LATE EOCENE-OLIGOCENE SHORTENING EPISODE IN EASTERN CORDILLERA OF COLOMBIA VIEWED BY EMERALD DATING

Alain CHEILLETZ[1], Gaston GIULIANI[1,2], and Thierry ARHAN[1]

(1) ENSG and CRPG-CNRS, BP 20, 54501, Vandoeuvre, France
(2) ORSTOM, Département TOA-UR 1H, 213 rue La Fayette, 75480 Paris, France

RESUMÉ: L'étude métallogénique des gisements d'émeraude de Colombie encaissés dans les shales noirs du Crétacé inférieur, conduit à d'intéressantes applications concernant l'évolution tectonique de la Cordillère Orientale et notamment la phase de déformation fini Eocène-Oligocène à laquelle sont attribués les mouvements ascendants de saumures hydrothermales associées à la formation des émeraudes.

KEY WORDS: Eastern Cordillera, Colombia, Emerald, Lower Cretaceous black shale, Eocene-Oligocene, Petroleum exploration.

INTRODUCTION

Recent progress in metallogenetic studies of Colombian emerald deposits (Giuliani et al., 1990a; Cheilletz et al., 1991) have issued important tectonic implications interesting the Eastern Cordillera of Colombian Andes. As suggested by Mégard (1987), the Eastern Cordillera constitutes an inverted sedimentary back-arc basin of Jurassic-Late Cretaceous age filled with thick accumulations of marine sediments. Eocene-Late Oligocene synorogenic non-marine molasse sequences buried the basin as a response to uplift of the Central Cordillera. Inversion of the Eastern Cordillera basin occurred during the Andean compressional episode at Late Miocene-Pliocene time.

The Colombian emerald deposits are grouped within two belts (Fig. 1) situated along the two major polyphased thrust zones that correspond approximatively to the original limits of the Cretaceous basin (Mégard, 1987; Schamel, 1991). The emerald mineralization consists of carbonate-pyrite veins and breccia hosted by Lower Cretaceous black-shales corresponding to Macanal (Berriasian-Valanginian; Eastern belt) and Paja (Hauterivian-Barremian; Western belt) formations. The genesis of the emerald mineralization is undoubtly attributed to epigenetic hydrothermal fluid circulations (Beus and Mineev, 1972.); however, the age of the tectonic phase responsible for the extension-vein network and hydraulic breccia trapping the mineralization has only recently been obtained by $^{40}Ar/^{39}Ar$ dating of cogenetic muscovite (Cheilletz et al., 1993). Two distinct Upper Eocene-Lower Oligocene ages have been determined for the deposits of Coscuez (35-38 Ma) and Muzo-Quipama (31.5-32.6) in the western belt.

In this paper, we attempt to briefly examine the consequences of the age of emerald formation on the regional tectonic-geologic framework.

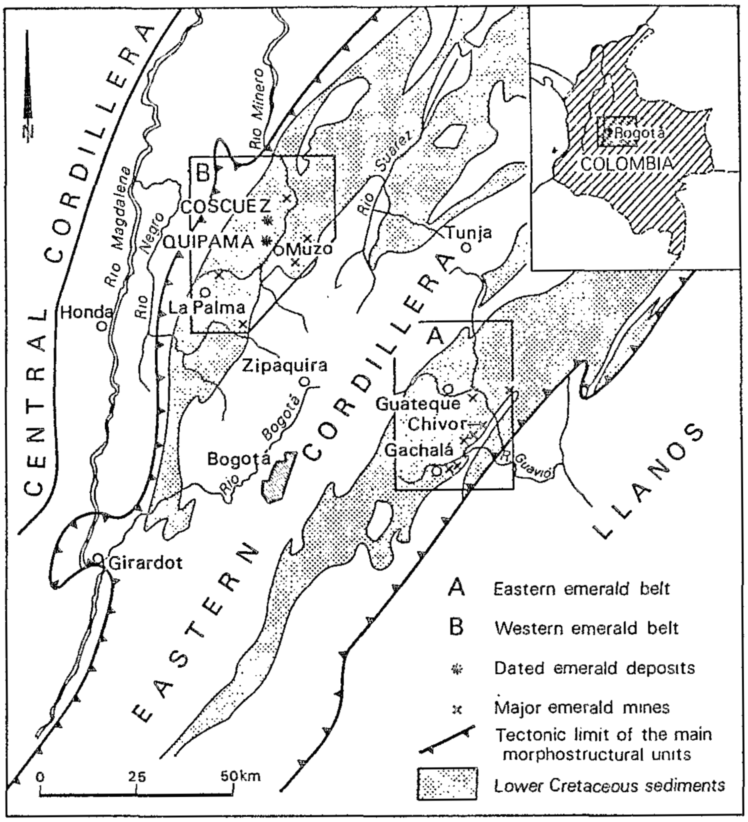

Figure 1: Tectonic provinces of the Colombian Andes and location of emerald deposits belts.

ORIGIN OF THE EMERALD DEPOSITS OF COLOMBIA

Petrographic observations and mass balance calculation in black-shale hosting the emerald vein network demonstrate that the hydrothermal fluid infiltration process is accompanied by a strong fluid-rock interaction leading to sodium and carbonate metasomatism; as a consequence, the enclosing black-shales are conversely leached in major, trace and REE elements (Giuliani et al., 1990b; 1993a). These chemical exchanges involve a local sedimentary origin for most of the elements constituting the vein-infilling minerals and particularly emerald (Be, Cr, V, Si, Al). The origin of the hydrothermal fluid responsible for chemical transfers has been approached by oxygen isotopic measurements (Giuliani et al., 1992); calculated $\delta^{18}O$ H_2O for carbonate and quartz indicate values of basinal formation waters. Sulfur isotopic data on pyrite and fluid inclusion studies of trapped brines within emerald crystals indicate an evaporitic source for the chlorine and sulfate components of the hydrothermal fluids (Giuliani et al., 1993b). Indeed, evaporitic plugs are known within the Cretaceous formations (Campbell and Bürgl, 1965) and thus might have been in contact with or percolated by the hydrothermal brines. Constrained by (1) the $^{40}Ar/^{39}Ar$ age determination, (2) an Eastern Cordillera subsiding model (Hébrard, 1985), and (3) lithostatic pressure equilibration assumption, isochoric extrapolation of these complex brines in the NaCl-H_2O system lead to a pressure-temperature estimate of 1 Kb and 290-360°C for the emerald deposition (Cheilletz et al., 1993).

TECTONIC CONSEQUENCES

The location of the emerald deposits along the original limits of the Cretaceous basin suggests that these limits might constitute deep-seated rejuvenated faults allowing hot-fluid circulations up through the sedimentary pile. Hydro-fracturing and strongly reducing environment conditions highly favoured by the black shale lower Cretaceous horizons, provoked the emerald-pyrite-calcite precipitation. Comparison between thermo-barometric data for emerald generation (290-360° C, 1Kb; Cheilletz et al., 1993) and burial temperature estimations (135° C at 4500 m depth; Hébrard, 1985) requires a 165 to 225° C additional input within the Lower Cretaceous formations at the Eocene-Oligocene boundary. This can be obtained either by correlative intrusive emplacement as suggested earlier by Campbell and Burgl (1965) and Escovar (1979), but already not found in that area, or by heat conduction implemented during halokinetic ascent. Both mechanisms might be related to extensional or transtensional tectonic regime as evidenced at that period in the northernmost portion of the Andean chain (Stephan, 1985; Beck, 1986). However, detailed structural data are lacking in the emeraldiferous area to support that hypothesis.

CONLUSIONS

The tectonic evolution of the Eastern Cordillera is characterized by a strong shortening episode starting during the Eocene and corresponding to an acceleration of the convergence rate between Nazca and South American plates (Daly, 1989). At that time, sedimentation in the Eastern Cordillera basin is changing to non-marine clastic deposition, whereas the underlying mesozoic series are affected by alternating compressive and extensive-transpressive episodes in response to general crustal shortening. The emerald formation at 38-31 Ma appears as a good clock of this strong change in the tectonic regime of the Colombian Andes. Following that period, major crustal deformation involves collisional regime between the Caribbean arc system and South America, leading to thrusting and uplift of Eastern Cordillera during Late Miocene-Pliocene time particularly through rejuvenation of the older faulted limits of the Cretaceous basin (Fig.1). Considering the depth of formation of emerald (4250-4500m; Cheilletz et al., 1993), a minimum of 6000 m (excluding erosion) of vertical transfer can be deduced which is responsible for the inversion of the Cretaceous back-arc basin and emerald outcropping.

Considering petroleum exploration in the Magdalena Valley-Eastern Cordillera system, the study of emerald genesis within the Lower Cretaceous black-shales shows that temperatures of 360°C were reached at least in two large belts of these petroleum source rocks at Upper Eocene-Lower Oligocene time, implying that after an earlier maturation phase, some remobilization of trapped oil might have occurred in response to hydrothermal activity, as suggested by Fabre (1987).

REFERENCES

BECK C. (1986) - Collision caraïbe, dérive andine, et évolution géodynamique mésozoïque-cénozoïque des Caraïbes. *Rev. Géogr. Phys. et Géol. Dyn. Fr.*, 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. *Inf. Ingeomin.*, 1-50, unpubl. rep.

CAMPBELL C.J. & BÜRGL H. (1965) - Section through the Eastern Cordillera of Colombia. South Amer., *Geol. Soc. Amer. Bull.*, U.S.A., 76/5, 567-589.

CHEILLETZ A., FÉRAUD G., GIULIANI G. & RODRIGUEZ C.T. (1991) - $^{40}Ar/^{39}Ar$ laser-probe dating of the Colombian emerald deposits: metallogenic implications. *S.G.A. Meeting, 25 Years Anniversary*, Nancy, 373-376.

CHEILLETZ A., FÉRAUD G., GIULIANI G. & RODRIGUEZ C.T. (1993)- Time-pressure-temperature constraints on the formation of Colombian emeralds: an $^{40}Ar/^{39}Ar$ laser-probe and fluid inclusion study. Accepted to *Economic Geology*.

DALY, M.D.(1989) - Correlations between Nazca/Farallon plate kinematics and forearc basin evolution in Ecuador. *Tectonics*, V.8, N°4, 769-790.

ESCOVAR R. (1979) - Geologia y geoquimica de las minas de esmeraldas de Gachalà, Cundinamaraca. *Bol. Geol.*, Republica Colombia, Minist. Minas y Petroleos, Inst. Nac. Invest. Geol.-Min., 22/3, 116-153.

FABRE, A. (1987) - Tectonique et génération d'hydrocarbures: un modèle de l'évolution de la Cordillère Orientale de Colombie et du bassin des Llanos pendant le Crétacé et le Tertiaire. *Arch. Sc. Genève*, V.40, 145-190.

GIULIANI G., RODRIGUEZ C.T. & RUEDA F. (1990a) - Les gisements d'émeraude de la Cordillère orientale de la Colombie: nouvelles données métallogéniques. *Mineralium Deposita*, 25, 105-111.

GIULIANI G., CHEILLETZ A. & RODRIGUEZ C.T. (1990b) - New metallogenic data on the emerald deposits of Colombia. *8th IAGOD Symposium*, Ottawa, 12-18 August 1990, Abstracts, 185-186.

GIULIANI G., SHEPPARD S.M.F. & CHEILLETZ A. (1992) - Fluid inclusions and $^{18}O/^{16}O$, $^{13}C/^{12}C$ isotope geochemistry contribution to the genesis of emerald deposits from the Oriental Cordillera of Colombia. *C. R. Acad. Sci. Paris*, t. 314, II: 269-274.

GIULIANI G., CHEILLETZ A., SHEPPARD S.M.F. & ARBOLEDA C. (1993a) - Geochemistry and origin of the emerald deposits of Colombia. *2nd SGA Meeting*, Granada, Spain, Extended Abstract, 4 p.

GIULIANI G., CHEILLETZ A., BAKER J. & ARHAN T. (1993b) - Evaporitic origin of the parent brines-bearing Colombian emeralds: fluid inclusion and sulfur isotopic evidences. *ECROFI Symposium*, Warsaw, Poland, Abstract, 2p.

HEBRARD F. (1985) - Les Foot-hills de la Cordillère Orientale de la 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., 162 p.

MEGARD F. (1987) - Cordilleran Andes and Marginal Andes: A review of Andean Geology North of the Arica Elbow (18 deg.S) in Monger, J.W.H. and J. Francheteau, eds., Circum-Pacific orogenic belts and evolution of the Pacific ocean. *Am. Geophys. Union, Geodynamics Series*, V.18, 71-95.

SCHAMEL, S. (1991). Middle and Upper Magdalena basins, in Biddle, K.T. ed., Active Margin Basins, *AAPG memoir* 52, 283-303.

STEPHAN, J.F. (1985) - Andes et chaîne Caraïbe sur la transversale de Barquisimeto (Venezuela). Evolution Géodynamique: *Symposium Géodyn. Caraïbes*, Paris 5-8 Février 1985, ed. technip Paris, 505-529