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The Salamangone Paleoproterozoic Au-deposit, Lourenço District, Amapá, Brazil: U-Pb, Sm-Nd, Rb-Sr, Pb-Pb and K-Ar isotopic signatures

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Nogueira, S.A.A.¹, Bettencourt, J.S.² and Tassinari, C.C.G.³

¹ Instituto Geológico, Secretaria do Meio Ambiente do Estado de São Paulo. e-mail: snogueira@igeologico.sp.gov.br

² Departamento de Mineralogia e Geotectônica, Instituto Geociências/USP. e-mail: jsbetten@usp.br

³ Centro de Pesquisas Geocronológicas – CPGeo, Instituto Geociências/USP. e-mail: ccgtassi@usp.br

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INTRODUCTION The Salamangone Au-deposit is the most important among the several Au-deposits and prospects, which have been mined in the Lourenço Gold District-Amapá. Here the Au-quartz-vein system is contained within a calc-alkaline granitoid complex (tonalite-trondjemite-granodiorite), and the ore is enclosed within a shear zone.

GEOLOGICAL SETTING The Lourenço Au-District is located in the central portion of the State of Amapá, within the Maroni-Itacaiúnas Province, 2.2-1.95Ga (Teixeira et al. 1989), of the Amazonian Craton. The Lourenço region is included within a Paleoproterozoic suite of high-grade partially migmatized metamorphic supracrustal rocks and calc-alkaline (TTG-type) complexes (Fig. 1). All these rocks are crosscut by a ductile-brittle shear zone, to which the Salamangone and a variety of mineralized Au-quartz-vein are associated.

THE SALAMANGONE GOLD DEPOSIT The deposit is contained within a ductile-brittle shear zone striking N50-60°W and dipping 55 to 70°NE, which is over 350m long and has an average thickness of about 50m. It lies within a calc-alkaline, metaluminous to slightly peraluminous tonalite to granodiorite pluton. It is characterized by high contents of incompatible trace elements and LREE, showing a geochemical signature of volcanic arc granites. The primary mineralization consists of ribbon-quartz veins enriched in Au and As, exhibiting relatively low enrichment of Ag, Pb, Cu Bi, and Au-quartz infill in microfractures. Au is associated with sulfides, mainly arsenopyrite. The deposit is epigenetic in character and structurally controlled by a ductile-brittle shear zone.

RESULTS AND DISCUSSION Sm-Nd and Rb-Sr (whole rock), K-Ar (biotite) and Pb-Pb (arsenopyrite) isotopic analyses were carried out at the Geochronological Research Center of São Paulo University (CPGeO-USP), whereas U-Pb (zircon) and Pb-Pb (whole rock) at the Institute of Precambrian Geology and Geochronology, Russian Academy of Sciences (IPGG-RAS), St-Petersburg, Russia.

Zircons extracted from the tonalite were analyzed by the U-Pb method, and analytical points are plotted on a Concordia Diagram defining a discordia line (Fig. 2a), with upper and lower intercepts of 2.16 ± 0.13 Ga and 0.48 ± 0.13 Ga respectively. The first age is interpreted as the crystallization age of the plutonism, while the second one has no geological meaning due to extreme Pb loss by continuous-diffusion processes. Furthermore the same granitoid define a Pb-Pb whole-rock isochron (Fig. 2b), which yields an age of 1995 ± 260 Ma with a μ_1 value = 8.4 (MSWD=0.7).

Sm-Nd depleted mantle model ages calculated for both tonalite and granodiorite gave ages of 2.24 and 2.34 Ga respectively (Fig. 3). ϵ_{Nd} values calculated to 2.1 Ga range from +2.88 to +3.02, which indicate that the mantle-crust differentiation episode of the juvenile parent magmas took place c.a. 100 to 200Ma before the crystallization event. It is also suggested that the Lourenço region represents a vast area of juvenile continental crust with no contamination with Archean crust. In this way, the isotopic data reinforce previous interpretation that consider the Lourenço area as part of the Maroni-Itacaiunas Geochronological Province, whose crustal evolution took place during a major Paleoproterozoic accretion event between 2.25 and 1.95 Ga.

The U-Pb and Pb-Pb study has been complemented by Rb-Sr analyses. Six whole-rock samples from the granodiorite gave a Rb-Sr isochronic age of 2169 ± 89 Ma, an $^{87}\text{Sr}/^{86}\text{Sr}$ initial ratio of 0.7023 ± 0.0004 and a MSWD value of 1.3 (Fig. 4a), while four whole-rock samples from the tonalite yield a Rb-Sr age of 2278 ± 240 Ma with $^{87}\text{Sr}/^{86}\text{Sr}$ initial ratio of 0.7019 ± 0.0012 and MSWD=0.58 (Fig. 4b). The low initial $^{87}\text{Sr}/^{86}\text{Sr}$ ratios obtained for both contemporaneous granodiorite and tonalite are in close agreement, with the Sm-Nd isotope data, suggesting that their parental magmas were derived from similar source.

Younger magmatic activities in the Lourenço region are represented by aplitic-veins, which crosscut the 2.1 Ga granitoids. Samples from the aplites yield an Rb-Sr whole-rock isochronic age of 1976 ± 200 Ma with an initial $^{87}\text{Sr}/^{86}\text{Sr}$ ratio of 0.708 ± 0.021 and MSWD = 0.13 (Fig. 4c). The high error of the Sr initial ratio, due to the lack of analytical points close to the origin, is responsible for the high uncertainty of the age.

In order to constraint the proper age of the Au-mineralization, whole-rock samples and biotite crystals of the hydrothermal altered tonalite and arsenopyrite crystals from the quartz-veins, were analyzed for $^{87}\text{Sr}/^{86}\text{Sr}$, K-Ar and Pb-Pb. The analytical points, plotted in the Rb-Sr isochronic diagram, yield a slope age of 1830 ± 270 Ma and $^{87}\text{Sr}/^{86}\text{Sr}$ initial ratio of 0.7045 ± 0.0029 and MSWD = 5.4 (Fig. 4d). The scattering of some of the points about the isochron may have been caused by uncompleted Sr isotope homogenization during the mineralization event or by subsequent disturbance of the isotope system associated with mineralization overprint and/or shear episodes. The altered tonalite exhibit a more radiogenic initial $^{87}\text{Sr}/^{86}\text{Sr}$ ratio than the fresh tonalite. The higher initial $^{87}\text{Sr}/^{86}\text{Sr}$ ratio of altered tonalite in relation to the expected low Sr isotopic composition of fresh tonalite, can be related to the overall effect of mineralizing fluid/rock interaction and Sr fractionation processes. K-Ar age determinations on biotite from the altered tonalite yield values ranging from 1794 to 1758 Ma. It is more likely that the biotite K-Ar ages express the regional cooling ages or apparent ages reflecting subsequent isotopic disturbance during younger tectono-metamorphic activity (remobilization within the mineralized zone) related to the neighboring 1.76Ga felsic and alkaline bodies of the Falsino and Mapari suites (Tassinari et al. 1984).

For directly date the ore minerals, age determinations were made on sample of arsenopyrite by stepwise leaching technique using Pb-Pb systematic, the analytical points define a isochron age (14 points), which yield an age of 2002 ± 61 Ma and MSWD = 520 (Fig.5), consistent with the main mineralization stage. The radiogenic Pb-Pb isotopic composition suggests a crustal source for the Pb.

FINAL CONSIDERATIONS The data obtained on granitoids of the Lourenço region are indistinguishable from previous geochronological results on similar rocks in other areas of the Maroni-Itacaiúnas Province. In the French Guiana, syntectonic granitoids and gneissic-migmatitic terranes of “Série Ile de Cayenne” yielded ages of 2.1–1.95 Ga, with Sr initial ratios around 0.7018–0.7024, μ_1 value of 8.2 and positive ϵ_{Nd} values (Teixeira et al. 1985, Milési et al. 1995). The volcanism of the Vila Nova Group in northeast Pará and the Paramaca Group in French Guiana, both related to the greenstone belt sequences, yield Sm-Nd isochronic ages of 2.26 and 2.1 Ga respectively (McReath and Faraco 1997, Gruau et al. 1985). In addition Vanderhaeghe et al. (1998) constrained an episode of trondjhemitic magmatism at 2.17 Ga followed by the emplacement of calc-alkaline intrusions at 2.14–2.11 Ga and a late high-K magmatism at 2.09–2.08 Ga.

The isotopic data available for the Lourenço Au-District and neighboring regions in Amapá and French Guiana, strongly suggest a geodynamic crustal evolution model, based on the development of a calc-alkaline magmatic arc in the time interval (2.25-2.0). This can be explained by subduction of oceanic lithosphere in the beginning of the collision between a continental mass, composed at that time by the Central Amazonian Province-Carajás-Iricoumé Block (Tassinari 1996) and the West African craton (Tassinari and Macambira 1999).

In this way, the Salamangone gold deposit represents an orogenic mesozonal gold deposit (Groves et al. 1998), which were formed during compressional to transpressional deformation processes at Paleoproterozoic convergent plate margins in accretionary orogens.

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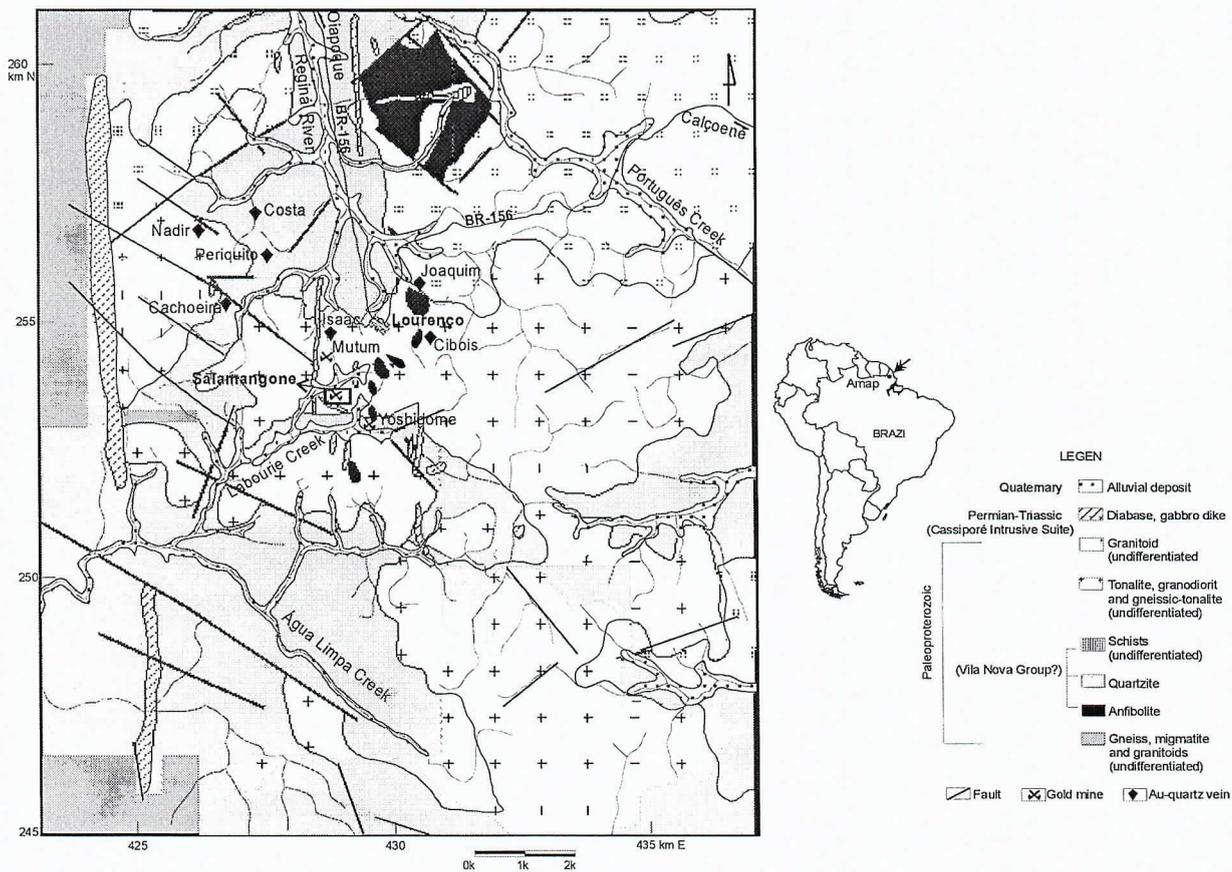


Figure 1. Geological sketch map of the Lourenço Gold District, modified and complemented after Terraconsult (1986).

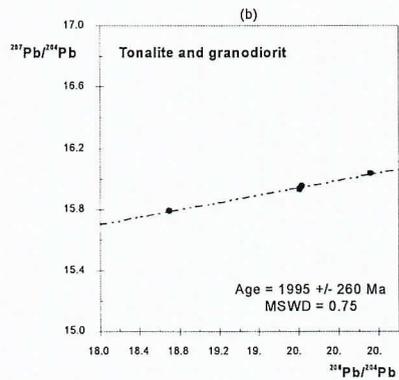
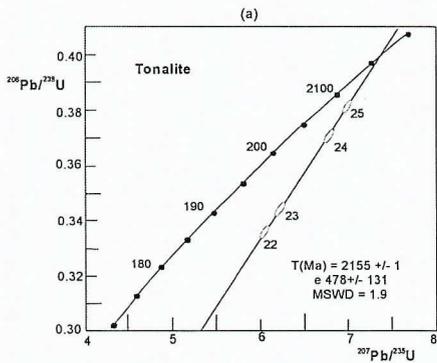


Figure 2. Host rocks of the Salamangone mineralization: (a) U-Pb concordia diagram for tonalite and (b) Pb-Pb whole rock isochron for tonalite and granodiorite

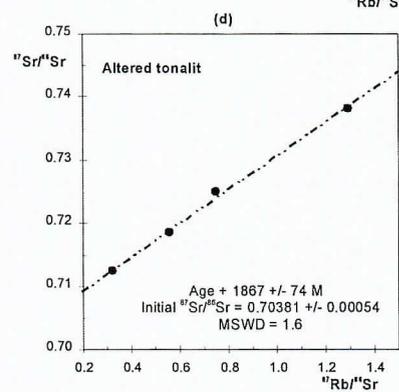
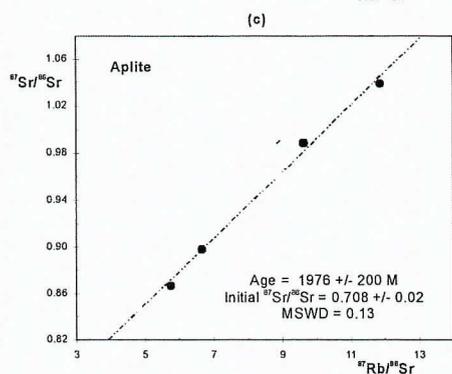
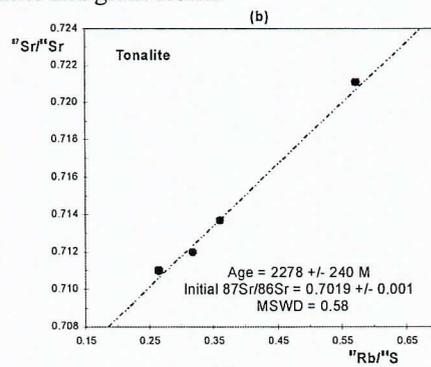
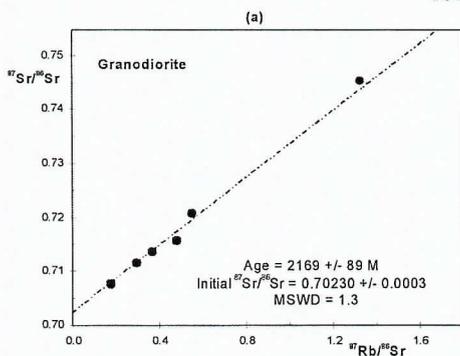


Figure 4. Rb-Sr whole rock isochron for host rocks of the Salamangone mineralization.

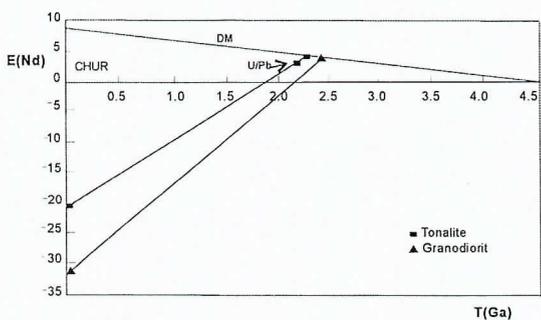


Figure 3. Nd vs. age diagram showing evolution lines for tonalite and granodiorite of the mine site.

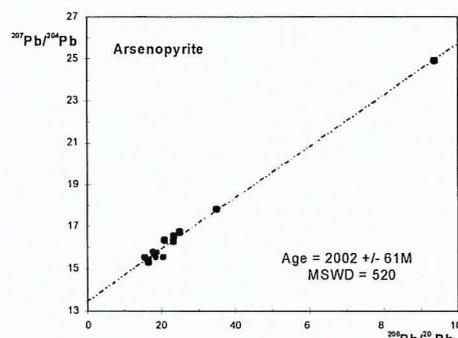


Figure 5. Pb-Pb isochron for arsenopyrite crystals of the quartz-veins mineralized.