Journal of South American Earth Sciences, Vol. 5, No. 1, pp. 33–46, 1992
Printed in Great Britain

0895-9811/92 $5.00+.00

Pb–Pb, Rb–Sr, and K–Ar systematics of the Lagoa Real uranium province (south–central Bahia, Brazil) and the Espinhaço Cycle (*ca.* 1.5–1.0 Ga)

U. G. CORDANI*[1], S. S. IYER[2], P. N. TAYLOR[3], K. KAWASHITA[1], K. SATO[1], and I. MCREATH[1]

[1]Instituto de Geociências, Universidade de São Paulo, CP 20899, 01498 São Paulo SP, Brazil; [2]Instituto de Pesquisas Energéticas e Nucleares (CNEN), CP 11049, 05499 São Paulo SP, Brazil; [3]Department of Earth Sciences, Oxford University, Oxford OX1 3PR, England, UK

(*Received May 1991; Revision Accepted October 1991*)

Abstract—Geochronologic investigations using Pb-Pb, Rb-Sr, and K-Ar systems have been carried out on the granite-orthogneiss complex of Lagoa Real, Bahia — one of Brazil's most important uranium provinces. Rb-Sr whole rock data on the basement complex yielded an isochron age of about 2700 Ma. The age corresponds to the peak of the Jequié orogenic cycle, when the regional crustal province was probably consolidated. Pb-Pb data for five undeformed examples of the São Timóteo granite and seven gneissic samples defined a well-fitted isochron with an age of 1710±100 Ma. The same undeformed samples furnished a similar Rb-Sr whole rock isochron age of 1710±45 Ma. These ages agree with published U-Pb (zircon) dates, confirming that the intrusion age was around 1700-1720 Ma. The magmas were probably formed largely by melting of crustal components, as shown by $(^{87}Sr/^{86}Sr)_i$ and μ_1 values. In complete contrast to the Pb-Pb system, the Rb-Sr system was seriously affected by later events in the orthogneisses. A Rb-Sr isochron apparent age of about 1500 Ma, obtained in one locality, is repeated in other isolated Rb-Sr ages, and also by a U-Pb (zircon) age obtained in albitites within the region. Other Rb-Sr apparent ages of *ca.* 1200 and *ca.* 1000 Ma were obtained, but their real geologic significance remains uncertain. K-Ar ages in separated minerals fall within the interval 570-500 Ma and show the influence of the Brasiliano tectonothermal cycle.

Resumo—Investigações geocronológicas empregando os sistemas Pb-Pb, Rb-Sr e K-Ar foram realizadas no complexo ortognaissico-granítico de Lagoa Real, Bahia, uma das províncias uraníferas mais importantes do Brasil. Dados Rb-Sr para o complexo do embasamento revelaram uma idade isocrônica em rocha total em torno de 2700 Ma. Tal idade corresponde ao ciclo orogênico Jequié, quando da consolidação da província crustal regional. Dados de Pb-Pb em cinco amostras não deformadas do Granito São Timóteo, bem como sete amostras de ortognaisses, definem uma isócrona bem ajustada cuja idade é de 1710±100 Ma. As mesmas amostras não deformadas forneceram uma idade isocrônica Rb-Sr em rocha total em torno de 1710±45 Ma. Tais idades concordam com as publicadas para o sistema U-Pb (zircão), e confirmam que a formação do corpo granítico ocorreu no intervalo aproximado de 1720-1700 Ma. Os valores calculados para μ_1 e $(^{87}Sr/^{86}Sr)_i$ indicam um papel importante para a fusão de componentes crustais na formação dos magmas. Em contraste com o sistema Pb-Pb, os dados Rb-Sr dos ortognaisses graníticos revelam que o sistema Rb-Sr sofreu sérias perturbações posteriores. A idade aparente em torno de 1500 Ma, obtida numa das localidades do complexo, encontra respaldo em outras idades isocrônicas Rb-Sr na mesma região, como também numa idade U-Pb (zircão) em albititos do complexo. Por outro lado, idades aparentes pelo método Rb-Sr de *ca.* 1200 e *ca.* 1000 Ma, ainda não confirmadas por outros métodos geocronológicos permanecem com seu significado incerto. Idades K-Ar em minerais separados recaem no intervalo 570-500 Ma, e refletem a influência do ciclo tectono-termal brasiliano.

INTRODUCTION

URANIFEROUS ALBITITES occurring in the granite-orthogneiss complex of Lagoa Real (State of Bahia, Brazil) constitute an important uranium province. The regional chronology and genesis of the uranium mineralization are the subject of debate. Recently, Turpin *et al.* (1988) published results of a multichronometric approach using U-Pb, Rb-Sr, and Sm-Nd methods and suggested that three events, at 1725 Ma, 1395 Ma, and 480 Ma, correspond to the ages of the granite protolith, uranium mineralization, and reworking, respectively. Their results were obtained mainly from U-Pb measurements on zircons, which these authors believe to be the only reliable and unequivocal method for registering the main events in polycyclic terranes. In fact, their Rb-Sr and Nd-Sm data show a large scatter of difficult interpretation.

We carried out a complementary geochronologic investigation in this area, using Pb-Pb (whole rock), Rb-Sr (whole rock), and K-Ar (separated minerals) methods. Our isotopic data are presented here with the following specific aims:

- to elaborate a regional geochronologic model;
- to compare the behavior of the different isotopic clocks, thereby testing their "reliability"; and
- to discuss genesis of the albitites and the uranium mineralization, based on isotopic and other data.

---

*Address all correspondence and reprint requests to:
Dr. U. G. Cordani: telephone [55] (11) 813-8777;
telefax [55] (11) 210-4958; telex 1182564 UVSI-BR.

GEOLOGIC SETTING AND PETROGRAPHY

The Lagoa Real Complex lies in the north-central part of the São Francisco craton (Fig. 1), one of the major tectonic units in the Brazilian Shield (Almeida, 1977; Cordani and Brito Neves, 1982). Archaean and Lower Proterozoic supracrustal belts (including greenstones), granite-gneissic, migmatitic, and granulitic metamorphic complexes represent the principal ancient terranes within the craton. They are exposed mainly in the northeastern and north-central parts, underlying the eastern and central parts of the State of Bahia, and form the basement to the Middle Proterozoic Espinhaço and Chapada Diamantina metasedimentary series of the Espinhaço Supergroup. Upper Proterozoic and Phanerozoic sediments cover a large part of the craton.

Radiometric dating programs carried out in Bahia up to 1986 have been summarized in a geochronologic map (Mascarenhas and Weber, 1986, 1989), in which the following major regional geotectonic cycles were recognized: 1) Jequié (2900-2700 Ma); 2) Transamazonian (2100-1700 Ma); 3) Espinhaço (1400-1000 Ma); and 4) Brasiliano (700-500 Ma). The significance of the Espinhaço Cycle is still under debate (see below).

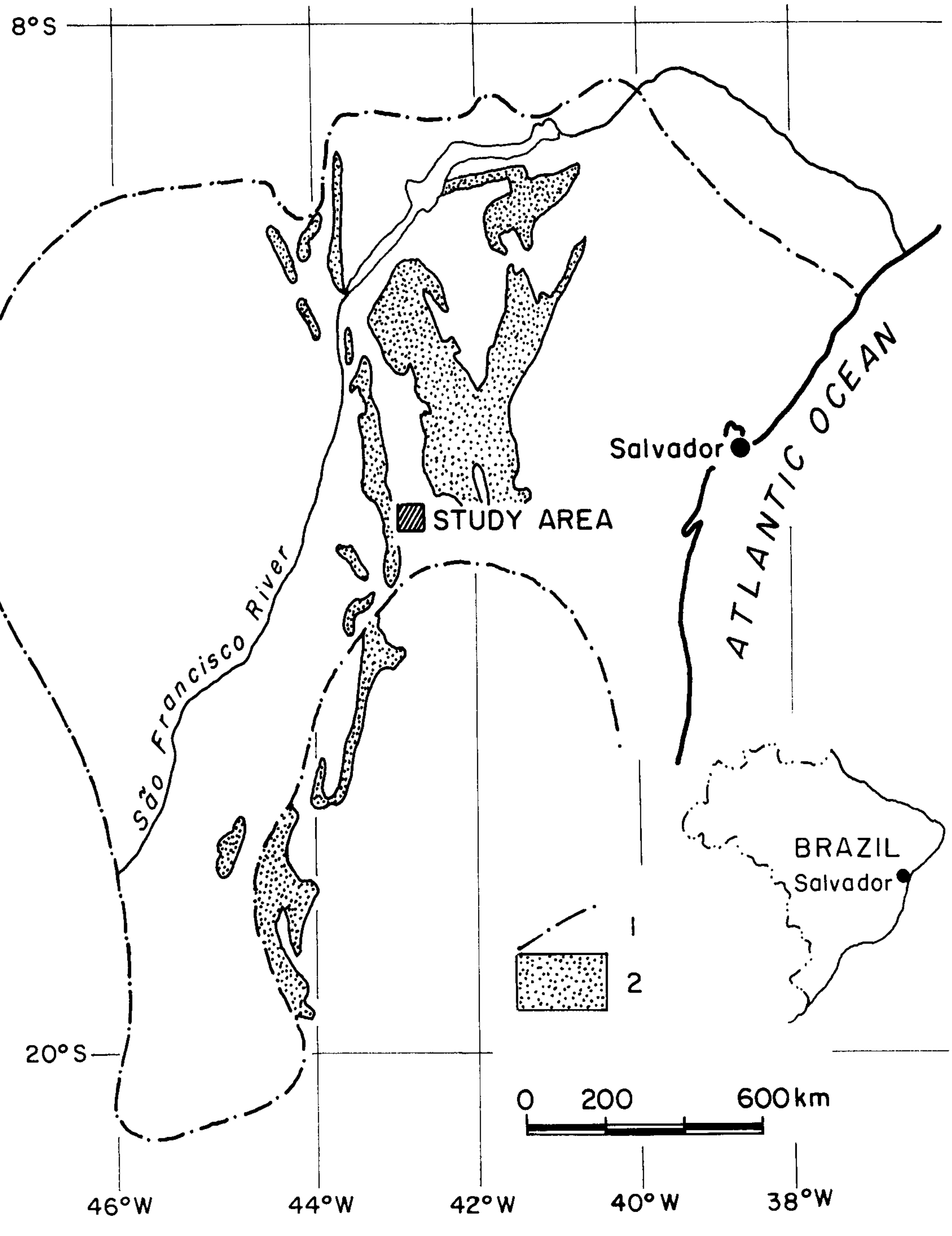

Fig. 1. Location of the study area within the São Francisco craton: 1) approximate limit of the craton after Almeida (1977) and Mascarenhas and Sá (1982); 2) main outcrops of Espinhaço Supergroup; inset, location in Brazil.

The Lagoa Real granite-orthogneiss complex occurs to the east of the Macaúbas range of the Espinhaço Fold Belt and includes U-mineralized albitites. It is enclosed within the basement terrane (Fig. 2). To the north of the study area, this basement has been described as comprising calc-alkaline orthogneisses of late Archaean age, together with products of their migmatization (Jardim de Sá, 1978). The bulk of the granitoid complex at Lagoa Real consists of orthogneisses produced by the deformation and metamorphism of porphyritic granites. In particular, some of these orthogneisses are clearly products of deformation of the São Timóteo granite. On the other hand, unlike the more homogeneous São Timóteo granite, some other orthogneisses of the Lagoa Real Complex are frequently intercalated with ortho-amphibolites/metagabbros.

Within the deformed part of the complex, lenticular albitite bodies occur along a slightly arcuate structure that has a length of about 100 km and submeridional orientation. Some of these albitites are the main hosts to uranium mineralization.

Petrography and Geochemistry of Part of the Lagoa Real Complex

The main rock types in the Lagoa Real Complex are the São Timóteo granite, orthogneisses probably derived by deformation of the São Timóteo granite, other orthogneisses that represent intercalations of the old basement, albitites, and amphibolites.

The São Timóteo granite has been described by a number of authors (Fernandes *et al.*, 1982; Costa *et al.*, 1983; Maruejol *et al.*, 1987). We believe at least three associations are present.

The most abundant facies is coarse grained to porphyritic, the latter with fine- to medium- or coarse-grained groundmass. The porphyritic varieties are sometimes rapakivi-like; the type with fine- to medium-grained groundmass occurs as wide dikes or lenses and may be hypabyssal. Parts of the apparently individual intrusive bodies are undeformed, but the rocks are usually incipiently or strongly foliated at the borders of these bodies. It is possible, therefore, that the mapped bodies are tectonic slices of an originally more extensive pluton.

Mineralogically, this facies can be described as hornblende-biotite monzo- or syeno-granite with blue quartz and accessory sphene, magnetite, ilmenite, apatite, zircon, and traces of allanite, sometimes associated with monazite and Nb±Ti-REE oxides and silicates (Maruejol *et al.*, 1987). Late magmatic stage crystallization in the presence of a fluid phase is believed to be responsible for the presence of many of the trace minerals. The same authors also record the presence of less abundant clinopyroxene- and biotite-granites. Their sampling was apparently undertaken mainly in the southern part of the present study area. Samples from the northern part of the area sometimes have traces of late alkali pyroxenes and/or amphiboles.

This predominant facies is potassic, transitional between sub-alkaline and alkaline, and presents relatively high Rb (*ca.* 160-385 ppm), low Sr (*ca.* 55-380 ppm) and Ba (*ca.* 370-880 ppm), usually high F (*ca.* 1000-5000 ppm), and low Sn (<5 ppm) contents (Fernandes *et al.*, 1982; Maruejol *et al.*, 1987; McReath, unpublished results).

A second facies associated with the São Timóteo granite occurs as a number of generations of fine-grained granodiorites or monzogranites that are often foliated or lineated and are distributed throughout the Lagoa Real Complex and the São Timóteo granite. Near Lagoa do Barro, an early generation of this type is found in a stoped contact breccia together with a foliated variety of the porphyritic São Timóteo type, whereas a later generation occurs as veins and dikes cutting the São Timóteo granite and accompanying xenoliths. These types have not been studied in detail, and their petrogenetic relationships with the main São Timóteo facies are therefore unknown.

The third association has little surface expression, occurring as xenoliths within the main São Timóteo granite facies or in isolated small bodies accompanying it, close to the contact between the Lagoa Real Complex and the old basement. This association includes gabbro, gabbro-norite, and perhaps norite or monzo-norite. Some of the latter hypersthene-bearing varieties underwent late magmatic or subsequent hydrothermal/metasomatic activity that led to the present mineralogic complexity, with biotite and K-feldspar forming part of the composition. This is reflected by the different descriptions given to the same rock type: charnockite of quartz-monzonite composition (Maruejol *et al.*, 1987) and metadiorite (Jardim de Sá, 1978) correspond to our norite or monzo-norite.

The samples of this apparently early association often exhibit trace quantities of sulfide minerals, and the very few analyzed for Sn present anomalously high values (350-1000 ppm). The norite or monzo-norite has very high Ba (*ca.* 2500 ppm) and Sr (*ca.* 1500 ppm) contents, accompanied by relatively low Rb (*ca.* 100 ppm). The former features contrast strongly with those of the gabbro and gabbro-norite and may be of hydrothermal origin (see below).

Some orthogneisses are coarse to medium grained granoblastic rocks whose primary mineralogic compositions are similar to those of the main São Timóteo granite facies. The main mineralogic transformations are amphibole + ilmenite reaction with the formation of biotite + sphene + magnetite ± calcite aggregates, together with transformations of perthitic orthoclase into microcline and sodic plagioclase. According to Maruejol *et al.* (1987), these transformations occurred under relatively isochemical conditions, and some of the chemical systems, therefore, may have escaped re-setting during gneissification.

The albitites (*s.l.* — as some are better termed oligoclasites, and many contain much less than 90% sodic plagioclase) are of two types: quartz-bearing,

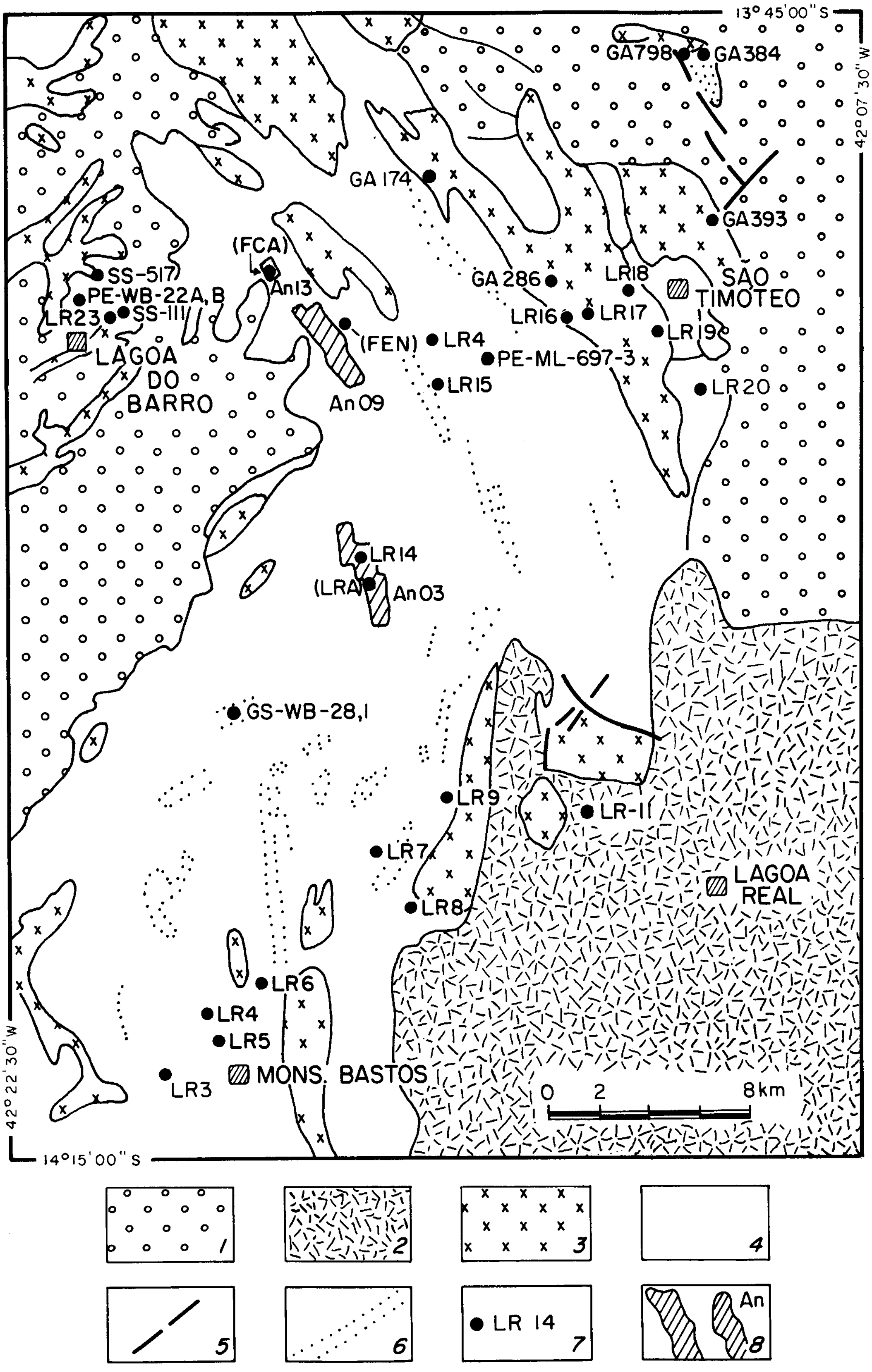

Fig. 2. The study area and sample locations; main elements of geology from Costa *et al.* (1983): 1) late cover; 2) Archaean basement; 3) São Timóteo granite; 4) Lagoa Real Complex; 5) faults; 6) albitites; 7) sample locations (drill hole locations identified in brackets); 8) U anomalies. SS-42 is just off the map near São Timóteo.

and pyroxene + garnet-bearing. The latter type is the most common host to uranium mineralizations, where uraninite occurs as small inclusions in albite and mafic minerals but is preferentially associated with andradite (Lobato *et al.*, 1982). Mineralized and unmineralized albitites are frequently associated with albitized orthogneisses.

In the preferred genetic interpretation of Nuclebrás SA (Stein *et al.*, 1980), the albitites are the product of sodic metasomatism of microcline-bearing granitoids or orthogneisses which, in their turn, are products of an early potassic metasomatic phase. Lobato *et al.* (1982) accepted this model and suggested that, during albitization, most K and some Si — together with Rb, Ba, and Y — were removed from the protoliths, while strong Na and less conspicuous Al gains occurred. These authors also noted that the behaviors of Fe^{+3}, Ca, Ti, Sr, Zr, and Th are variable.

Later, Turpin *et al.* (1988) found that, in generally unmineralized albitites, Na increases were accompanied by K, Ba, and Ca losses at approximately constant Si contents. In mineralized types, on the other hand, Si, K, and Rb depletions were accompanied by Sr, Na, and Ca enrichments. Stein *et al.* (1980) showed that only the mineralized albitites were consistently inriched in Pb. If these models of the element mobility are correct, it is thus clear that albitization will cause readjustment of the Rb-Sr system, whereas the U-mineralization may reorganize the U-Pb system and the Pb isotopic composition of the rocks.

Stein *et al.* (1980) mentioned that preserved relicts of the supposed K-gneiss protoliths of the albitites are very rare. In addition, many mineralized albitites lack substitution textures and some even lack oriented fabrics, being composed of equigranular mosaics of unzoned, "clean" mineral grains. We believe that at least some of the albitite bodies may well be products of nearly isochemical metamorphism of soda-rich protoliths.

The exact relationship between albitization and U-mineralization remains unclear. Although the microcline gneisses do not host economic U-mineralization, a few have anomalous (50-200 ppm) uranium contents. Stein *et al.* (1980) called attention to the possibility that the present disposition of the mineralization may be the result of reconcentration of uranium along faults reactivated during the Brasiliano Cycle.

Neighboring Supracrustal Sequences

The Espinhaço Fold Belt in Bahia, to the west of the study area, is a portion of a large, elongated structure that continues south through the State of Minas Gerais, whereas the Chapada Diamantina sequence to the east is restricted to Bahia (Fig. 1). Both sequences have basal conglomerates with associated felsic volcanic rocks. The latter have been dated using the U-Pb method on zircons from samples from Minas Gerais, where ages from 1770 Ma (Brito Neves *et al.*, 1979) to about 1700 Ma (Machado *et al.*, 1989) have been obtained. Other efforts to date the deposition of the Espinhaço Supergroup, which includes both sequences, or discrete episodes of its evolution (summarized by Brito Neves *et al.*, 1980, and Mascarenhas and Weber, 1986, 1989) have been frustrated by extreme perturbations of the Rb-Sr system during late open-system events.

A mafic sill that intrudes sediments near the middle of the Chapada Diamantina sequence yielded a K-Ar (plagioclase) age of 1111±52 Ma (Jardim de Sá *et al.*, 1976a). Rb-Sr isochron ages on the illitic fine fraction of relatively unmetamorphosed Chapada Diamantina sedimentary rocks probably reflect diagenetic or anchimetamorphic phenomena (Macedo and Bonhomme, 1984). Rocks from a single outcrop within the upper part of the pile yielded an age of about 960 Ma, while the lower part of the discordantly overlying São Francisco Supergroup furnished an age of 920 Ma. In Minas Gerais, a diabase dike cutting the Espinhaço Supergroup was dated by U-Pb (zircon and baddeleyite) at about 900 Ma (Machado *et al.*, 1989). A later horizon of the São Francisco Supergroup furnished a Rb-Sr fine fraction Rb-Sr isochron age of around 770 Ma (Macedo and Bonhomme, 1984). Finally, a saussuritized gabbro in the same horizon as the fresh sill previously cited yielded a K-Ar age of 492±25 Ma (Jardim de Sá *et al.*, 1976a).

According to Costa and Inda (1982) and Jardim de Sá (1981), the Espinhaço sediments and accompanying igneous rocks were deposited in an aulacogen or continental rift structure. Costa and Silva (1980) favor the idea of a discontinuity between early and late Espinhaço sedimentation. The age of deformation of the sequence is also uncertain. In Minas Gerais, a number of recent studies favor a monocyclic evolution for the supergroup, with early Middle Proterozoic deposition and Brasiliano deformation, which also involves the overlying São Francisco Supergroup (see, for example, Chemale, Jr., *et al.*, 1990). Similar deformation styles and sequence have been observed in south-central Bahia by Rocha and Domingues (1989). Nevertheless, the metamorphic and deformational histories in the two states may be different, as many apparent isotopic ages, especially in the Bahia area, fall within the interval *ca.* 1400-1000 Ma (Mascarenhas and Weber, 1986, 1989).

The Brasiliano tectono-thermal overprint on the isotopic systems, especially K-Ar (mineral), of many samples is firmly established throughout the area (Mascarenhas and Weber, 1986, 1989; also see below), although not in the basement to the west of the Espinhaço Fold Belt, where mid-Proterozoic K-Ar mineral ages (possibly cooling ages of an "Espinhaço" Cycle) are recorded. This region was regarded as tectonically stable during the Brasiliano orogeny (Souza *et al.*, 1986).

SAMPLING AND ANALYTICAL TECHNIQUES

Migmatitic gneisses, granites, and orthogneisses were analyzed in this study. Migmatite, granite, and some orthogneiss samples were collected from surface outcrops, while the majority of orthogneiss samples came from drill cores from the mineralized region, designated as anomalies by Nuclebrás SA. Core samples from Anomalies 3, 9, and 13 and unweathered whole-rock samples were prepared for Rb-Sr and Pb-Pb isotope studies; micas and amphiboles from all main rock types were separated for K-Ar analyses.

K-Ar and Rb-Sr analyses were carried out in the Geochronological Research Center of the University of São Paulo, Brazil. The lead isotope analyses were performed in the Department of Earth Sciences of the University of Oxford, UK. Experimental details of the K-Ar and Rb-Sr methods are given in Cordani *et al.* (1985), and the Pb-Pb procedure used was based on that described by Taylor *et al.* (1984), except that lead separation was carried out by anion exchange using HBr and water as eluants.

Strontium isotope analyses were carried out using a Varian TH5 mass spectrometer coupled to a microcomputer system for on-line data processing. All errors quoted are 2σ. The $^{87}Sr/^{86}Sr$ ratios were normalized to a $^{86}Sr/^{88}Sr$ value of 0.1194, and the NBS987 and Eimer and Amend strontium standards run concurrently yielded $^{87}Sr/^{86}Sr$ values of 0.71028 ± 0.00036 and 0.7081 ± 0.0005, respectively. Rb and Sr contents were measured by X-ray fluorescence spectrometry for contents above 50 ppm, and below this level by isotope dilution. The relative standard deviations for Rb/Sr (XRF) and $^{87}Sr/^{86}Sr$ measurements were around $\pm 2\%$ and 0.1%, respectively, and these values were used in the regression calculation using a modified version of the one described by York (1966).

The lead isotope analyses were carried out on an automated, single collector VG Isomass 54E spectrometer, using a single filament. Samples were loaded with phosphoric acid and silica gel. The data reported in Table 1 have been corrected for mass fractionation of 0.125% amu, obtained by regular analysis of NBS SRM981 and SRM982 lead isotope standards. Uncertainties in lead isotope compositions are estimated at 0.1%, and the Pb/Pb isochron fitting followed the procedure of York (1969). The decay and other constants used in the age calculation are based on the values of Steiger and Jaeger (1977) and Jaffey *et al.* (1971), and are given in Taylor *et al.* (1984).

RESULTS AND DISCUSSION

Lead-Lead Isotope Data

Table 1 shows the lead isotope data for seven undeformed granites and eight granitic orthogneisses. The samples are geographically separated and there is no guarantee that they are all strictly cogenetic. Nevertheless, in the ^{207}Pb-^{206}Pb isochron diagram (Fig. 3) all the analyzed samples, except two granites and two gneisses, define a resonably well-fitted isochron with a calculated age of 1706 ± 107 Ma and a model μ_1 value of 8.38. Among the samples that fall off the isochron, two gneisses and one undeformed granite plot below the isochron line, which could imply U gain and/or Pb loss at some time after *ca.* 1700 Ma. The undeformed granite GA-798 lies near a small albitite body at the extreme northeastern portion of the area (Fig. 2) and may thus have been influenced during the formation of this body. On the other hand, because the São Timóteo granite has an important crustal component (see below), original isotopic heterogeneity may have occurred and the rather large 2σ uncertainty could be viewed in this light. Finally, one other data point for an undeformed granitic sample falls above the best-fit line.

Table 1. Pb–Pb isotope data for granites and orthogneisses.

Sample/Core		$\frac{^{206}Pb}{^{204}Pb}$	$\frac{^{207}Pb}{^{204}Pb}$	$\frac{^{208}Pb}{^{204}Pb}$
Undeformed granite				
PE-WB-22A		18.801	15.798	41.462
GS-WB-28.1		18.112	15.715	39.813
PE-ML-697-3		24.749	16.573	53.702
LR-16B		17.951	15.713	43.295
LR-17A		17.163	15.624	38.025
GA-286B		18.485	15.764	42.080
GA-798		19.224	5.735	43.580
Granitic orthogneiss*				
FEN-01	(54.50)	22.009	16.134	42.266
FEN-01	(79.75)	21.527	16.076	43.932
FCA-03	(88.25)	19.594	15.881	40.944
FCA-15	(97.50)	18.603	15.748	40.935
FEN-01	(81.75)	20.688	15.998	45.342
FEN-01	(83.50)	34.234	17.533	50.741
FCA-10	(116.25)	17.984	15.718	39.734
FCA-13	(66.50)	18.475	15.781	40.727

* For the orthogneisses, the location of the FEN core is indicated on Fig. 2; the two digits refer to the hole number, and the number in parentheses is depth in meters of the top of the interval sampled.

The ranges of Pb isotopic compositions for granites and orthogneisses overlap, some orthogneisses having more radiogenic compositions. This lends support to the hypothesis that the orthogneisses are deformed equivalents of the granites and that the common lead geochemistry was not seriously affected by gneissification. The *ca.* 1700 Ma Pb-Pb age is in reasonable agreement with the U-Pb zircon age value of 1725 ± 5 Ma obtained by Turpin *et al.* (1988) for both non-deformed and deformed, partially recrystallized granites and orthogneisses. According to these authors, gneissification did not affect most

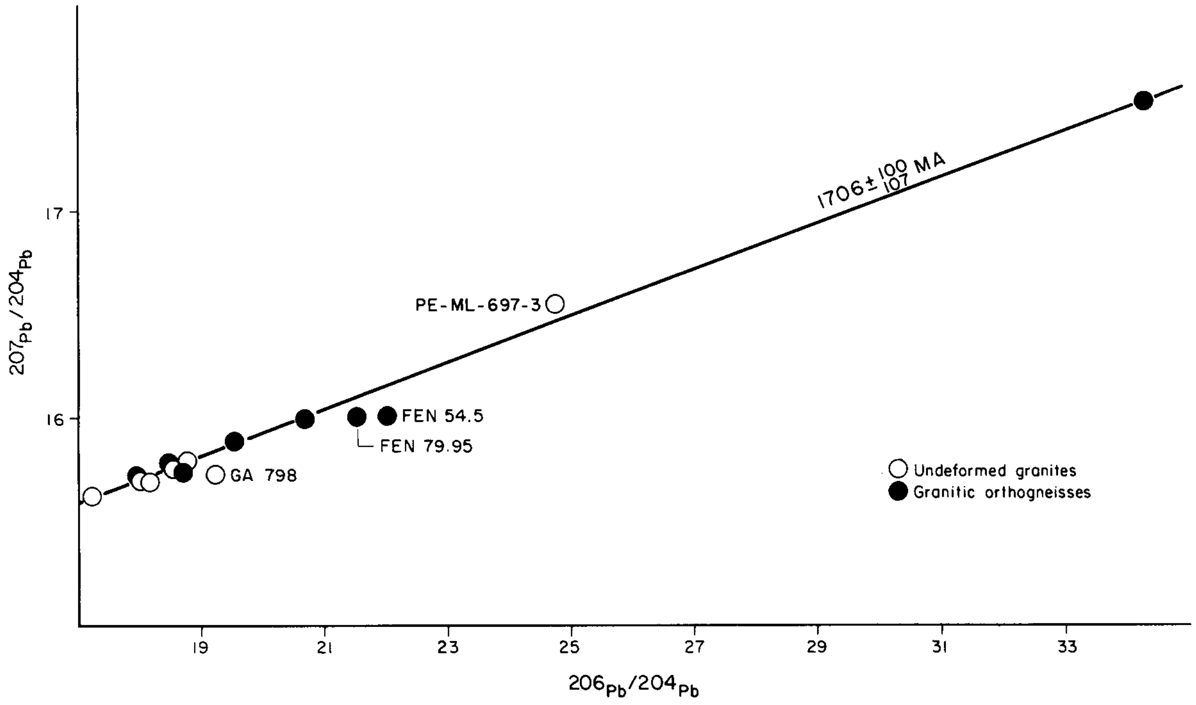

Fig. 3. Pb-Pb isochron plot for granites and orthogneisses from the Lagoa Real area (São Timóteo granite); only discrepant samples are identified.

zircons, and only metamict or small zircons recorded a much younger event — at around 500 Ma. In our interpretation, the Pb-Pb systems in most orthogneisses and granites have remained closed since about 1725 Ma, when the crystallization of the São Timóteo granite took place. This is in strong contrast to the behavior of the Rb-Sr (see discussion below) and Sm-Nd (Turpin *et al.*, 1988) systems, which show evidence for later re-equilibration. Our results are a good indication of the relative reliability of the common lead dating method in preserving early isotopic equilibria in polycyclic terranes.

The *ca.* 1725 Ma age can be considered to define the crystallization or emplacement age of the parent granite magma. The model μ_1 value of 8.38 is obviously too high for this magma to be a new, mantle-derived addition to the crust; more probably, it was derived by remelting of older continental crust.

Rb-Sr Results

Basement Samples. Table 2 presents the results of Rb-Sr analyses for whole rock samples from the basement. The data points for these migmatites, from two outcrops near Lagoa Real (LR-11) and one near São Timóteo (LR-20), are plotted in a Rb-Sr isochron diagram in Fig. 4. The samples are predominantly neosomes whose contacts with melanosomes are diffuse, characterizing metatexites with nebulitic textures. The data points for the five samples from near São Timóteo, together with three samples from near Lagoa Real, define a 2650±100 Ma isochron (MSWD=2.0) with $(^{87}Sr/^{86}Sr)_i$ = 0.712 ±0.004. As shown in Fig. 4, a better fit (MSWD=0.6) is obtained by omitting the two samples with the highest Rb/Sr values (LR-20F and LR-20G), yielding an age of 2765±75 Ma — the initial ratio and uncertainty remaining unchanged. Using only the results from the São Timóteo region, a less well-defined isochron age of 2700±130 Ma (MSWD=4.7) is obtained with $(^{87}Sr/^{86}Sr)_i$ = 0.706±0.9.

The late Archaean ages obtained are probably related to the age of migmatization and correspond to the Jequié Cycle, one of the most important tectono-magmatic periods of Bahia (Cordani and Iyer, 1979; Cordani and Brito Neves, 1982; Cordani *et al.*, 1985; Barbosa, 1987). In south-central Bahia, ages from the Paramirim river valley gneisses to the north of the study area (Jardim Sá *et al.*, 1976a), as well as from granitoid basement rocks in the region of Brumado-Anagé to the east and east-southeast (Mascarenhas, 1979), are very similar to those inferred for the migmatitic gneisses studied here. Large-scale isotopic homogenization of Sr seems to have affected the basement rocks during the Jequié Cycle.

In Fig. 4, three samples (two migmatitic layers from sample LR-11: LR-11-C-1 and LR-11-C-2, and a discordant granitic vein LR-11-D-2) define a much younger, three-point reference isochron with an age of about 1300 Ma and a high $(^{87}Sr/^{86}Sr)_i$ of 0.788. This probably represents a localized rehomogenization.

Granitic Rocks. The granitic rocks analyzed in this study were selected from the regions of São Timóteo and Lagoa do Barro, in the northern part of the area. Six samples from the former and two from the latter define a best-fit line that may be inter-

Table 2. Rb–Sr data.

Sample	Rock Type	Rb (ppm)	Sr (ppm)	^{87}Rb / ^{86}Sr	^{87}Sr / ^{86}Sr
Migmatite gneisses from basement or enclaves within the Lagoa Real Complex					
LR-11-C-1	mig	226.0	82.9	8.06	0.9385
LR-11-C-2	mig	172.0	82.9	5.64	0.8923
LR-11-D-1	mig	187.0	154.0	3.57	0.8544
LR-11-D-2	gran.v	367.0	107.0	10.25	0.9783
LR-11-G	mig	150.0	197.0	2.23	0.8032
LR-11-J	mig	180.0	177.0	2.97	0.8281
LR-20-B	mig	143.0	179.0	2.33	0.7945
LR-20-F	bi-gn	209.0	61.9	10.13	1.0886
LR-20-G	bi-gn	244.0	54.3	3.63	1.2064
LR-20-I	bi-gn	182.0	104.0	5.17	0.9162
LR-20-E	bi-gn	187.0	72.1	7.75	1.0276
Granitic rocks					
PE-WB-22A	gr-gn	116.0	234.0	1.45	0.7496
LR-17A	gr	202.0	167.0	3.54	0.7959
GA-174	gr-gn	133.0	88.1	4.41	0.8333
GA-286B	gr	180.0	79.1	6.71	0.8738
GS-WB-28.1	gr-gn	222.0	91.6	7.13	0.8839
LR-16B	gr	177.0	62.5	8.35	0.9038
SS-111	l-gr	336.0	112.0	8.90	0.9320
GA-798	gr	270.0	71.5	11.23	0.9864
LR-23	l-gr	253.0	29.5	26.14	1.2553
SS-517	l-gr	384.0	24.9	48.80	1.6549
PE-WB-22B	gr-gn	295.0	31.4	29.09	1.4192
PE-ML-697-3	gr	371.0	45.7	24.99	1.3564
Orthogneiss and albitized gneisses from mineralized regions*					
Anomaly 3					
LRA-44 (66.00)	mig-gn	31.8	190.0	0.49	0.7285
LRA-44 (111.00)	mig-gn	155.0	299.0	1.50	0.7465
LRA-44 (100.00)	mig-gn	167.0	273.0	1.78	0.7483
LRA-60 (70.50)	mig-gn	139.0	195.0	2.08	0.7580
LR-14C	mig-gn	175.0	266.0	2.25	0.7497
LR-14B	mig-gn	181.0	281.0	1.87	0.7516
LRA-44 (64.25)	mig-gn	98.0	125.0	2.27	0.7538
LRA-66 (73.75)	mig-gn	110.0	141.0	2.28	0.7550
LRA-84 (162.25)	mig-gn	178.0	193.0	2.68	0.7614
Anomaly 9					
FEN-01 (83.50)	gn	13.2	163.0	0.24	0.7267
FEN-01 (81.75)	gn	78.1	166.0	1.37	0.7518
FEN-07 (54.50)	gn	161.0	178.0	2.63	0.7777
FEN-07 (193.25)	gn	201.0	216.0	2.71	0.7792
FEN-01 (79.75)	gn	194.0	189.0	3.00	0.7795
Anomaly 13					
FCA-10 (116.25)	gn	113.0	216.0	1.45	0.7542
FCA-10 (91.50)	gn	126.0	210.0	1.75	0.7563
FCA-10 (74.50)	gn	126.0	186.0	1.97	0.7619
FCA-13 (66.50)	gn	132.0	174.0	2.20	0.7698
FCA-13 (88.25)	gn	141.0	85.8	4.82	0.8283
FCA-15 (97.50)	pl-gn	152.0	168.0	2.64	0.7792
Orthogneisses from near Mons. Bastos					
LR-8		4.8	194.0	0.07	0.7171
LR-5C		9.2	113.0	0.24	0.7294
LR-4		132.0	310.0	1.23	0.7437
LR-5D		105.0	103.0	1.51	0.7528
LR-5A		155.0	267.0	1.69	0.7540
LR-5E		117.0	184.0	1.85	0.7499
LR-5F		120.0	192.0	1.82	0.7482
LR-6A		172.0	173.0	2.89	0.7779
LR-7		183.0	57.0	9.41	0.8796

Key to rock types: bi-gn, biotite gneiss; gr, granite; gran.v, granitic vein; gr-gn, granitic gneiss; l-gr, lineated granite; mig, migmatite.

preted as a whole-rock isochron with an age of 1710 ±45 Ma (MSWD = 3.34) and (^{87}Sr/^{86}Sr)$_i$ = 0.7135 ± 0.003 (Fig. 5). The exclusion of some lineated or foliated samples leads to no significant difference or improvement in the results. The high (^{87}Sr/^{86}Sr)$_i$ value is strong evidence for an important crustal component in the parent magma.

The inclusion of three samples of undeformed granite from the southern part of the area, using analytical data of Turpin *et al.* (1988), resulted in an

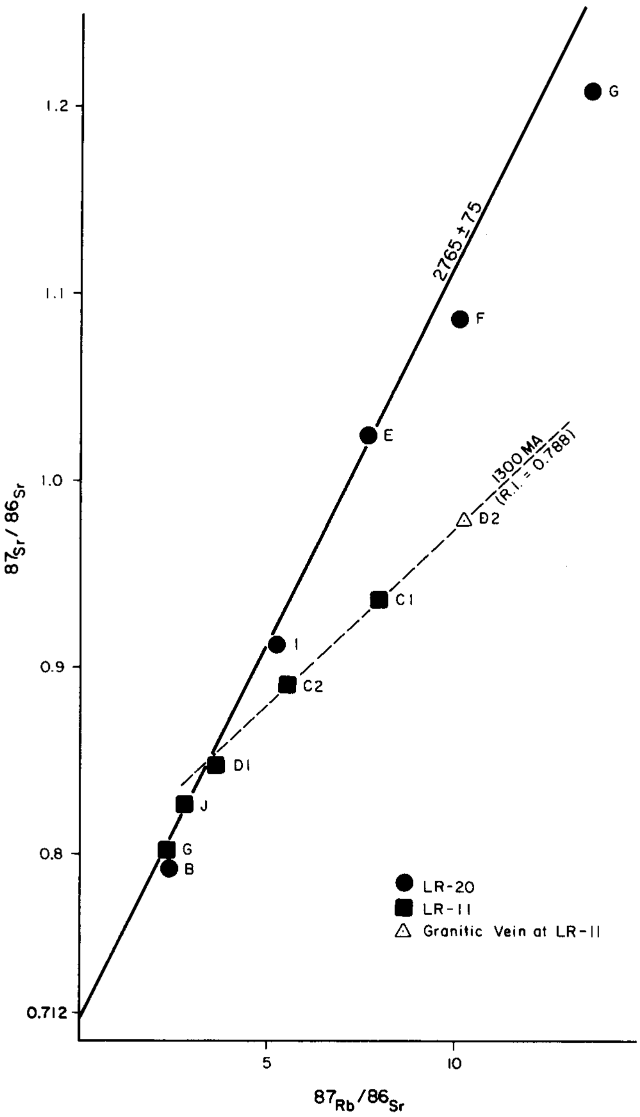

Fig. 4. Rb-Sr plot for for basement rocks; see text for other possible fits of the data.

increased dispersion of data points around the best-fit line in the isochron diagram, together with a higher uncertainty — although the age value obtained is similar. Once again, the overall scatter may reflect an initial isotopic heterogeneity of the granitic magma.

The concordance of the Pb-Pb and Rb-Sr age values presented here, as well as the U-Pb zircon ages obtained by Turpin *et al.* (1988), is an indication that the isotopic systems in these rocks may have remained essentially closed since *ca.* 1725 Ma, here considered the most probable age for the granite formation.

The data points for three fine-grained lineated granites near Lagoa do Barro define a best-fit line with an age value of 1280±20 Ma and an extremely high value of $(^{87}Sr/^{86}Sr)_i$ = 0.775±0.005 (Fig. 5), thus indicating an isotopic resetting in this locality. Other lineated granites (PE-WB-22A and 22B) fall on the *ca.* 1700 Ma reference isochron (Fig. 5), and the resetting of their systems may therefore have been a widespread but irregular phenomenon.

Orthogneiss, Albitized Orthogneisses, and Albitites. These rocks are often very intimately associated in the drill cores. Albitites, with their low Rb/Sr ratios, proved unsuitable for Rb-Sr dating using the facilities available. Six FCA and five FEN samples (from the closely associated Anomalies 9 and 13), all of which are variably albitized with very few or without augen or porphyroblasts, define a reasonably fitted isochron with an age of 1520±20 Ma (MSWD=0.36) and $(^{87}Sr/^{86}Sr)_i$ = 0.7221±0.0005 (Fig. 6). Some of these samples are included in the 1700 Ma Pb-Pb isochron diagram of Fig. 3 and, therefore, a later perturbation of the Rb-Sr system probably occurred at the whole-rock scale. Modeling of the isotopic evolution demonstrated that the $(^{87}Sr/^{86}Sr)_i$ ratios of these rocks at 1700 Ma were close to the $(^{87}Sr/^{86}Sr)_i$ value for the undeformed granites, confirming that the elements were probably confined in a regional closed system which opened locally at hand specimen or outcrop scales. Three other FCA samples may lie along a best-fit line with a similar age but lower $(^{87}Sr/^{86}Sr)_i$ ratio.

The disturbance of the Rb-Sr system in these rocks is also clearly seen in the much younger apparent ages from Anomaly 3 and from the Mons. Bastos region. The data are not well aligned but tend to conform to best-fit lines defining apparent ages of 1000±60 Ma (MSWD=3.0; Fig. 7) and 1220±130 Ma (MSWD=11.4; Fig. 8), with corresponding $(^{87}Sr/^{86}Sr)_i$ values of 0.722±0.002 and 0.723±0.003, respectively.

K-Ar Data

Six mineral separates from all rock types were analyzed for K and Ar, and the data obtained are reported in Table 3. The strong tectono-thermal effect of the Brasiliano Cycle (*ca.* 500 Ma) is clearly seen in these samples — some of which are amphibole, a mineral with high argon retentivity reflected by closure temperatures around 450-500°C. It can therefore be assumed that the temperature reached during the Brasiliano Cycle must have exceeded this level. In the U-Pb dating of zircons (Turpin *et al.*, 1988), the lower intercepts of the discordia for mineralized samples and small metamict zircons occur at 487±7 Ma, thus confirming the interpretation based on K-Ar results.

DISCUSSION AND CONCLUSIONS

The age of the main São Timóteo granite and gneiss protolith is constrained at about 1725 Ma by the concordance of zircon U-Pb, as well as the Pb-Pb and Rb-Sr whole-rock data. This age is younger than that generally assigned as the upper limit of the Transamazonian Cycle (1800 Ma; see, however, Mascarenhas and Weber, 1986, 1989), but it is similar to zircon ages obtained for felsic volcanic rocks in basal units of the overlaying supracrustal sequence (Brito Neves *et al.*, 1979; Machado *et al.*, 1989). Mineralogically and geochemically, the main São Timóteo granite type is not unequivocally related to any specific tectonic environment. Somewhat similar rocks are found, for example, as late- to post-tectonic intrusions in orogenic situations or as anorogenic rocks (Whalen *et al.*, 1987). Although the São Timóteo granite lacks the common associates of modern anorogenic plutons intruded at high crustal levels, McReath (1985) favored an anorogenic origin largely on the basis of the existing geologic models.

The available data for the Guanambi area to the west of the Espinhaço Fold Belt show the presence of Transamazonian calc-alkaline granitoids, whose latest manifestation is a 2100 Ma (Rb-Sr whole-rock isochron age) post-tectonic, quartz-saturated syenite (Fernandes *et al.*, 1982) with shoshonitic chemical affinities. The gap of *ca.* 400 million years between the age of this intrusion and the age of the São Timóteo granite is excessively long when compared to modern situations (Sylvester, 1989); therefore, we exclude the possibility of an orogenic relationship

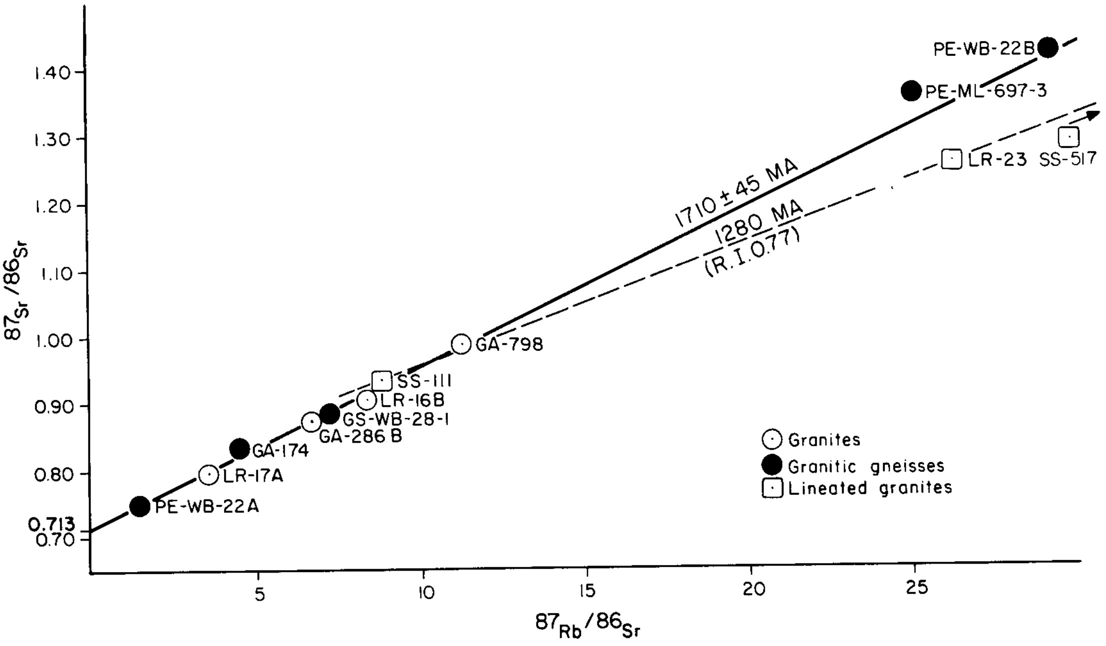

Fig. 5. Rb-Sr plot for granites and orthogneisses from Lagoa Real area (São Timóteo granite).

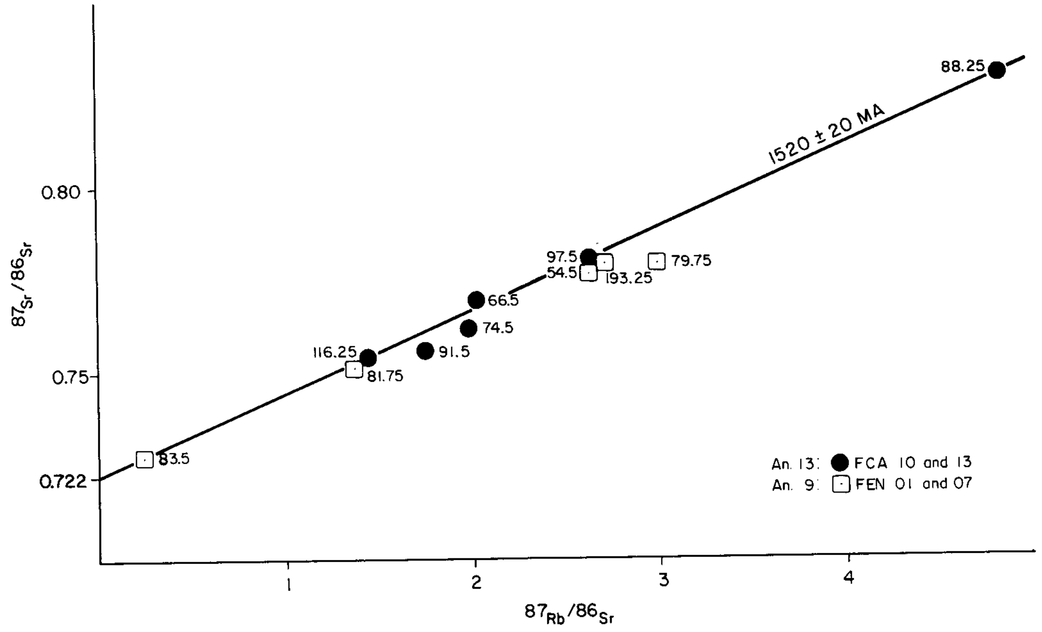

Fig. 6. Rb-Sr plot for granitic orthogneisses from anomalies An09 and An13 (drill holes FCA and FEN).

between the São Timóteo granite and the western granitoids. To the east of the study area, crustal anatectic granites intruded along the meridional Juazeiro-Contendas Belt (McReath and Sabaté, 1987) yielded intrusion ages around 2000 Ma. In this belt, K-Ar mineral ages around 1800 Ma indicate Transamazonian regional cooling and uplift (Mascarenhas and Weber, 1986, 1989). Once again there appears to be no relationship between these granites and the São Timóteo intrusion.

Turpin *et al.* (1988) discussed the genesis of the main São Timóteo granite type. Their Nd model

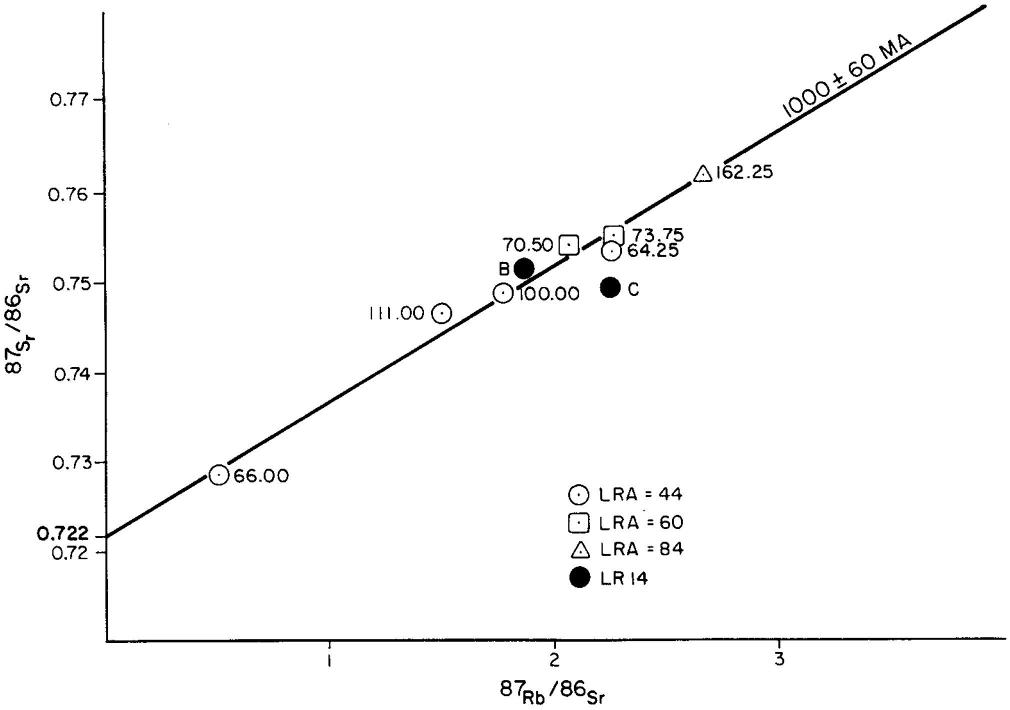

Fig. 7. Rb-Sr plot for orthogneisses from anomaly An3 (LRA drill holes and LR-14 surface samples).

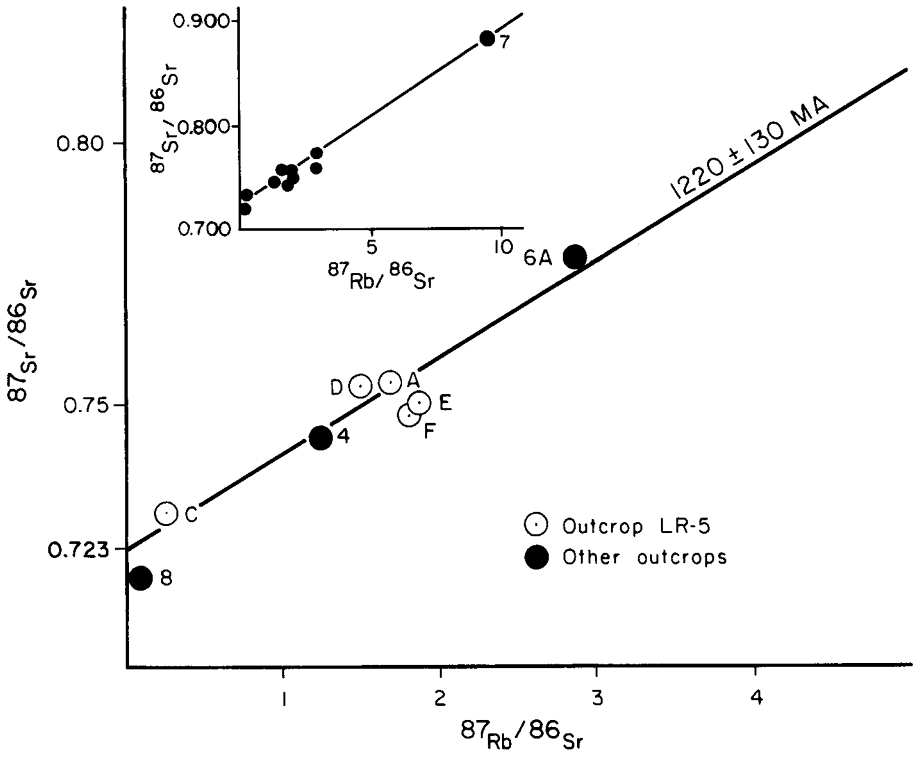

Fig. 8. Rb-Sr plot of orthogneisses from the Mons. Bastos area; inset shows data point for LR-7.

Table 3. K–Ar data for minerals from Lagoa Real.

Sample	Rock Type	Mineral	K (%)	^{40}Ar CC STP/g × 10^{-5}	^{40}Ar$_{atm}$ (%)	K-Ar Age (Ma)
LR-4	gn	Amphibole	1.653	3.72	17.9	503
LR-16A	gr	Biotite	7.503	19.66	2.2	573
LR-20A	bi-gn	Biotite	7.955	19.38	5.0	538
LR-20B	mig	Amphibole	1.636	3.59	12.6	491
SS-42	amph	Amphibole	0.606	1.397	30.8	514

Key to rock types: amph, amphibolite; bi-gn, biotite gneiss; gn, undifferentiated granitic gneiss or albitized gneiss; gr, granite; mig, migmatite.

ages between 2950 and 2160 Ma were interpreted to imply that the granite had an essentially crustal source, with a possible minor juvenile component. They cited oxygen isotope data obtained by Lobato *et al.* (1983) in support of their hypothesis. Our investigation confirms a predominately crustal origin for the granitic magma through the μ_1 and (^{87}Sr/^{86}Sr)$_i$ values obtained.

For the associated xenolith suite, Jardim de Sá *et al.* (1976b) presented a Rb-Sr analysis of a metanorite from near São Timóteo. Present-day values are ^{87}Sr/^{86}Sr = 0.7458 ± 0.002 and Rb/Sr = 0.05, and the rock presents high Sr and Ba contents. Although this evidence is not unequivocal, it seems possible that the calculated (^{87}Sr/^{86}Sr)$_i$ 1700 Ma value (about 0.742) points to a substantial addition of radiogenic strontium, and these rocks are not cogenetic with the main facies.

The *ca.* 1520 Ma Rb-Sr whole-rock isochron age recorded in orthogneisses from Anomalies 9 and 13 in the northwestern part of the study area is also seen in a model Sr age obtained for a high Rb/Sr granite near Paramirim to the north of the area (Jardim de Sá *et al.*, 1976a) and in a Rb-Sr whole-rock isochron age of 1498 ± 50 Ma for gneisses in the same area (Mascarenhas and Weber, 1986, 1989). More important, U-Pb zircon data for three albitites localized near the center of the study area, reported by Turpin *et al.* (1988), fall along a line with a concordia intersection at 1550-1525 Ma, a fact not discussed by these authors. They obtained a U-Pb age of *ca.* 1400 Ma by selective uraninite leaching of albitites, together with heavy mineral concentrates, and attributed the U-mineralization to this time. Fuzikawa *et al.* (1988) believed that albitization also occurred at that time and presented textural evidence showing uranium concentration along foliation planes in gneissic albitites.

Younger apparent ages are also found here (by Rb-Sr work) in basement gneisses, lineated granites, and orthogneisses, but these results are not backed up by independent determinations using other methods and may well be without geologic significance.

Stein *et al.* (1980, p. 1775) cited U-Pb data on two uraninites from the southern part of the area which register an event at around 820 Ma. One sample gave isotopic ratios that lie exactly on the concordia.

Our interpretation of currently available data is as follows (Table 4). The main São Timóteo granite, together with roughly contemporaneous felsic volcanics, is part of an intracontinental, anorogenic episode initiated at 1800 to 1900 Ma, shortly after the end of the Transamazonian orogeny. Initial albitization and uranium concentration may have occurred at around 1520 Ma, during a tectono-metamorphic event (Espinhaço Cycle) accompanied by strong hydrothermal-metasomatic activity. This regional episode is responsible for the main deformation of the orthogneisses and the appearance of the main metamorphic parageneses of the albitites (garnet-pyroxene-plagioclase, with inclusions of uraninite) at conditions of high-amphibolite facies. We consider as highly significant the result of *ca.* 1520 Ma obtained by Turpin *et al.* (1988) by the U-Pb method on zircons from three different albitites, confirming the Rb-Sr isochron of the orthogneisses from Anomalies 9 and 13 and strongly suggesting the neoformation of zircon crystals during a major metamorphic episode. A subsequent *ca.* 1400 Ma event probably resulted in a redistribution of uraninite; other readjustments of the Rb-Sr system may have occurred during the interval 1,300-1,000 Ma, and another widespread remobilization of uranium occurred during the Brasiliano orogeny, between 820

Table 4. Summary of radiometric data for Lagoa Real.

Age	Event	Isotopic Evidence*
~2760 Ma	Formation of basement rocks	*Rb-Sr WR isochron*
~1700 Ma	Formation of granitoid rocks (São Timóteo granite)	*U-Pb zircon age* (Concordia) *Pb-Pb WR isochron* *Rb-Sr WR isochron*
1500–1200 Ma	Regional metamorphism, formation of orthogneisses, albitites, and related rocks; U mineralization	*U-Pb zircon age* (Concordia) Rb-Sr disturbed systems, WR and mineral separates Sm-Nd
800–500 Ma	Regional thermal event; final U mineralization and metasomatism	*U-Pb uranium minerals* *K-Ar mineral ages*

*Entries in italics refer to probable geologically significant ages.

and 500 Ma. The apparently localized nature of the phenomena should be viewed in terms of overprinting of previous isotopic registers, with rock permeability developing at different places and different times in response to tectonic forces developed during both the Espinhaço and Brasiliano orogenic cycles. The question as to the response of the Espinhaço Supergroup supracrustal rocks to these events in the underlying basement remains open, as no similar confirmable ages have been obtained in the metasediments.

Our investigation demonstrates that the Rb-Sr isotope clock is highly susceptible to local resetting, and the geologic significance of the numerical age values obtained is open to question unless confirmation is obtained from other methods. The Pb-Pb system, on the other hand, seems to be more "reliable" in the case studied here. It is clear that a multimethod approach is essential to an understanding of the geologic evolution of complex metamorphic terranes.

Acknowledgments—This work was supported by an agreement between Nuclebrás SA and the University of São Paulo. Thanks are due to colleagues from this company and the CBPM, especially A. G. Angeiras, P. H. Costa, and L. M. Lobato, for their assistance and background knowledge during the field work and for stimulating discussions of the results obtained. The referees W. R. van Schmus and R. A. Fuck made useful comments and criticisms of an earlier version of this paper. I. McReath thanks FAPESP for support during preparation of the manuscript.

REFERENCES

Almeida, F. F. M. de, 1977. O Craton do São Francisco. *Revista Brasileira de Geociências* 7 (4), 349-364.

Barbosa, J., 1987. *Constitution Lithologique et Métamorphique de la Région Granulitique du Sud de Bahia-Brésil.* Unpublished PhD thesis, Université de Paris, France, 402 p.

Brito Neves, B. B., Cordani, U. G. and Torquato, J. R. F., 1980. Evolução geocronológica do Precambriano do Estado da Bahia. *Geologia e Recursos Minerais do Estado da Bahia: Textos Básicos* 3, 125 p.

Brito Neves, B. B., Kawashita, K., Cordani, U. G., and Delhal, J., 1979. A evolução geocronológica da cordilheira do Espinhaço: Dados novos e integração. *Revista Brasileira de Geociências* 9, 71-85.

Chemale, F., Jr., Dossin, I. A., and Dossin, T. M., 1990. Evolução tectônica proterozóica do Espinhaço Meridional e regiões adjacentes. *Resumos, XXXVI Congresso Brasileiro de Geologia, Natal,* 293.

Cordani, U. G., and Brito Neves, B. B., 1982. The geologic evolution of South America during the Archaean and Early Proterozoic. In: "International Symposium on Archaean and Early Proterozoic Geologic Evolution and Metallogenesis." *Revista Brasileira de Geociências* 12, 78-88.

Cordani, U. G., and Iyer, S. S., 1979. Geochronological investigation on the Precambrian granulite terrain of Bahia-Brazil. *Precambrian Research* 9, 255-274.

Cordani, U. G., Sato, K., and Marinho, M. M., 1985. The geologic evolution of the ancient granite-greenstone terrane of central-southern Bahia, Brazil. *Precambrian Research* 27, 187-213.

Costa, L. A. M. da, and Inda, H. V., 1982. O aulacógeno do Espinhaço. *Ciências da Terra (Salvador)* 2, 13-18.

Costa, L. A. M. da, and Silva, W. G. da, 1980. *Projeto Santo Onofre: Mapeamento Geológico — Relatório Final: Texto Vol. 1.* Triservice/CPRM/DNPM, Ministério das Minas e Energia, Brasília, Brazil, 385 p.

Costa, P. H., Vianna, I., Andrade, A., Lopes, G., and Sousa, S., 1983. *Projeto Lagoa Real, Mapeamento Geológico 1:50,000.* Unpublished report, CBPM, Salvador, Brazil.

Fernandes, P. E. C. A., Montes, M. L., Braz, E. R. C., Montes, A. de S. L., Oliveira, F. L. L. de, Ghignone, J. I., Siga, O., Jr., and Castro, H. E. F. de, 1982. *Levantamento de Recursos Naturais, Vol. 29—Folha SD.23 Brasília.* Projeto Radambrasil, Ministério das Minas e Energia, Rio de Janeiro, Brazil, 655 p.

Fuzikawa, K., Alves, J. V., Maruejol, P., Cuney, M., Kosztolanyc, C., and Poty, B., 1988. The Lagoa Real uranium province, Bahia State, Brazil: Some petrographic and fluid inclusion studies. *Geochimica Brasiliensis* 2 (2), 109-118.

Jaffey, A. H., Flynn, K. F., Glendenin, L. E., Bently, W. C., and Essling, A. M., 1971. Precision measurement of half lives and specific activities of ^{235}U and ^{238}U. *Physics Reviews* C, 1889-1906.

Jardim de Sá, E. F., 1978. *Geologia da Chapada Diamantina e Faixa Santo Onofre, Bahia, e Geoquímica do Vulcanismo Ácido Associado.* Unpublished MSc thesis, Universidade Federal da Bahia, Salvador, Brazil, 180 p.

Jardim de Sá, E. F., 1981. A Chapada Diamantina e Faixa Santo Onofre: Um exemplo de tectônica intra-placa no Proterozóico Médio do Craton S. Francisco. *Geologia e Recursos Minerais do Estado da Bahia: Textos Básicos* 4, 111-120.

Jardim de Sá, E. F., Bartels, R. L., Brito Neves, B. B., and McReath, I., 1976a. Geocronologia e modelo tectonomagmático da Chapada Diamantina e Espinhaço Setentrional, Bahia. *Anais, XXIX Congresso Brasileiro de Geologia, Ouro Preto* 4, 205-227.

Jardim de Sá, E. F., McReath, I., Brito Neves, B. B., and Bartels, R. L., 1976b. Novos dados geocronológicos sobre o Craton São Francisco no Estado da Bahia. *Anais, XXIX Congresso Brasileiro de Geologia, Ouro Preto* 4, 185-204.

Lobato, L. M., Forman, J. M. A., Fuzikawa, K., Fyfe, W. S., and Kerrich, R., 1982. Uranium enrichment in Archean basement: Lagoa Real, Brazil. *Revista Brasileira de Geociências* 12, 484-486.

Lobato, L. M., Forman, J. M. A., Fyfe, W. S., Kerrich, R., and Barnett, R. L., 1983. Uranium enrichment in Archean crustal basement with overthrusting. *Nature* 303, 235-237.

Macedo, M. H. F., and Bonhomme, M. G., 1984. Contribuição à cronoestratigrafia das formações Caboclo, Bebedouro e Salitre na Chapada Diamantina (BA) pelos métodos Rb-Sr e K-Ar. *Revista Brasileira de Geociências* 14, 153-163.

Machado, N., Schrank, A., Abreu, F. R. de, Knauer, L. A., and Abreu, P. A. A., 1989. Resultados preliminares da geocronologia U/Pb na Serra do Espinhaço Meridional. *Anais, V Simpósio de Geologia, Núcleo Minas Gerais e I Simpósio de Geologia, Núcleo Brasília, Belo Horizonte* 10, 45-49.

Maruejol, P., Cuney, M., Fuzikawa, K., Netto, A. M., and Poty, B., 1987. The Lagoa Real subalkaline complex (South Bahia, Brazil): A source for uranium mineralization associated with Na-Ca metasomatism. *Revista Brasileira de Geociências* 17 (4), 574-94.

Mascarenhas, J. F., 1979. Estruturas do tipo "greenstone belt" no leste da Bahia. *Geologia e Recursos Minerais do Estado da Bahia: Textos Básicos* 2,23-63.

Mascarenhas, J. F., and Sá, J. H. S., 1982. Geological and metallogenic patterns within Archean and Early Proterozoic of Bahia State, eastern Brazil. *Revista Brasileira de Geociências* 12, 193-214.

Mascarenhas, J. F., and Weber, T. M., 1986. *Mapa Geocronológico do Estado da Bahia.* Secretaria das Minas e Energia, Salvador, Bahia, Brazil.

Mascarenhas, J. F., and Weber, T. M., 1989. *Mapa Geocronológico do Estado da Bahia: Texto Explicativo.* Secretaria das Minas e Energia, Salvador, Bahia, Brazil.

McReath, I., 1985. Magmatismo intracratônico proterozóico da bacia do Rio Paramirim. *Abstracts of the Workshop on Granites and Associated Mineralizations, Caruaru, Pernambuco*, 8.

McReath, I., and Sabaté, P., 1987. Granitoids of the State of Bahia, Brazil: A review. *Revista Brasileira de Geociências* 17, 404-414.

Rocha, G. M. F., and Dominguez, J. M. L., 1989. Espinhaço setentrional — Dobramentos isoclinais como causadores de camadas invertidas [extended abstract]. *Anais, V Simpósio de Geologia, Núcleo Minas Gerais e I Simpósio de Geologia, Núcleo Brasília, Belo Horizonte* 10, 184-189.

Souza, S. L. de, Fróes, R. J. B., and Moraes, A. M. V. de, 1986. Nova concepção sobre a evolução geotectônica do Espinhaço Setentrional. *Anais, XXXIV Congresso Brasileiro de Geologia, Goiânia* 3, 1176-1190.

Steiger, R. H., and Jaeger, F., 1977. Subcommission on Geochronology: Report. *Earth and Planetary Science Letters* 36, 359-62.

Stein, J. H., Neto, A. M., Drummond, D., and Angeiras, A. G., 1980. Nota preliminar sobre os processos de albitização uranífera de Lagoa Real (Bahia) e sua comparação com os da URSS e Suecia. *Anais, XXXI Congresso Brasileiro de Geologia, Camboriú* 3, 1758-1775.

Sylvester, P. J., 1989. Post-collisional alkaline granites. *Journal of Geology* 97, 261-280.

Távora, F. J., Cordani, U. G., and Kawashita, K., 1967. Determinação de idades potássio-argônio em rochas da região central da Bahia. *Anais, XXI Congresso Brasilero de Geologia, Curitiba*, 159-165.

Taylor, P. N., Chadwick, B., Moorbath, S., Ramakrishnan, M., and Viswanatha, M. N., 1984. Petrography, chemistry and isotopic ages of Peninsular gneiss, Dharwar acid volcanic rocks and Chitradurga granite with special reference to late Archaean evolution of Karnataka Craton, southern India. *Precambrian Research* 23,349-375.

Turpin, L., Maruejol, P., and Cuney, M., 1988. U-Pb, Rb-Sr and Sm-Nd chronology of basement, hydrothermal albitites and uranium mineralization, Lagoa Real, South Bahia, Brazil. *Contributions to Mineralogy and Petrology* 98 (2), 139-147.

Whalen, J. B., Currie, K. L., and Chappell, B. W., 1987. A-type granites: Geochemical characteristics, discrimination and petrogenesis. *Contributions to Mineralogy and Petrology* 95, 407-419.

York, D., 1966. Least square fitting of a straight line. *Canadian Journal of Physics* 64, 1079-86.

York, D., 1969. Least squares fitting of a straight line with correlated errors. *Earth and Planetary Science Letters* 5, 320-4.