- magnetitite | x | | | x | | | | | | x | x |

Table 2 displays the results of the Sm-Nd isotopic analyses. The samples exhibit $^{143}Nd/^{144}Nd$ expressed as $\varepsilon_{Nd}$ values from -6.36 to -31.08. The data unfortunately did not yield sufficient spreading to produce reliable isochronic ages for the mafic-ultramafic differentiates. Nevertheless three groups of samples with distinct $T_{DM}$ model ages could be distinguished.

The first correspond to the intrusive diabase, which yielded a Mesoproterozoic $T_{DM}$ model age of 1.49 Ga. The second consists of the gabbroic rocks that yielded Lowerproterozoic $T_{DM}$ ages, from 2.32 to 2.34 Ga. The third group comprises the noritoid and metamorphosed magnetite-hyperstenites that produced Archaean Sm-Nd model ages as old as 2.71-2.86 Ga.

**Table 2.** Sm-Nd data for the Serrote da Laje Complex.

| Sample | Sm ppm | Nd ppm | $^{147}Sm/^{144}Nd$ | $^{143}Nd/^{144}Nd$ (± 2σ) | ε(o) | $T_{DM}$ (Ga) |
|---|---|---|---|---|---|---|
| **FD 37-25.20** | 11.620 | 50.31 | 0.1396 | 0.512312±06 | -6.36 | 1.489 |
| **FD 48-24(2)** | 6.709 | 32.01 | 0.1267 | 0.511711±06 | -18.08 | 2.322 |
| **FD 37-38** | 5.921 | 28.59 | 0.1252 | 0.511677±06 | -18.75 | 2.343 |
| **FD 02-40.80** | 2.729 | 12.366 | 0.1334 | 0.511618±09 | -19.90 | 2.708 |
| **FD 02-67-40** | 3.007 | 13.130 | 0.1385 | 0.511634±06 | -19.58 | 2.864 |
| **FD 51-4.5** | 0.361 | 1.513 | 0.1442 | 0.511465±16 | -22.89 | - |
| **FD 46-66,35** | 0.490 | 3.158 | 0.0937 | 0.511045±13 | -31.08 | - |
| **FD 46-90** | 0,151 | 0,385 | 0,2405 | 0,512692±16 | +1,04 | |

Pb-Pb SYSTEMATICS

A sample from the enclosing biotite gneiss (metarkose) was collected 2 meter below the mineralized noritoids. Detrital zircon grains were investigated in order to assess upper limit for the age of deposition of the original sediment.

The zircon crystals separated from this sample were dated via Pb evaporation zircon method (*cf.* Kober, 1987) at Pará-Iso Laboratories (UFPa). Data are presented at 2σ level . The Pb corrections have been done according to basis of the Pb double stage evolution model (*cf.* Stacey & Kramers, 1975) Analyses were carried out using a Finnigan MAT 262 spectrometer.

Fifteen zircon crystals were separated from the original sample. They are interpreted as detrital grains, which have been classified into two morphological groups. The first displays corroded, round and dirty surfaces, which exhibit elongated prismatic-like shapes, yellow to brownish colors, rare concentric zoning, scarce metamictization and moderate to strong fracturing. The second group corresponds to brownish, corroded, round and sometimes weakly fractured pyramidal-shaped zircon crystals, some of them exhibiting metamictization.

Only five, out these fifteen analyzed zircon crystals, yielded reliable data for age determinations. Three crystals from the first group could be aligned in a plateau and $^{207}Pb/^{206}Pb$ ratios have given a mean age value of 1778 ± 23 Ma (Table 3). Two zircons of the second group produced similar age values yielding an averaged value of 1417 ± 14 Ma (Table 3). This preliminary data suggests, therefore, that the Serrote da Laje is younger than *ca.*1.4 Ga.

**DISCUSSION**

Sm-Nd method has been proved to be a valuable tool to date layered intrusions. Whole-rock Sm-Nd isochronic ages are usually obtained from coeval differentiates of fresh unmetamorphosed mafic-ultramafic series. Nevertheless the reliability of whole rock Sm-Nd dating is often challenged due to assimilation of older sialic contaminants by parent magmas during ascent.

Considering the 1.4 Ga as the maximum age for emplacement of the Serrote da Laje intrusion, the $\varepsilon_{Nd}$ (t=1.4 Ga) values for the individual samples investigated must be smaller than approximately -7.5 (Table 2). This demonstrates that, regardeless of the time of intrusion, the original magma has been contaminated with older sialic crust (Fig. 3). Contamination with continental material is also suggested by low Sm/Nd ratios presented by most o the rock samples. The effect of this contamination would be more severe for the ultramafic differentiates which contains less neodymium and are more sensitive to assimilation of Nd from older external sources.

The preliminary Pb-Pb data from detrital zircons provided two groups of ages. The younger may be considered as the maximum age for the metarkose and it can be "correlated" to the 1,412 Ma Rb-Sr age of the granitic gneisses from Pedreira Triunfo site (Bela Aurora-type). Furthermore, this age is also the maximum age of the Serrote da Laje intrusion, which intrudes into the metasediments. These indirect dating of the Serrote da Laje and arkose should only be considered in the case that the Sm-Nd and Pb-Pb systems have both remained closed during the Brasiliano orogeny. Sm-Nd $T_{DM}$ and Pb-Pb ages together, when considered as related to undisturbed isotopic systems would thus indicate that the Serrote da Laje Complex and the sediments are younger than 1,417 Ma (Fig. 3).

**CONCLUSIONS**

Sm-Nd and Pb-Pb ages reported here can not be related to the crystallization of the Serrote da Laje Complex. Sm-Nd method was able to discriminate the three groups of rocks that could either be coeval or represent three different magmatic events. Sm-Nd data also show that these rocks display different degrees of contamination with older sources. The Pb-Pb zircon evaporation younger ages were interpreted as the minimum age of the zircons so far analysed and this might be the possible maximum age of the metarkose. Pb-Pb dating indicate that Serrote da Laje Complex and metarkose are both younger than 1, 412 Ma and this is partially in agreement with the Rb-Sr age for the Bela Aurora-type granites. The older Pb-Pb zircon age is here considered an important data as it registered the possible presence of Paleoproterozoic crust in this part of the Southern Alagoas Zone during the metarkose deposition. Additional geocronological investigation is now being carried out by the Geological Survey of Brazil in this area, which will certainly help to constrain the age of the Serrote da Laje Complex.

**Table 3.** Pb-Pb data for 5 zircon crystals from a sample of metarkose.

| Zircon | T(C°) | Ratios | $^{204}Pb/^{206}Pb$ | 2σ | $^{208}Pb/^{206}Pb$ | 2σ | $^{207}Pb/^{206}Pb$ | 2σ | $(^{207}Pb/^{206}Pb)c$ | 2σ | Age (Ma) | 2σ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| F037/10 | 1450 | 34/34 | 0.000118 | 4 | 0.02835 | 47 | 0.11042 | 57 | 0.10846 | 59 | 1774 | 10 |
| F037/11 | 1500 | 8/8 | 0.000089 | 20 | 0.03892 | 51 | 0.11071 | 76 | 0.10951 | 81 | 1791 | 14 |
| F037/14 | 1450 | 4/4 | 0.000080 | 2 | 0.07436 | 433 | 0.10883 | 33 | 0.10774 | 33 | 1762 | 6 |
| F037/17 | 1450 | 36/36 | 0.000330 | 33 | 0.01273 | 153 | 0.09388 | 55 | 0.08955 | 69 | 1416 | 15 |
| F037/13 | 1500 | 6/6 | 0.000000 | 0 | 0.02637 | 121 | 0.09031 | 255 | 0.09031 | 255 | 1432 | 54 |

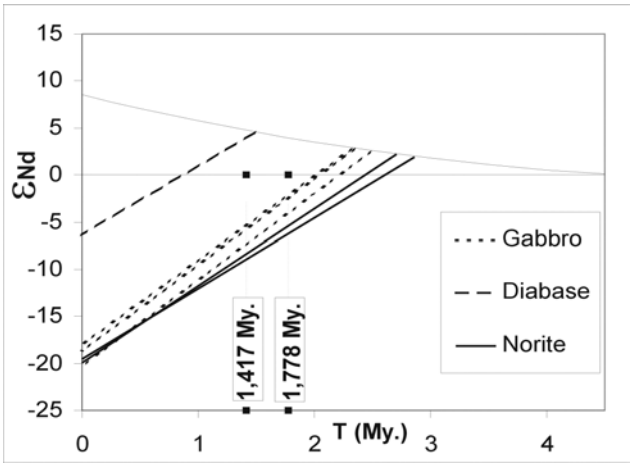


**Figure 3.** Nd evolution diagram displaying the two Pb-Pb evaporation zircon ages.

## FINAL REMARK

The authors wish to pay a *post-morten* tribute to late Jânio Leite de Amorim who gave an outstanding contribution to the knowledge of the geology of Alagoas.

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