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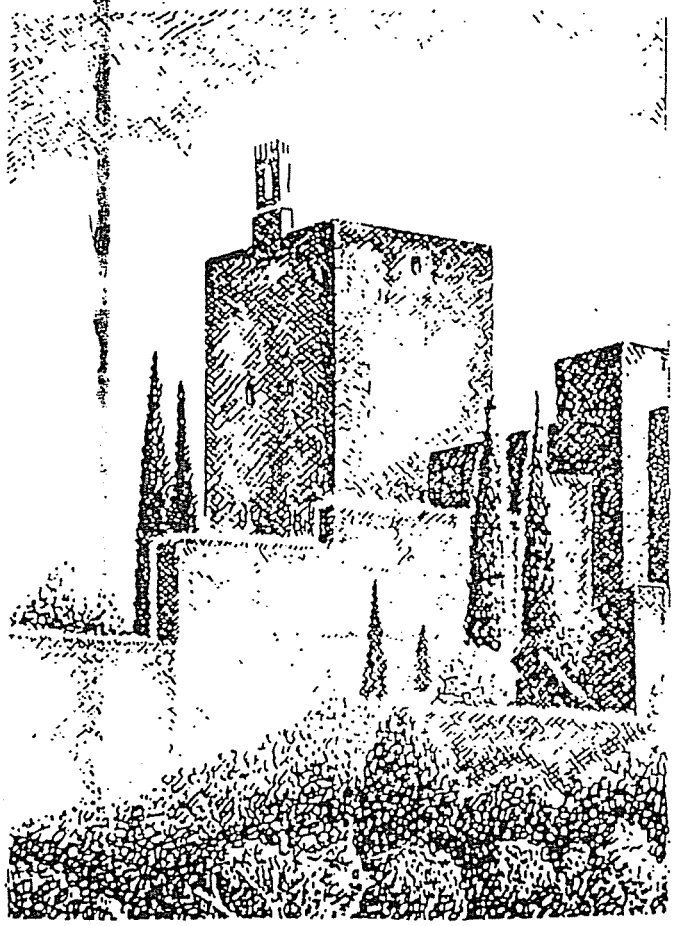

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GLAUBERITE GROWTH IN PLAYA-LAKE ENVIRONMENTS (TERTIARY OF THE EBRO BASIN, ALCANADRE-ARRUBAL ZONE)

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INTRODUCTION. In the Alcanadre-Arrúbal zone (La Rioja, Spain) mining operations carried out decades ago exploited several glauberitic horizons intercalated in the extensive clayey-gypsiferous deposits, which represent the intermontane Tertiary sedimentation in the W side of the Ebro Basin. Glauberite beds in this area belong to Lerín Gypsum Fm. (Oligocene-Miocene), which outcrops throughout the southern half of Navarra, reaching thicknesses up to 500-600 m.

EVAPORITIC SEQUENCES. Lerín Gypsum Fm is characterized (ORTÍ and SALVANY, 1986) by the development of mixed detrital-chemical cycles, with individual thicknesses averaging 40-90 m. In Lodosa-Alcanadre zone such cycles are constituted by these three terms: a) lower detrital: it is built up by red clays which intercalate some channalized sandstone bodies; b) intermediate carbonatic: it is usually thin and consists on laminated mudstones intercalated between red and gray (variegated) clays; and c) upper sulphate: it is very thick and consists on gypsum beds which intercalate some gray lutitic layers. Major gypsum lithofacies are laminated-displaying wavy-like morphologies partly controled by algal growths - and nodular (also contorted and enterolithic).

Term a) corresponds to the distal mud flat of an alluvial fan system, and becomes progressively hypersaline upwards. Term b) represents the establishment of a chemical (carbonatic), more or less hypersaline environment on the former mud flats. Term c) represents the final installation of very shallow lacustrine water bodies, or playa-lakes, in which the water table continuously falls from a very shallow subaerial position (lake or "salina" stage, with deposition of algal-colonized, fine-grained gypsum laminae) to an interstitial one (playa or "sabkha" stage, with the production of abundant nodular anhydrite in the very early diagenesis). All gypsum present now in Lerín Fm is of secondary origin, coming from the hydration of precursor anhydrite. The latter formed in early diagenesis as well as in deep burial.

Each detrital-chemical cycle is an evaporitic sequence becoming progressively more concentrated upwards ("halo-crescent"), which can be defined as a "salina cycle". In it, frequently, a subordinated "sabkha maximum" develops at the base of the sulphate term. In the zone where glauberite beds outcrop, three of these cycles are present at least, their sulphate terms reaching thicknesses between 15 and 70 m. This zone is affected by smooth faulting and folding with somewhat variable axe directions.

GLAUBERITE BEDS AND PARAGENESIS. In outcrop and for each cycle, glauberite beds mainly happen at the top of the lower detrital terms or just towards the base of the upper sulphate ones. Lateral continuity of these layers is rather limited. Individual bed thickness varies from some cm to a few m. Most important layers are intercalated in the lowermost outcroping cycle (near Aradón Church, Alcanadre). Glauberite beds and mines located in Arrúbal zone are intercalated in the uppermost outcroping cycle, whose sulphate term is directly overlain by the red detrital "Tudela facies" of Miocene age. Thus, glauberite is mainly associated with clay and gypsum in outcrops as well as in mine galleries. But an abandoned mine of layered halite exists in Arrúbal zone, and also in prospecting boreholes (USE, S.A.) halite and anhydrite have found to be present: layered halite alternates with gypsum and/or glauberite. Thenardite is not noticeable neither in mine galleries nor in boreholes.

GLAUBERITE LITHOFACIES AND HABITS. Major lithofacies displayed by this glauberite are: a) nodular and enterolithic, which are dominant (ORTI et al., 1979): nodule diameters reach several dcm and morphologies are subspherical to rather

deformed. Crystalline size varies from mms to cms and common habits are prismatic to tabular-prismatic. Enterolithic (contorted) beds grade to flow structures; b) fine-grained massive: many glauberite beds are formed by a very fine-grained type (less than 1 mm) of (dark-) gray massive glauberite, in which convoluted-like bedding structures are common, c) interstitial macrocrystalline: it is characterized by mm- to cm-sized crystals which have grown randomly orientated inside the massive lutite beds, frequently resembling "desert-rosettes". In boreholes this lithofacies is combined with halite, also. Crystalline size and habits are similar to a). This lithofacies gradually changes to a); d) banded: it consists on even or sligthly wavy beds in which glauberite crystals are either very fine-grained to mm-sized. This lithofacies usually intercalates with the former ones.

Most frequent gypsum/glauberite lithofacies association is: nodular/enterolithic glauberite intercalated between laminated gypsum. Also, flow, load and convolution-like structures are common in glauberite beds.

GLAUBERITE GENERATIONS. Wide variability in crystalline size and lithofacies accounts for multistage glauberite growths. Poorness in perfectly banded or laminated bedding suggests that primary subacuatic precipitation on a depositional floor was not the dominant sedimentological mechanism. Richness in nodular and related lithofacies suggests intrasedimentary glauberite crystallization, which partly happened, probably, replacing former sulphates (gypsum/anhydrite) in very early diagenesis. Flow structures accounts for the same mechanism, but also suggest easy deformation of originally banded layering. Contorted bedding is frequently characterized by the presence of external coated films made of coarse crystals developed normally to bedding, directed either up or downwards, thus projecting towards the inner and being surrounded by a finner glauberite matrix. Such coarse-grained generations have probably grown later than the matrix.

EARLY AND LATE MINERAL REPLACEMENT EPISODES. Gypsum, glauberite and anhydrite might have been synsedimentary products of mutual replacement in very early diagenesis, depending on the chemical evolution of brines. Also halite could eventually participate in these processes. Sometimes glauberite clearly replaces gypsum nodules and laminae, but also secondary gypsum has locally replaced glauberite. Late diagenetic stages affecting these deposits are: 1) primary gypsum transformation into anhydrite by burial, and 2) final rehydration of the anhydrite during exhumation. Assocciated with this final stage a small part of glauberite was replaced by secondary gypsum also.

GENETIC CONSIDERATIONS. As is the case for other sulphate minerals in Lerín Fm, glauberite was deposited in playa-lake environments, in a repetitive way. Salina stages of different concentrations gave way to laminated/banded lithofacies of gypsum, glauberite and halite. Sabkha stages gave way to nodular/enterolithic and interstitial lithofacies of (gypsum), anhydrite and glauberite as well. Similar glauberite lithofacies and halite-glauberite-anhydrite (gypsum) alternancies were described (ORTI et al., 1979) in the Tajo basin (El Castellar mine galleries and boreholes) and interpreted as deposited in playa-lake environments.

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