LEAD ISOTOPE EVIDENCE REGARDING AGE OF GOLD DEPOSITS IN THE NOVA LIMA DISTRICT, MINAS GERAIS, BRAZIL

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ABSTRACT Lead isotope data for trace galenas associated with five generally stratiform gold deposits in the vicinity of the Morro Velho mine confirm an Archean age for the host Nova Lima Group. The least radiogenic lead, from the Bela Fama deposit, yields a model age of 2 710 Ma, possibly near the true age for the host rocks, including the various facies of iron formation and related chemical sediments that constitute and are associated with the primary ore zones. Galenas from the Esperança III and Bicalho deposits give model ages of about 2,550 Ma and 2,575 Ma, another from Bicalho a model age of about 2,495 Ma, and those from the Cuiabá and Faria deposits model ages of 2,410 to 2,425 Ma. A more radiogenic specimen from the Bela Fama deposit has a model age of 1,935 Ma. Alternatively, two-stage calculations can be applied to some of these data. The galenas in any case are interpreted to reflect deformation of the gold deposits and host rocks, and accompanying relatively local remobilization of constituents, including silica and lead, during a number of Proterozoic orogenic events. Correlations are suggested between these events and isotopic resetting events that have been identified for basement rocks in the region. These are the most primitive lead isotope compositions that have been obtained for Brazilian galenas.

RESUMO Dados de isótopos de chumbo para galenas associadas a cinco depósitos de ouro geralmente estratiformes, situados nas proximidades da Mina de Morro Velho, confirmam uma idade arqueana para o Grupo Nova Lima, que as contém. O chumbo menos radiogênico, proveniente do depósito de Bela Fama, fornece uma idade-modelo de 2 710 Ma, possivelmente próxima à idade verdadeira das rochas encaixantes, incluindo as várias fácies da formação ferrífera e sedimentos químicos relacionados, que constituem as zonas do minério primário⁺⁺ e acham-se a elas associados. As galenas dos depósitos de Esperança III e Bicalho fornecem idades-modelo de aproximadamente 2 550 Ma e 2 575 Ma; a do depósito de Bicalho fornece uma idade-modelo de cerca de 2 495 Ma, e as dos depósitos de Cuiabá e Faria, de 2 410 a 2 425 Ma. Um espécime mais radiogênico, proveniente de Bela Fama, possui uma idade-modelo de 1 935 Ma. Alternativamente, cálculos em dois estágios podem ser aplicados a alguns desses dados. Em qualquer dos casos as galenas são interpretadas como refletindo a deformação dos depósitos de ouro e das rochas encaixantes, acompanhada de relativa remobilização local dos constituintes, incluindo sílica e chumbo, durante vários eventos orogênicos do Proterozóico. São sugeridas correlações entre esses eventos e os de acomodação isotópica que têm sido identificados para rochas do embasamento na região. Estas são as mais antigas composições de isótopos de chumbo já obtidas para galenas brasileiras.

INTRODUCTION AND GENERAL GEOLOGY The important gold deposits of the Quadrilátero Ferrífero region, including the internationally-known Morro Velho mine, are hosted by rocks of the Nova Lima Group (Fig. 1), which form the main part of the Rio das Velhas Supergroup. This supergroup is considered by Schorscher (1982) to represent a complete greenstone-belt succession and includes also 1) the Quebra Osso Group which underlies the Nova Lima Group in the Santa Barbara region and consists predominantly of peridotitic komatiite lavas (and associated intrusions?), and 2) the overlying Maquiné Group which consists predominantly of phyllite, greywacke, quartzite and related sedimentary rocks. The Rio das Velhas Supergroup has generally been considered as Archean, although its age is not well established.

The Nova Lima Group consists of a thick sequence of generally schistose and, in many cases, chloritic rocks that include phyllite, chlorite schist, volcanoclastic and mafic volcanic rocks. It is apparently more than 4 000 m thick (Dorr 1969, Schorscher 1982) and is exposed over a large area. Schorscher (1982) has emphasized the overall mafic composition of the group. Pillow lavas have been recognized locally (Ladeira 1980, 1981). The group also contains thin units of chemical metasedimentary rocks which include quartz-rich rocks (metachert?), and iron formation of oxide, carbonate and sulfide facies. Much of the gold mineralization is associated with these horizons of chemical sedi-

ments, in particular with semi-massive sulfide units that contain pyrrhotite, pyrite, arsenopyrite and minor chalcopyrite (Ladeira 1980) and with siliceous "lapa seca". Gold is also concentrated in irregular quartz bodies and less commonly in quartz veins that crosscut Nova Lima Group rocks, particularly in close association with the chemical sedimentary ("exhalative" or "lapa seca") horizons, and may possibly have been remobilized from these horizons.

The Rio das Velhas Supergroup is considered to be younger than the surrounding migmatite-gneiss "basement" terranes, with which it is always in fault contact, because of its lower metamorphic grade and because it lacks granitic intrusions, although such intrusions are common in the Basement Complex (Ladeira 1980, Schorscher 1982). These authors considered that there is good evidence for polyphase deformation of Rio das Velhas rocks. Schorscher (*op. cit.*) attributed the earlier phase of intense folding about subvertical axes (not, however, observed in the Nova Lima district) to the Rio das Velhas orogeny, dated at 2 790 Ma (Herz 1970) by the Rb-Sr method on muscovite from mica schist of the Rio das Velhas Supergroup (Nova Lima Group?). This age, however, is about 2 890 Ma using the presently-accepted decay constant for ⁸⁷Rb ($\lambda^{87}\text{Rb} = 1.42 \times 10^{-11}/\text{yr}$). In the south-central part of the Quadrilátero Ferrífero, the Bação Complex of basement rocks has "intruded" Rio das Velhas rocks as a mantled gneiss dome (Ladeira 1980, Schorscher 1982, Cordani & Brito Neves

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Figure 1. Geological index map showing the gold deposits studied and the major Morro Velho and Raposos mines in the Nova Lima District.

1982) and has deformed adjacent Minas rocks. The Bação Complex rocks are Archean (about 2 700 Ma), but were remobilized at about 2 000 Ma (Cordani & Brito Neves 1982).

Rocks in the region, including those of the Minas Supergroup of Proterozoic age, were subjected to the major Minas-Espinhaço orogeny at about 2 000 Ma. This corresponds to the widely recognized Transamazônico orogenic cycle (1 900 to 2 100 Ma by Rb-Sr dating; Cordani & Brito Neves 1982). According to Cordani *et al.* (1980) the rocks were also deformed during an Upper Proterozoic orogeny (Brasiliano cycle).

Geochronological data remain very sparse for rocks other than those of the basement domains in the Quadrilátero Ferrífero region. Principal geochronological gaps include the lack of reliable ages for the Nova Lima Group, and for the time of formation of "remobilized" or epigenetic gold deposits, assuming gold ore in sulfide-rich units closely associated with "lapa seca" phases is syngenetic. This study reports the results of lead isotope analyses of trace galenas associated with gold orebodies in the Nova Lima area, undertaken in an attempt to define age limits for the mineralization, or ore remobilization, and for the host rocks of the Nova Lima Group.

Previous geochronology The most extensive geochronological studies have been of the basement rocks in the southern part of the São Francisco craton, adjacent to the Quadrilátero Ferrífero. On the basis of 60 new Rb-Sr and K-Ar age determinations and the data previously available, Teixeira (1982) subdivided the granitic-gneissic basement terrane west of the Quadrilátero Ferrífero into four do-

main. In the west-central region the Rb-Sr data indicate an age of about 3 000 Ma, a possible secondary event at about 2 500 Ma, and a probable Transamazônico cycle age for the Cristais granite batholith, at about $2\,048 \pm 70$ Ma. The Transamazônico event was also reflected by a few K-Ar amphibole, plagioclase and biotite ages at about 2 140 Ma, a Rb-Sr isochron at $2\,078 \pm 78$ Ma for a pegmatitic intrusion, and by other K-Ar mineral ages ranging from $2\,077 \pm 62$ to $1\,763 \pm 82$ Ma. In the central region whole-rock Rb-Sr isochrons at about 2 350 and 2 100 Ma were obtained, and both apparently reflect reworking of older crustal material. K-Ar analyses yielded Transamazônico cycle ages of 1 730 to 2 000 Ma. In the northern region Besang *et al.* (1977) obtained an approximate Rb-Sr isochron age of 2 400 Ma for granitic-granodioritic gneisses from the Cario-ca-Pará de Minas area. Cordani *et al.* (*in press*; results reported by Teixeira 1982) have concluded that gneisses and granitic rocks in the Sete Lagoas area define a Rb-Sr isochron at about 2 100 Ma. Data for the Barbacena area (generally not considered as belonging to the São Francisco craton according to Teixeira 1982) in the eastern region define a Rb-Sr whole-rock isochron age of about 3 000 Ma. Rocks from elsewhere in the eastern region, from near Congonhas do Campo, Mariana and Itabirito, yield a poorly-defined isochron at 2 750 Ma, and others yield a similar isochron representing the Minas-Espinhaço orogeny (Transamazônico Cycle) at 2 100 Ma. The rocks of the Bação Complex yielded a wide range of apparent ages. Numerous K-Ar ages in the 550 to 450 Ma range interpreted by Teixeira to reflect a Brasiliano Cycle thermal overprint associated with large thrust faults.

Character of the gold deposits The Morro Velho, which has produced more than 250 tons of gold during its history, and Raposos mines are the most important and famous deposits of the district. The orebodies are typically stratabound, in many cases very strictly stratiform, and are closely associated with carbonate facies iron formation, sulfide-rich units (sulfide facies iron formation?), and quartz-rich units (siliceous "lapa seca", metachert?). However, some of the quartz-rich ore zones are at present, due perhaps to intense deformation, very irregular rather than stratiform bodies. The host rocks are chlorite schists, sericite schists, phyllites and quartz-carbonate rocks of the Nova Lima Group. At the Raposos mine gold is associated with four facies of iron formation (Ladeira 1980, Vial 1980a): oxide (magnetite), carbonate (siderite, ankerite, iron-dolomite), silicate (biotite, cummingtonite-grunerite), and sulfide (pyrite, pyrrhotite, arsenopyrite and chalcopyrite). The Morro Velho mine has been described recently by Ladeira (1980), who concluded that many of the orebodies represent primary syngenetic accumulation of gold in association with chemical sediments. The Agnico-Eagle Mine at Joutel, Quebec, Canada has many of the lithological characteristics of Morro Velho, but has been much less deformed and thus has much better preservation of primary textures and features (Barnett *et al.* 1982). Observations at the Agnico-Eagle deposit are in accord with interpretation of sulfide-rich and carbonate-rich units at Morro Velho as chemical sedimentary in nature and siliceous "lapa seca" as metachert.

The Bicalho deposit was mined by the St. John del Rey Mining Co. between 1940 and 1943. Gair (1962) consider-

ed the ore to be identical to that at the Morro Velho mine. Gold is associated with pyrite and pyrrhotite in a conformable bed of gray "lapa seca". The deposit has also been described by Vial (1980b). Production at the Faria mine, which also commenced in 1940, was suspended in 1947. The Faria lode has been reported to be mainly in schist with iron-formation forming the footwall (Gair 1962). The orebodies are unrelated to folding of the strata. Moreschi (1977) has described the deposit in greater detail. The gold mineralization is associated with pyrite, pyrrhotite and arsenopyrite that are concentrated in carbonate-facies iron formation, specifically in particular layers in the well-layered rock. The iron formation is associated with graphitic phyllite in a sedimentary sequence (quartz-feldspathic schist, sericite schist, chlorite schist, and quartz-carbonate schist) that includes tuffaceous rocks and is both overlain and underlain by mafic volcanic rocks. Very little information has been published on the Bela Fama deposit (Gair 1962, Torres 1975). According to Gair (1962) the deposits evidently consist of sulfides in a northward-trending, northeastward-dipping bed of "lapa seca".

Lead isotope results Galenas for lead isotope study were obtained wherever possible from gold deposits in the area and represent a minor mineral phase in the ores. Galenas from the Faria, Esperança III and Cuiabá mines (Fig. 1) are from veins that cut iron formation, while those from the Bicalho and Bela Fama mines are from white quartz veins that cut siliceous "lapa seca". For the latter mines, therefore, the galena and associated white quartz may have been epigenetically introduced or simply remobilized and recrystallized *in situ*.

The galena specimens were analyzed in the mass spectrometry laboratory of the Department of Physics, University of Alberta, Edmonton. Samples were prepared by dissolving a small fragment of the galena in 10 ml of high purity 2N HCl, and evaporating the solution slowly until $PbCl_2$ crystallized. The crystals were extracted from the solution, washed in 4N HCl, dried and dissolved in water. An aliquot of 1 to 2 μ gm was loaded on a Re filament in a silica gel-phosphoric acid mixture and analyzed on a Micro-mass MM-30 mass spectrometer. Nineteen recent analyses of the NBS SRM981 standard have yielded measuring errors of 0.21, 0.26 and 0.29‰ for the $^{206}Pb/^{204}Pb$, $^{207}Pb/^{204}Pb$ and $^{208}Pb/^{204}Pb$ ratios, respectively. The correlation coefficient between pairs of ratios is 0.84.

Nine analyses (Tab. 1) have been obtained for seven galena specimens from five gold deposits in the Nova Lima area. These data clearly establish an Archean age for part of the galena mineralization (Tab. 1, Fig. 2). They are very similar to analyses that have been obtained for galenas from gold deposits in the Superior Province of the Canadian Shield (Thorpe 1982, 1983). Specifically, data for the Bicalho and Esperança III deposits, and for the least radiogenic Bela Fama analysis, lie within or very near the main field that has been established for these Canadian deposits. The Cuiabá and Faria analyses are a little more radiogenic.

Bela Fama analysis TQ82-148, which plots near the Superior Province paleoisochron (Thorpe 1982) in a position similar to a large number of Superior Province gold deposits, yields a model age of 2 710 Ma. This age, based on the model of Thorpe (1982, 1983), is particularly significant because it suggests that the gold mineralization with which

Figure 2. Lead isotope data for gold deposits of the Nova Lima District in relation to isochrons according to the model proposed by Thorpe (1982, 1983) and the main field of analyses for gold deposits of the Superior Province, Canada. The least radiogenic previous analyses for Brazilian galenas, for the Morro do Bule vein and Boquira Mine, are also shown.

Table 1 – Lead isotope data for galena from gold deposits in the Nova Lima district

Sample No.	Mine*	$^{206}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{208}Pb/^{204}Pb$	μ	Th/U	Model Age
TQ82-146	1	13.729	14.694	33.432	9.000	3.916	2569 Ma
TQ82-146**	1	13.726	14.695	33.441	9.015	4.021	2574 Ma
TQ82-147	1	13.901	14.763	33.543	9.228	3.852	2493 Ma
TQ82-148	2	13.527	14.648	33.263	9.258	3.955	2710 Ma
TQ83-37	2	14.731	14.907	34.275	8.515	3.826	1935 Ma
TQ83-38	3	14.112	14.867	33.809	9.202	4.014	2425 Ma
TQ83-39	4	13.626	14.598	33.301	8.637	3.951	2551 Ma
TQ83-57	5	13.854	14.660	33.483	8.516	3.898	2409 Ma
TQ83-57**	5	13.856	14.669	33.495	8.561	3.912	2418 Ma

* 1 = Bicalho; 2 = Bela Fama; 3 = Faria; 4 = Esperança III; 5 = Cuiabá

** duplicate analyses

this galena is associated, and the host rocks, are at least this old. The calculated Th/U ratio shows some promise as a parameter that may indicate which leads have had a single stage or essentially single-stage evolution. It has recently been observed by the senior author that such deposits generally have calculated Th/U ratios in the range 3.96 to 4.20. The Faria and Esperança III analyses, and one each from the Bicalho and Bela Fama deposits, fall in or very near this range (Tab. 1), indicating possible single stage evolution.

If the Esperança III and Bicalho TQ82-146 leads were essentially single-stage, an age of formation of about 2 550 to 2 575 Ma is indicated. The Faria and Cuiabá leads, although the latter falls slightly outside the criterion range of Th/U values, have comparable and possibly meaningful 2 410 to 2 425 Ma model ages.

The lead isotope data, however, define at least two possible secondary isochrons for which two-stage calculations may be appropriate. The Bicalho analyses lie on a possible subparallel line above the Matachewan line (Fig. 2) established by Sinclair (1982) for deposits and occurrences of gold and other types in the Matachewan area, Superior Province, Ontario. The Matachewan line was interpreted as due to mineralization or remobilization at about 2 400 Ma, with the lead being derived from source rocks about 2 720 Ma old. An alternative explanation, isotopically equivalent to remobilization, is that some radiogenic lead was added at 2 400 Ma to galenas that originally formed at about 2 720 Ma. If the Bicalho analyses define a two-point secondary isochron, with a slope of 0.395 ± 0.015 at 1σ , it would appear that some reasonable limits to the ages of the source and of the mineralization or remobilization can be postulated. Assuming reasonable accuracy for model ages by the Superior Province model, it is unlikely that t_2 is greater than about 2 500 Ma, the approximate model age for the most radiogenic analysis. It can probably also be reasonably assumed that the 2 710 Ma model age of the Bela Fama deposit is a minimum value for t_1 , the age for the source of the lead (and also the age of primary mineralization if t_2 is interpreted as the age of a remobilization event). Some possible two-stage pairs are:

t_1	t_2
2 680 Ma	2 500 Ma (probable max.)
2 710 Ma	2 465 Ma
3 890 Ma (max.)	0
3 000 Ma	2 105 Ma

A value as great as 3 890 Ma for t_1 seems unlikely. If the maximum μ value for the source of the Bicalho leads is taken to be 9.4, the approximate maximum value established to date for Superior Province gold deposits, the intersection of the Bicalho secondary isochron with a growth curve of this μ value gives a practical maximum value of 2 985 to 2 990 Ma for μt_1 . For this reason an age for the source rocks, and for the mineralization, no greater than about 3 000 Ma is preferred. It is of interest that this corresponds to the maximum Rb-Sr whole-rock isochron ages obtained by Teixeira (1982) for basement rocks in the region. Although U-Pb zircon ages would be more relevant to the present study, and are commonly at least slightly older than Rb-Sr isochron ages on the same rock suites, it nevertheless appears that 3 000 Ma is the maximum source

age that can be defended on the basis of known geological relationships and available geochronological data. With 3 000 Ma as the maximum source age, mineralization, remobilization or addition of a radiogenic lead component must have occurred prior to about 2 105 Ma. The latter is in reasonable agreement with ages for the major Minas-Espinhaço orogeny (Transamazônico Cycle) that affected rocks in the region, and throughout the São Francisco Craton. However, it is striking that the calculated 2 710 Ma – 2 465 Ma two-stage ages are in good agreement with the model ages of the least radiogenic Bela Fama lead and the most radiogenic Bicalho analysis. Also, some of the basement rocks west of the Quadrilátero Ferrífero were affected by a secondary event at about 2 500 Ma (Teixeira 1982). Thus, both the 3 000 Ma – 2 105 Ma and 2 710 Ma – 2 465 Ma pairs are possibilities, although the authors tentatively favour the latter because, while some rocks in basement domains in the region are 3 000 Ma old, Nova Lima Group rocks are a more logical source for the lead and these are probably somewhat younger.

The best apparent secondary isochron is defined by the Esperança III, Cuiabá and Bela Fama TQ83-37 analyses. This line has a slope of 0.279 ± 0.003 at 1σ , with a MSWD value of 2.62. The data are also nearly linear on a plot of $^{208}\text{Pb}/^{206}\text{Pb}$ versus $^{207}\text{Pb}/^{206}\text{Pb}$, suggesting that the leads may have had comparable two-stage histories. The calculated maximum age of mineralization or remobilization (and minimum source age) is about 2 175 Ma. While a slightly greater source age than this in combination with a slightly lower mineralization age would explain the slope of the secondary isochron, and an approximate 2 175 Ma age might be acceptable as a reflection of the Minas-Espinhaço orogeny, it seems unlikely that the isotopic difference was generated in this way. This is because, 1) the Esperança III yields a significantly older model age, 2) evolution of the Bela Fama TQ83-37 lead isotope composition would require a very high μ value, and 3) short-term evolution would be expected to result in very much greater dispersion of calculated Th/U values. Calculated deposition or remobilization ages for leads on the line at assumed source ages of 3 000 Ma, 2 700 Ma and 2 400 Ma are about 975 Ma, 1 520 Ma and 1 930 Ma, respectively. However, none of the latter ages are in agreement with the approximate ages established for Proterozoic orogenic events in the region. While the Esperança III, Cuiabá and Bela Fama TQ83-37 analyses plot in a very linear manner, the precise interpretation of this possible secondary isochron is thus obscure. Perhaps they are best considered as unrelated, and the Esperança III and Cuiabá leads interpreted in terms of model ages.

It may be of interest that the possible Esperança III-Bela Fama and Bicalho secondary isochrons intersect approximately on the Stacey-Kramers (1975) average lead evolution curve at a point that has a model age of about 2 900 Ma. However, in view of the wide range of isotope ratios for Superior Province gold deposits (Fig. 2) there is no compelling reason to believe that the sources for the lead in the five galena specimens had a single initial isotopic composition, and this calculated age thus probably has no real significance.

The most radiogenic Bela Fama analysis should possibly be related to the less radiogenic Bela Fama value. This line, which includes the least radiogenic Bicalho analysis, has a slope of 0.214 ± 0.003 at 1σ , with a MSWD value of 0.63.

These data are also linearly distributed on a plot of $^{208}\text{Pb}/^{206}\text{Pb}$ versus $^{207}\text{Pb}/^{206}\text{Pb}$, which suggests that the line may be either a valid secondary isochron or due to mixing. Two-stage calculations in this case yield a 595 Ma mineralization or remobilization age for the more radiogenic lead at an assumed source age of 2 710 Ma. This calculated 595 Ma age is close to the 620 Ma age suggested by Cordani *et al.* (1973) for the Brasiliano orogenic cycles that has been superimposed, at least as a thermal event, on rocks of the region (Teixeira 1982).

DISCUSSION The lead isotope analyses reported here are the least radiogenic that have been obtained for Brazilian galenas. The least radiogenic analyses previously published are for the Boquira mine in Bahia State (Cassedanne & Duthou 1981) and for galena from the Morro do Bule vein that cuts dolomite of the Minas Group in the Ouro Preto region (Cassedanne *et al.* 1972). The Boquira data, which has a very large scatter due to ^{204}Pb measurement error, yields average isotope values from 13 analyses (one analysis eliminated because it appears to represent a more radiogenic composition) of 14.608, 15.252 and 34.558 for the $^{206}\text{Pb}/^{204}\text{Pb}$, $^{207}\text{Pb}/^{204}\text{Pb}$ and $^{208}\text{Pb}/^{204}\text{Pb}$ ratios, respectively. This average and the Morro do Bule analysis have been plotted in Fig. 2. Model ages for these according to the Superior Province paleoisochron model of Thorpe (1982, 1983) are 2 437 and about 2 150 Ma, respectively.

The Bicalho, Esperança III and Bela Fama TQ-82-148 analyses are very comparable to values that have been obtained for Archean gold deposits in the granite-greenstone belts of the Superior Province, Canada. The established zircon U-Pb ages for these belts are in most cases in the range 2 692 to 2 750 Ma. The 2 710 Ma model age for the Bela Fama analysis could be close to a primary age because, as noted previously, the galena is from white quartz that "cuts" quartz "lapa seca" and could thus be primary, with the epigenetic appearance of the host quartz due to recrystallization *in situ*. It is not clear which of the more radiogenic lead isotope analyses should be interpreted in terms of model ages and which in terms of secondary isochron relationships. In any case they should be attributed to lead introduction or remobilization during subsequent Proterozoic deformation events. The isotopic imprint of a series of major Proterozoic orogenic events in the region has been documented (Teixeira 1982), and some of these can be tentatively correlated with possible ages for galenas from the gold deposits. Because the galenas are only trace constituents of the gold zones within the mines, the most logical lead source would appear to be the host Nova Lima Group rocks. Remobilization of some constituents, including lead and silica, and formation of epigenetic gold-quartz veins

and irregular bodies, possibly by relatively local remobilization from syngenetic gold zones, might be anticipated in conjunction with the major Proterozoic orogenic events. The formation of many of the trace galenas may thus be closely linked to the formation of epigenetic gold orebodies.

CONCLUSIONS The lead isotope data for galenas from gold deposits in the Nova Lima district clearly indicate an Archean age for the Nova Lima Group, in accord with the conclusions of Ladeira (1980), Schorscher (1982) and many other workers, but in contrast to the Proterozoic age recently inferred by some authors (e.g. Muller *et al.* 1982). Gold mineralization in the district was emplaced in part in the Archean, possibly at about 2 710 Ma, the model lead age of the least radiogenic galena. However, we consider that the lead isotope data only constrains the primary age of mineralization to the interval 2 700 to 3 000 Ma.

The gold ores were slightly remobilized with the introduction of small amounts of lead to form galena during Proterozoic orogenic events, possibly at 2 410 to 2 425 Ma, at approximately 2 100 to 2 175 Ma during the Transamazônica orogeny, and at about 600 Ma during the Brasiliano orogeny. Some features of the lead isotope compositions can be explained by invoking events at about 1 935 Ma and/or 1 520 Ma, but such events must be considered highly speculative until they are supported by additional evidence. Epigenetic gold-bearing quartz veins and irregular bodies may have been formed by more extensive remobilization, or by the introduction of gold-bearing fluids from external sources, during the major Proterozoic orogenic events.

While confirming an Archean age for rocks of the Nova Lima Group, this study only serves to emphasize the need for more precise geochronological definition of their age and of the subsequent Proterozoic orogenic events. Such a study could contribute significantly to resolving the problem of the relative importance of syngenetic and of later remobilization processes in genesis of gold orebodies within the Nova Lima district.

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MANUSCRITO

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"As simplicidades das leis naturais surgem das complexidades das linguagens que usamos para exprimi-las."

Eugene P. Wigner