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Mineral Deposits at the Beginning of the 21st Century

Edited by

Adam Piestrzyński et al
Faculty of Geology, Geophysics and Environmental Protection
University of Mining and Metallurgy, Kraków, Poland

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Cover photograph: Marcasite from the MVT deposits, Pomorzany Mine, S-Poland
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The Taxco fluorite deposit (Mexico): a new pseudo-chromatographic mechanism for rhythmite formation

J. Tritlla, & A.. Camprubí
Unidad de Investigación en Ciencias de la Tierra, UNAM, Campus Juriquilla, Querétaro. Mexico.

R. Corona-Esquivel
Departamento de Geoquímica, Instituto de Geología, UNAM. México D.F., Mexico.

ABSTRACT: Taxco is a well known locality for their low-sulphidation epithermal Ag deposits, but also hosts a number of medium-size to small carbonate-hosted fluorite deposits that received little or no attention, even though can be linked to the main silver-bearing veins. The main deposit is known as "La Azul" and consists on carbonate replacements by banded fluorite- and breccia chimneys filling, in close relationship with the regional "Xochicalco-Gavilán" fault.

1 INTRODUCTION

1.1 *Geographical and geological setting*

The Taxco Mining District is located within the Mixteco Terrane, in Northern Guerrero State (Fig. 1). More specifically, the study area is located near the villages of Acamitxla, Huajojutla, San Miguel de Acuitlapán and San Francisco de Acuitlapán, near the city of Taxco, in the State of Guerrero, close to the border with the Morelos and Mexico states. This district includes Ag-Zn-Pb producing mines (San Antonio, Guerrero, Babilonia, Guadalupe, Golondrina, Pedregal and Hueyapa mines) presently mined by IMMSA. These mines are all made on low-sulphidation epithermal veins with some development of "mantos", of assumed Oligocene age, closely related to the magmatic activity of the volcanism of Western Sierra Madre (Mexican Ignimbritic Belt). A medium-size fluorite mine (La Azul), presently abandoned, and a number of small fluorite mines and workings, whose study is the subject for this work.

The sedimentary, volcanic and metamorphic rocks that outcrop in the region represent an stratigraphic record from the Paleozoic to the Holocene. The basement is represented by the Taxco Schist, of probable Paleozoic age. The Taxco Viejo Greenstone (mainly propilitised andesitic flows and tuffs) lies unconformable over the Taxco Schist and is of probable Late Triassic-Early Jurassic Age. After a late Jurassic erosion episode, the deposition of a sedimentary sequence started with the Acuitlapán Formation (shales, siltstones, limestones and greywackes), followed by the Xochicalco Formation (thin laminated limestones with chert) and the Morelos Formation (limestones and dolostones). Overlying these units lies the flyschoid Mexcala Formation and the unconformable Late Cretaceous Balsas Formation (molasse). The youngest deposits are volcanic rocks, being the oldest of these and of widest distribution the pyroclastic rhyolitic and rhyodacitic flows included in the Tilzapotla rhyolite of Oligocene age (De Cserna & Fries 1980).

Fig. 1. Geographical and geological setting of the Taxco District. The major physiographical and geological provinces of Mexico are displayed: WSM is the Western Sierra Madre or Mexican Ignimbritic Belt, ESM is the Eastern Sierra Madre, and TMVB is the Trans-Mexican Volcanic Belt.

1.2 *Previous works*

Mexico is widely known to host some of the most outstanding world-class fluorite deposits, as the Las Cuevas deposit in San Luis Potosí. Before the discovery of this deposit, the fluorite deposits from Guerrero and Mexico States had some economic importance.

Even though the closeness with a Ag producing district, the fluorite deposits of Taxco received little or no attention up to date. So, only few previous reports exist on those deposits (Skewes-Saunders 1938, Fowler et al. 1948, Osborne 1956; Gonzalez-Reyna 1956, Fernández 1956, Leija 1973, Florenzani 1974 and Clark 1990) concluding that, due to the proximity with the famous epithermal veins and mantos of Taxco, the fluorite deposits can also be linked to the hydrothermal episodes that originated these deposits.

Fowler et al. (1948) presented the first complete description of the La Azul mine, and their conclusions were essentially repeated by most of the subsequent authors. They described the mineralization as formed by fluorite of grayish color, fine grained and intimately mixed with silica (quartz or chalcedony), making their explotation rather difficult. Osborne (1956) considered the fluorite deposits as a product of a massive replacement by hydrothermal fluids of the enclosing rocks, despite their composition, always nearby the Xochicalco-Gavilán fault. Clark (1990) divided the fluorite deposits in five different typologies: mantos, stockworks, fissure fillings, replacements and breccia chimneys. The presence of a breccia structure, made up by fluorite blocks within a heavily altered igneous rock, suggested to all the authors, except Fowler et al. (1948), that the deposit was generated after the replacement of both the Tilzapotla rhyolite and the Morelos Formation by hydrothermal fluids that circulated through a major SW-NE fault. Fowler et al. (1948), on the contrary, interpreted the fluorite blocks "floating" within the altered igneous rock as xenoliths of a previously formed fluorite deposit that was subsequently intruded by a subvolcanic dike.

2 FLUORITE DEPOSITS

The main fluorite deposit of La Azul and the close Don Baldomero mine are replacement bodies hosted in the Cretaceous limestones of the Morelos Formation, near to the unconformable contact with the Tilzapotla rhyolite, always in close relationship with the Xochicalco-Gavilán fault zone. The small fluorite mines and prospects correspond to vein filling structures along extensional faults (El Gavilán mine and Los Tréboles prospect).

2.1 *La Azul and Don Baldomero mines*

La Azul mine is located in the Acamixtla municipality. This is the biggest fluorite deposit known in the disctrict, having around 1 million tons of proved reserves. This mine was worked as an open pit mine and abandoned due to the high silica content of the ore. Presentely, it is still under concession to the the mineralization, clearly visible in the open pit, is constituted by an irregular reaction front between the fluorite deposit and the Morelos Formation, where no fractures associated with the deposit have been found.

The fluorite is mainly present as rhythmites of deep purple, black or white colour that alternate with silica-rich layers, mainly chalcedony. The thickness of the fluorite layers grade from some mm to a few cm. Usually, the substitution of the limestone by fluorite is not complete, and some round blocks of limestone can be found completely covered by fluorite, looking like "cockade" textures. The porosity of the rock is also increased after the replacement, and abundant cavities are found. This type of rhythmitic texture is typical from low-temperature deposits (as in Mississippi Valley-type deposits like the Blue John fluorite deposits in the Pennines, United Kingdom) and could be easily taken as a breccia structure.

The lower limit of the deposits is not easily identified because it is mainly covered by quaternary alluvial deposits. It has to be pointed out that, in a few outcrops, the breccia chimney structure described by most of the authors has been recognized in the present study. This structure is a chaotic mass of clays with fluorite and carbonate blocks. In agreement with Fowler et al. (1948), we consider this structure as a "piecemeal stopping" developed after the intrusion of a felsic subvolcanic body of unknown morphology into an enclosing, rigid fluorite mass. This rock is strongly altered to a mixture of clays, quartz fragments and recognizable ferromagnesian minerals with "floating" centimeter to decimeter-size fluorite fragments. This "mélange", at the first glance, can be mistaken as a dissolution breccia within the limestones, filled up by fluorite and limestone remnants like decarbonation clays. Fluorite blocks have a characteristic grayish color probably due to decoloration after the heating caused by the intrusion of the subvolcanic rock.

Following the petrological examination of the deposit, we discriminate six different facies:

- A-1 facies (primary texture): finely banded fluorite (rhythmitic texture) constituted by aggregates of skeletic crystals up to few mm in diameter. The characteristic banded aspect is given by the alternance of light bands (colourless) of silica (chalcedony or quartz after chalcedony) and dark bands (deep purple to black) of fluorite. Occasionally, some late cavities formed and they are partially filled up by idiomorphic, purple fluorite crystals up to 1mm in size, quartz crystals and barite. Normally, within the bands and forming the core of fluorite crystals, relict calcite is common. Colour distribution in fluorite strongly depends on the distribution of an dark colour nuclei (almost black),the colour fading away from the opaque mineral and giving the dark fluorite bands a "spotty" appearance. These features suggest that the opaque phase is a radioactive mineral (probably an U or Th oxide) that is creating a metamictic aureole that breaks the fluorite crystalline structure. Also, this fluorite presents abundant biphasic fluid inclusions with coherent liquid to vapour ratios we are presently working in. The fluorites samples of this facies release a fetid odour when broken, indicating the presence of hydrocarbons within them.

- A-2 facies (primary texture): black and white alternating bands of fluorite up to 2 cm thick, forming botryoidal or globular masses that can attain up to 30 cm in thickness. The botryoidal internal structure of these globular masses is formed by fibrous-radiated crystals of fluorite that display continuity between the light and dark bands. The different colours are caused by the distribution of minute black inclusions within the dark bands but, contrasting to the A-1 facies, these inclusions are not of radioactive minerals, as no metamictic structures have been found. The strong smell detected on breaking or cutting fluorites from this facies indicates that they probably include limestone-derived organic matter that matured during the hydrothermal process. This possibility is being checked at this moment, while working on fluid inclusions.
- A-3 facies (primary texture): dissemination of small euhedral purple fluorite crystals in an altered limestone.
- A-4 facies (primary texture): fine grained (saccaroidal) fluorite in irregular "pockets" within the limestones of the Morelos Formation. This facies has been only found in the Don Baldomero mine.
- B-1 facies (secondary texture): after the main episode of substitution, a swarm of small fractures crosscut the whole fluorite deposit. These fractures are filled up by late rhythmites of grayish to purple fluorite, where the different bands are arranged parallel to the fracture walls. These late rhythmites probably represent the last pulsations of the mineralising solutions.
- B-2 facies (secondary texture): grayish, strongly recrystallized blocks of fluorite, belonging to the main mineralising episode, enclosed by the highly altered subvolcanic rocks at the lower parts of the deposit.

3 ORIGIN OF THE FLUORITE RHYTHMITES

The samples of the A-1 facies usually display a succession of silica-rich light bands and fluorite-rich dark bands. Very often, huge blocks of limestone are placement. A close look to the replacement front indicates that the fluorite fades away from the banded replacement body to the limestone and, in most of the cases, the limit is unprecise. Under the petrographic microscope, and from the fluorite mass to the fresh limestone this succession has repeatedly observed this way:

- Fluorite-silica rhythmite.
- Last band of purple fluorite in contact with limestone.
- Highly recrystallised limestone, where calcite crystals now display a blocky texture, with well developed triple junctions, indicating a passive recrystallisation. Close to the contact with the last fluorite band, small subhedral crystals of fluorite partially replace some calcite crystals just along the new-formed regular calcite grain borders. This band is devoid of silica.
- A silica-rich band in sharp contact with the recrystallised limestone, identical to the silica bands found within the rhythmite. Silica grains seldom contain limestone relicts.
- Non-recrystallized (fresh) fossiliferous limestone.

This succession is repeatedly found when facies A-1 rhythmites are in direct contact with the enclosing limestones. This transition zone, with a maximum thickness of 2 cm, is one of the keys to understand the origin of the silica-fluorite rhythmites.

The flow of the hydrothermal fluid through the rock is enhanced by the recrystallisation induced by the heat carried by the same fluid, in a feedback mechanism. This enhancement is reflected in the rock by the recrystallization of the carbonates just in front of the fluorite replacement front and prior to it. This recrystallization provokes a complete change in the distribution and characteristics of the intergranular porosity, changing from the irregular grain borders seen in the fresh limestone to the regularly distributed and highly connected grain borders in the recrystrallized calcite.

The above would be caused by a heat front during the flow of the hydrothermal fluid. Due to differences in the mechanism of precipitation between silica and fluorite, different reaction kinetics must be expected. On one hand, fluorine in the fluid reacts with the recrystallized calcite and flourite starts to replace the calcite trough the grain borders, as seen in the limestone band. On the other hand, quartz precipitation is usually highly controlled by temperature (Fournier 1985).

The recrystallization of carbonates is a heat consuming reaction, and thus cooling of hydrothermal fluids must be expected. Precipitation of quartz should not be in accordance with the borders of the quartz can not precipitate. This cooling path necessarily implies a certain distance of transport of silica from the fluorite reaction border and, moreover, allows the possible preservation of the calcite recrystallization front.

Thus, the different mechanisms of precipitation between fluorite and quartz, coupled with a heat-consuming reaction such as the recrystallization of the limestone to sparry calcite, explains the occurrence of three bands in the reaction front of the rhythmites. As the whole reactive mechanism progresses (recrystallization, replacement, cooling down, precipitation), the calcite bands may be totally replaced, leaving back fluorite-rich bands with calcite remnants in the core of fluorite crystals, until the silica band is achieved. New flows of hydrothermal fluids must be expected to make the substitution front go further into the limestone so that two new bands of fluorite and quartz are formed.

4 CONCLUSIONS

The fluorite deposits of the Taxco district are mainly formed by the substitution of the Morelos limestone by hydrothermal fluids. The H_2S odour detected on breaking fluorite blocks indicate the presence of organic matter within the deposit, whose origin is still uncertain. In any case, the internal structure of ores of this deposit have many resemblances to other banded fluorite deposits found elsewhere and generally classified as Mississippi Valley-type deposits. The breccia structure described by other authors is reinterpreted as a "piecemeal stopping" of fluorite blocks due to the intrusion of a subvolcanic body and has no relationship with the mechanism of formation of the La Azul deposit.

Five different primary textures are found. One of them (A-1) allows us to propose a new pseudo-chromatographic mechanism where coupled textural and porosity changes, differences in reaction kinetics and cooling down of the hydrothermal solutions may have caused the coetaneous precipitation of bands of marked composition in a single process. This mechanism also suggests a pulsing flow of hydrothermal fluids. The thickness of each fluorite-quartz band can also be interpreted as a time measure for each pulse of fluids.

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