Source, Transport and Deposition of Metals, Pagel & Leroy (eds) © 1991 Balkema, Rotterdam. ISBN 90 5410 020 6

$^{40}Ar/^{39}Ar$ laser-probe dating of the Colombian emerald deposits: Metallogenic implications

A.Cheilletz – *'Fluides et Minéraux' ENSG-CRPG, Vandoeuvre-lès-Nancy, France*
G.Féraud – *Institut de Géodynamique URA-CNRS, Université de Nice, France*
G.Giuliani – *ORSTOM, Département TOA et CRPG, Vandoeuvre-lès-Nancy, France*
C.T.Rodriguez – *Mineralco S.A., Bogota, Colombia*

ABSTRACT: The emerald mineralizations of the Muzo-Quipama and Coscuez mines, Colombia, have been dated for the first time by $^{40}Ar/^{39}Ar$ induction and continuous laser-probe on synchronous greenish K-micas following step-heating and spot-fusion procedures. Two distinct upper Eocene-lower Oligocene ages have been determined for the two deposits at respectively 31.5-32.6 Ma for Muzo-Quipama and 35-38 Ma for Coscuez. These ages provide better constraints for the genetic model of the mineralization particularly concerning (1) the depth and pressure (1.2 Kb) of formation and (2) the temperature of the hydrothermal solutions (270 ± 30°C) which gives to the Colombian emerald mineralization a low temperature character.

INTRODUCTION

The Colombian emeralds are worldwide known for their great quality and unique geological environment which is constituted by calcite-dolomite veins, pockets and brecciated zones within lower Cretaceous black-shales formations. Hydrofracturing and an intense alteration of the wall-rocks favoured the development of an epigenetic hydrothermal process for the emerald formation. However, the lack of precise dating of the deposits preclude any accurate P and T estimation of the deposition of the beryllium mineralization as a preliminary to debate about the possible origin of the involved hydrothermal fluids. The present work, based on $^{40}Ar/^{39}Ar$ dating using especially a laser probe step-heating procedure, gives a first unambiguous answer to this question.

GEOLOGICAL SETTING AND SAMPLE DESCRIPTION

The Colombian emerald deposits constitute two mineralized belts located in the Eastern Cordillera at about 100 km N-NE of Bogota. The eastern belt is defined by the districts of Gachalà and Chivor and the western belt, scope of this study, is represented by the districts of Coscuez, Muzo and La Palma-Yacopi. The analysed samples originate from the Muzo-Quipama (sample G 65) and the Coscuez (sample G 67) mines. For both samples, dating was realized using pale green micas deposited as 2-3 mm width patches on both walls of 2-5 cm width calcite-pyrite-emerald veins and considered as cogenetic with the emerald mineralization.

Microscopic examination of the G 67 sample shows the successive deposition of the micas band with the 001 planes perpendicular to the wall followed by a final calcite infilling of the vein; by places, calcite and micas are separated by aggregates of quartz and albite sometimes interlayered within the micas band. The G 65 sample displays the same microscopic organisation but with some chlorite (Donbassite) microgeodic rosettes interfacing the micas and calcite bands.

Diffractometric analysis of the micas agregates of the two samples showed a uniform muscovite $2M_1$ structure. Microprobe analysis revealed an apparent deficit of the interlayered charge (Σ K=0.59-0.76) and apparent excess of octaedric cations (Σ VI=2.01-2.11). These K-micas can therefore be considered as hydromicas (Brindley, 1980). An additional poorly represented Na-bearing phyllosilicate

phase interlayered within the K-hydromicas is also revealed by microprobe analysis in the G 65 sample but remains indistinguishable at a microscopic scale.

$^{40}Ar/^{39}Ar$ DATING RESULTS AND DISCUSSION

$^{40}Ar/^{39}Ar$ analyses were performed (1) on bulk samples of micas by the conventional step-heating procedure, (2) on single grains of mica aggregates, by step-heating procedure and (3) on sections perpendicular to the mica bands by spot fusion. The two last kinds of experiments were performed with the continuous laser probe.

Bulk samples and single grain aggregates of the two samples (Fig. 1 & 2) show similar age spectra characterized by increasing ages at low temperature, followed by decreasing ages, then a more or less flat domain. The sample G 65 (Fig. 1) gives a plateau-age at 31.5 ± 0.3 Ma (corresponding to 82 % of ^{39}Ar released) on a single grain aggregate, whereas the corresponding bulk sample displays more precise concordant ages with an integrated value of 32.6 ± 0.1 Ma, over 60 % of ^{39}Ar released only. The sample G 67 (Fig. 2) does not give any plateau-age over a high percentage of ^{39}Ar released, but excepted for the low temperature domain, it displays no more variable ages than for G 65. However, most of the apparent ages for this sample range from 35 to 38 Ma.

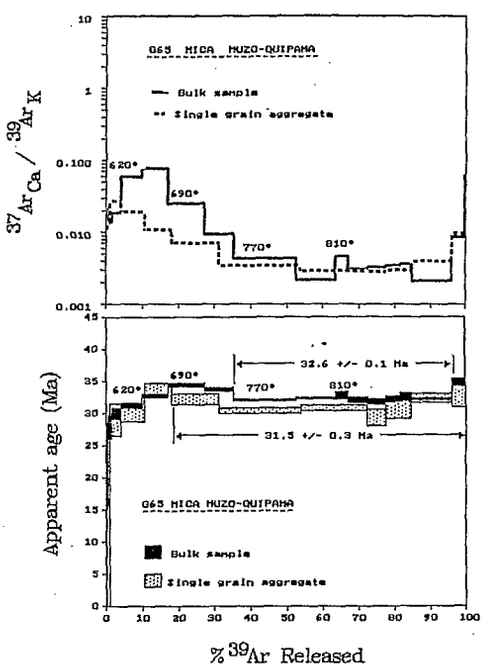

Figure 1- Induction (bulk sample) and continuous laser-probe step-heating (single grain aggregate) age spectra of sample G 65.

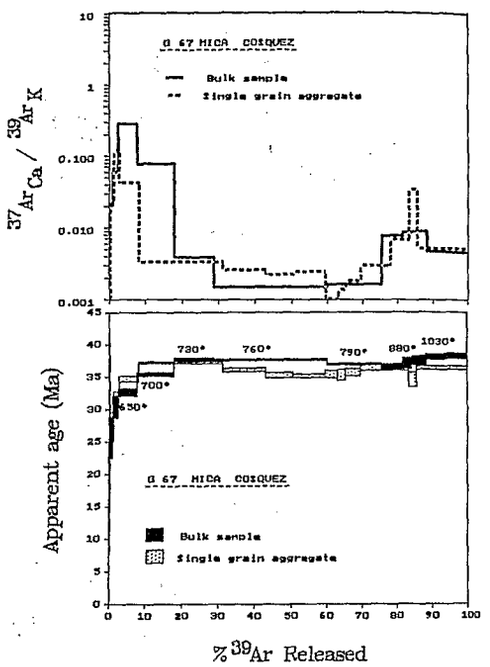

Figure 2- Induction (bulk sample) and continuous laser-probe step-heating (single grain aggregate) age spectra of sample G 67

Spot fusion analyses, performed on sections perpendicular to the mica bands of the two samples gave concordant ages (at the 2σ level) with (1) their weighted mean and (2) the integrated ages of step heating experiments, excepted for one G 65 spot fusion age. No correlation between ages and distances to the outer rim of the mica band could be detected, in spite of variable $^{37}Ar_{Ca}/^{39}Ar_K$ ratios (Fig. 1 & 2) related to minute calcite crystals which

may occur between the individual lamellae of K-micas.

In the G 67 section perpendicular to the mica band, three spot fusion analyses were performed on the quartz-albite-calcite assemblage adjacent to the mica band. The ages, ranging from 52.2 ± 7.4 to 150 ± 15 Ma, can probably be explained by excess argon.

Owing to the fact that a majority of ages obtained on the mica bands by spot fusion analyses are concordant, we interpret the heterogeneities in the age spectra as probably not due to a mixture of different mineral phases with different $^{40}Ar/^{39}Ar$ ratios, but rather to heterogeneities in the argon distribution at a significantly lower scale than that of the spot fusion (fused spot diameter ≥ 50 µm). Recoil of ^{39}Ar during irradiation of the samples is a good candidate to explain these heterogeneities, particularly because the thickness of the individual micas crystals (1 to 3 µm) is not very high compared to the accepted ^{39}Ar recoil distance (0.08 µm; Turner and Cadogan, 1974). Nevertheless, as it was already noticed by Bray et al. (1987) who analysed similar minerals by the $^{40}Ar/^{39}Ar$ method, no noticeable net loss of ^{39}Ar due to recoil may occur when the samples are left as aggregates. This may be due to the fact that ^{39}Ar that recoiled from one individual mica would have had a high probability to be implanted within a neighbouring crystal. In our case, minor amounts of calcite, quartz, albite, chlorite or Na-bearing phyllosilicate may be intercalated within the K-micas aggregates. It is therefore likely that some ^{39}Ar may have recoiled from K-micas to neighbouring grains of different nature. For instance, the humped shape around the 690°C step of the G 65 bulk sample age spectrum may be due to a deficit in ^{39}Ar, in the micas (K-rich phase), whereas the low ages displayed at lower temperature may originate from a gain of ^{39}Ar in K-poor phases. Let us notice that the integrated age of these two domains of the age spectrum (steps 400-720°C) is 33.1 ± 0.2 Ma, nearly similar to that of the plateau-age i.e. 32.6 ± 0.1 Ma. This is in agreement with a lack of total ^{39}Ar loss in the analysed samples.

Therefore, it is likely that the ages of 31.5-32.6 Ma (sample G 65) and 35-38 Ma (sample G 67) represent reasonable estimates of the age of the K-micas cogenetic with the emerald deposition.

METALLOGENIC IMPLICATIONS

These first $^{40}Ar/^{39}Ar$ dating of the Colombian emerald deposits give a representative late Eocene-lower Oligocene age following the stratigraphic scale of Odin and Odin (1990). This result rules out the hypothesis of Ulloa (1980) attributing the circulation of the emerald mineralizing fluids to the thermal effect provoked by the basic magmatism which intruded the lower Cretaceous series at 115-118 Ma (Fabre et Delaloye, 1983). On the other hand, these Paleogene ages are in agreement with the Escovar hypothesis (1979) of a tertiary age for the emerald mineralization correlated to the emplacement of supposed Cenozoic-aged rhyolitic intrusives. It can also be noticed that these ages correspond to a major compressive tectonic phase affecting the whole Andean-Carribean domain during the middle-late Eocene (Beck, 1986). This important shortening episode affecting the Eastern Cordillera may have created deep decolement levels, reverse faulting allowing further circulations of hydrothermal connate basinal or metamorphic fluids throughout the whole stratigraphic column. Following this model, the hydrothermal fluids can originate either from the cretaceous or older underlying rocks of the Eastern Cordillera, or from the overthrusted subsiding foreland Llanos basin.

Finally, the $^{40}Ar/^{39}Ar$ upper Eocene-lower Oligocene age for the emerald mineralization gives rise to an estimation of a 4500 m of overburding at that time using Hebrard (1985) stratigraphic reconstitution. i.e. a lithostatic pressure evaluation of 1.2 Kb. This permits to constrain the preliminary fluid inclusions results (Giuliani et al., 1990) at 270 ± 30°C as an effective trapping temperature for the hydrothermal solutions. Therefore, the Colombian emerald mineralizations appear to have developped at relatively low temperature conditions as early proposed by Beus and Mineev (1972). In that sense, they constitute an original type totally distinct from the classic high temperature pegmatite-biotite schists-emerald association (Schwarz, 1987; Giuliani et al., 1990).

REFERENCES

Beck, C. 1986. Collision caraïbe, dérive andine, et évolution géodynamique mésozoïque-

cénozoïque des Caraïbes. Rev. Géogr. phys. Géol. dyn. 27: 3-4, 163-182.

Beus, A.A. & Mineev, D.A. 1972. Some geological and geochemical features of the Muzo-Coscuez emerald zone, Cordillera oriental, Colombia. Informe Ingeominas, Bogotà: 1-50.

Bray, C.J., Spooner, E.T.C., Hall, C.M., York, D., Bills, T.M. & Krueger, H.W. 1987. Laser probe $^{40}Ar/^{39}Ar$ and conventional K/Ar dating of illites associated with the McClean unconformity-related uranium deposits, north Saskatchewan, Canada. Can. J. Earth Sci. 24: 10-23.

Brindley, G.W. 1980. Order-disorder in clay mineral structures. In: Brindley, G.W. and Brown G. (eds), Crystal Structures of Clay Minerals and Their X-ray Identification. Mineral. Soc., London: 125-195.

Fabre, A. & Delaloye, M. 1983. Intrusiones bàsicas cretacicas en las sedimentilas de la parte central de la Cordillera oriental. Geol. Norandina 6: 19-28.

Giuliani, G., Silva, L.J.H.D. & Couto, P. 1990. Origin of emerald deposits of Brazil. Mineral. Deposita 25: 57-64.

Giuliani, G., Cheilletz, A. & Rodriguez, C.T. 1990. 8th IAGOD Symp., Ottawa, 12-18 August, abstr.: 48-49.

Hebrard, F. 1985. Les Foot-hills de la Cordillère Orientale de Colombie entre les rios Casanare et Cusiana. Evolution géodynamique depuis l'Eo-Crétacé. Thèse Doct. 3è cycle, Univ. P. et M. Curie Paris VI, Sci. Nat., Géol., 29 janv.

Odin, G.S. & Odin, C. 1990. Echelle numérique des temps géologiques. Mise à jour 1990. Géochronique 35:12-21.

Schwarz, D. 1987. Esmeraldas-inclusoes em gemas. Imprensa Universitaria UFOP Ouro Preto, 450p.

Turner, G. & Cadogan, P.H. 1974. Possible effects of ^{39}Ar recoil in $^{40}Ar/^{39}Ar$ dating. Proc. in the 5th Lunar Scie conf.: 1601-1615.

Ulloa, C. 1980. Ambiente geologico de los yacimientos esmeraldiferos en Colombia. Bol. Soc. Geol. Perù 65: 157-170.