El Tule stratabound F-Sr deposit:a key to understand the origin and mobilization of basinal brines in NE México.

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ABSTRACT: The Mesozoic platform limestones that outcrop in NE México contain abundant small to medium sized stratabound, almost monomineralic celestine deposits. These deposits usually display a very monotonous fluid history with no major changes both in fluid temperature and composition. El Tule deposit stands out as a rare example of a transitional deposit between the celestine lenses and mantos, well represented at the south of the Coahuila State (La Paila and Alamitos Ranges), and the fluoritic mantos that are characteristic of the upper Cretaceous sediments at the north of the Coahuila State *(i.e.* La Encantada-Buenavista). This deposit records a history of fluid expulsion during and after the Laramide Orogeny in NE Mexico.

KEYWORDS: celestine, fluorite, Cretaceous carbonates, MVT, NE México.

1 INTRODUCTION

In North-East Mexico, several low-temperature, epigenetic, stratabound Pb-Zn-F-Ba ore deposits outcrop forming a newly defined MVT province (Tritlla *et al.*, 2006). These deposits appear scattered throughout the whole Mesozoic carbonate platform in the Coahuila, Chihuahua, Nuevo León and San Luis Potosí States. These deposits oftenly present a close association with organic matter, either liquid hydrocarbons or bitumen; they display a very simple mineralogy (hypogene: barite, celestine, fluorite, sphalerite, galena) and present low formation temperatures (90-105ºC) coupled with variable salinities.

Almost monomineralic celestine deposits are commonly found within the Acatita and Aurora Fm. (Albian) at the central part of the Coahuila Platform (Alamitos, Australia and La Paila Ranges); some other small and isolated celestine deposits are also found north of the San Marcos Fault and in the SE margin of the Parras Basin (Puente-Solís, 2005). Even though these deposits represent one of the biggest accumulation of celestine in the world; yet, this district received little attention from the scientific and mining world mainly due to the small and disperse character of the single ore bodies.

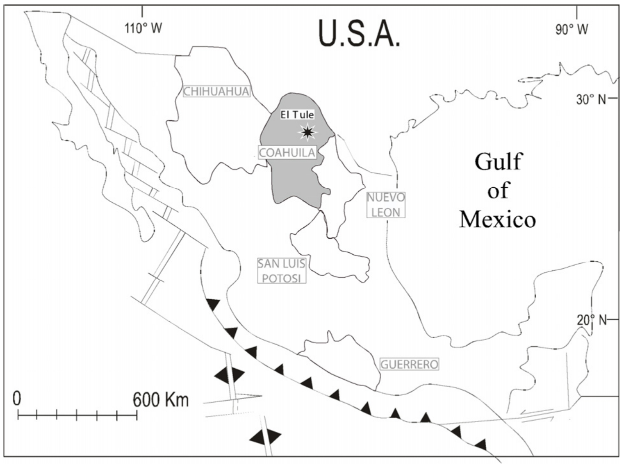

Figure 1. Location of El Tule Sr-F deposit.

These celestine deposits appear as "mantos" (flats) made up by medium size, white celestine crystals that contain variable amounts of remnants of the enclosing limestone. When the celestine lenses are pure, it is usual to find pockets and cavities filled up by idiomorphic crystals of celestine up to 10cm in length, with minor quantities of native sulphur, fluorite and gypsum. Very recently Ramos-Rosique *et al.* (2005) and Tritlla *et al*. (2004, 2005, 2006) studied some of the celestine lenses from Los Alamitos Ranges (El Venado, El Volcán, La Tinaja, La Víbora, El Diablo mines), presenting the first microthermometric data on these deposits and preliminary resuls on the brine halogen composition.

2 EL TULE DEPOSIT

An unusual mixed celestine-fluorite ore deposit is located at El Tule locality, north of Muzquiz (Coahuila). This deposit stands out as the northern last important celestine-bearing body, grading into zone with fluorite-dominated ore bodies (La Encantada-Buenavista district).

2.1 *Geology and structure.*

El Tule deposit is enclosed within the limestones of the Buda Formation (Washita Group, Upper Cretaceous). It is made up by a single stratabound mineralized body whose disposition is controlled by sub-horizontal estratification joints with clear evidences of layer-parallel slip, acquiring a "pinch and swell" overall shape. The mineralized structure presents a very variable thickness, with local mineralized zones up to 2 m thick (Lamadrid, *et al.*, 2006).

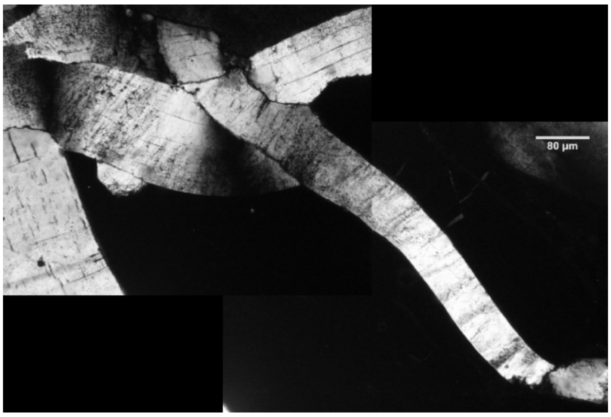

Figure 2. First generation of celestine (deformed).

The deposit is celestine-dominated, with minor fluorite. An early celestine generation show evidences of deformation during crystal growth (crystals bends, undulose extinction, mechanical twinning), while the latest, dominant celestine generation grew in a deformation-free environment presenting similar open space filling textures than the celestine-bearing deposits mentioned above (rhythmites, tabular centimetric to decimetric euhedral crystals, fetidness, etc.). After celestine precipitation ceased, minor quantities of fluorite formed as a late phase partially filling the remnant cavities and vugs in a passive succession. This fluorite always appear as bluish to colorless, zoned, idiomorphic cubic crystals growing on top of the celestine crystals.

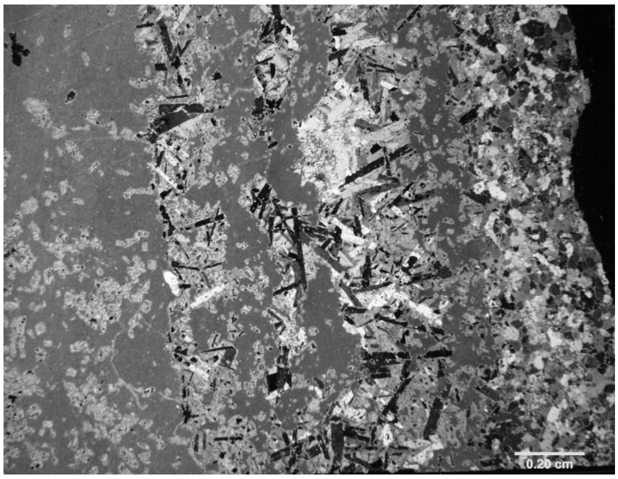

Figure 3. Fenestral porosity after anhydrite dissolution, occupied by celestine and fluorite.

Both celestine and fluorite also occur within the enclosing limestone, scattered filling up a fenestral porosity originated after the dissolution of pre-existing euhedral anhydrite crystals.

2.2 *Fluid Inclusions study.*

Celestine contains abundant aqueous, two-phase fluid inclusions with evidences of post-trapping changes (necking-down mainly). Homogenization temperatures are between 80 and 120°C with very variable salinities between 5 and 11.t wt% NaCl eq. (Lamadrid, *unpublished personal data*). Raman analyses indicate no traces of other gases than water wapor. The Th vs salinity plot suggest a mixing of fluids as the main mechanism for celestine precipitation, despite the heavy dispersion of data.

Fluorite contains two fluid inclusion types. The brine-bearing fluid inclusions are bi-phase (L+V) to poly-phase ($L+V+S_{trapped}$). The trapped solids are euhedral quartz crystals or high birrefringence minerals identified as calcite crystals. Raman analyses indicate the presence of variable amounts of CH_4, H_2S and CO_2 within the gas phase.

The hydrocarbon-bearing fluid inclusions are dark brown in color (heavy oils) and poly-phase (L+V+B), due to the presence of variable amounts of solid bitumen.

Homogenization temperatures and salinities for the aqueous fluid inclusions are between

120 and 150 °C and salinities between 11.7 and 16 wt% eq. of NaCl respectively (Lamadrid, unpublished personal data), showing much less dispersion than the celestine inclusions. In a Th vs salinity plot, the data disposition suggest that fluorite precipitated mainly by cooling after mixing of two, contrasted fluids.

Petrographic analysis give clear evidences of coeval trapping of hydrocarbon-bearing and brine-bearing fluid inclusions within the same growth zone. FTIR analyses and CLSM volumetric reconstruccions of the hydrocarbon-bearing fluids indicate the presence of heavy oils.

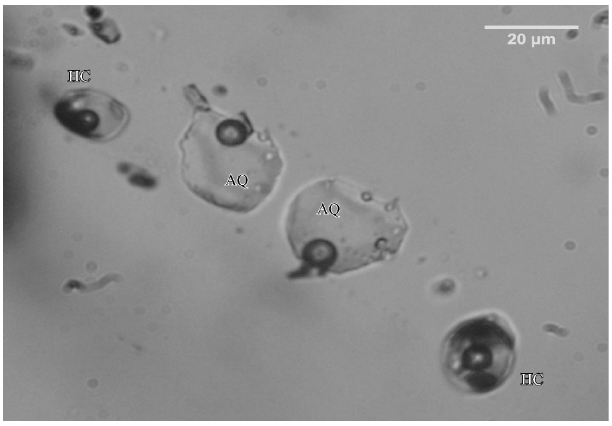

Figure 3. Coeval hydrocarbon-bearing (HC) and aqueous-bearing (AQ) fluid inclusions in fluorite.

Raman analyses of the gas phase of the brine-bearing fluid inclusions in fluorite indicate the presence of variable amounts of CH_4, H_2S and CO_2. All these data allow the PVT modelling of the fluorite precipitation conditions using the PIT software (Thiery *et al*, 2000).

2.3 *Discussion.*

The mineralogical change from celestine to fluorite precipitation probably reflects a change on the fluid regime and composition from a compressive regime (Laramide orogeny) to the subsequent post-laramide distension.

Celestine precipitated within opened sedimentary joint during and after the Laramide deformation, partially substituting the enclosing limestone, filling up the fenestral porosity after anhydrite dissolution. Then, the most plausible origin for the sulphate is the dissolution of the pre-existing evaporites as suggested for other deposits in the region (Tritlla *et al.*, 2006).

Fluorite precipitated after a dramatic change of the fluid composition, probably precluding the ongoing of celestine formation, during the mixing of the remaining brine after celestine precipitation, likely enriched in residual Ca^{2+}, with an external emulsion of brine and hydrocarbons, resulting in a partial degradation of the organic matter by means of TSR reactions and the generation of CH_4, H_2S and CO_2 found in the gas phase of the brine-bearing fluid inclusions.

The *in situ* origin for the small amounts of hydrocarbons found is unlikely, as the local -rock- source of organic matter was almost certainly depleted by the excess of sulphate during celestine formation.

3 CONCLUSIONS.

El Tule deposit represents a rare example of a transitional deposit between the celestine lenses and mantos, well represented at the south of the Coahuila State (La Paila and Alamitos Ranges), and the fluoritic mantos that are characteristic of the upper Cretaceous sediments at the north of the Coahuila State (*i.e.* La Encantada-Buenavista). This deposit contains the most complete history of fluid expulsion during the Laramide and post-laramide tectonic phases, reflecting a change in both fluid regime and chemistry.

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