Meganodular anhydritization in the Tertiary Ebro Basin (Spain)

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1 Introduction

The sabkha and the deep burial settings are the most common evaporite sites where diagenetic anhydrite forms. These two growth modes have been largely recognized in the assemblage of marine and non-marine evaporite units of Mesozoic and Tertiary ages, which are present in the sedimentary basins of Spain.

A different mode of anhydrite growth characterized in outcrop by the presence of large (>0.5 m) nodules of secondary gypsum (coming from the hydration of anhydrite) is documented in this work.

2 Geological setting

The Ebro Basin (Spain) is a foreland basin developed during the Paleogene. A number of gypsiferous units in this basin are located along their southern margins, including the Iberian and the Catalan margins (Figure 1, 2). These units, aged Paleogene to Miocene, were accumulated in small shallow saline lakes of low ionic concentration, in which Ca-sulphates (gypsum/anhydrite) precipitated.

The lakes were nourished by groundwater from deep regional aquifers, which had the recharge areas in the bounding chains and recycled sulphates/chlorides from the Mesozoic (Triassic, Liassic) evaporites. Some of these units graded laterally to the thick, highly-saline (halite, glauberite, polyhalite) evaporite units developed coevally in the basin center (Figure 3).

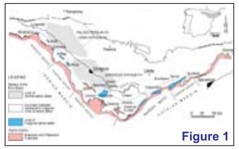
Figure 1

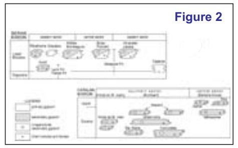
Figure 2

Figure 1. A number of central evaporite units are omitted (Cardona, Guendulain, Barbastro, Puente la Reina, Cerezo and Copons Fm).

Figure 2. The marginal evaporite units along the Iberian and the Catalan margins.

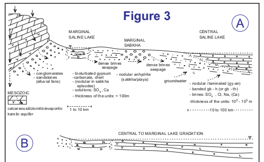

Figure 3

Figure 3. A. General case in which the marginal and central evaporite units are not connected. **B.** Case in which the marginal and

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3 Meganodule occurrences

3.1 IBERIAN MARGIN (Miocene)

*A number of marginal gypsum units were deposited during two major episodes in the Early Miocene.
*The oldest units underwent deep burial (>500m) and the bioturbated gypsum rocks were totally converted to anhydrite.
*The younger units, not so deeply buried, have partly or totally preserved the primary gypsum lithofacies.
*Meganodules (Mn) and large irregular mases of secondary gypsum are common.
*These structures, sized between 0.5 to >3 m, are found isolated or in discontinuous layers parallel to the stratification (Figures 4A, B, C).

Figure 4
Mn Meganodular secondary gypsum
Bs Bioturbated secondary gyspum

3.2 CATALAN MARGIN (Paleogene)

*Several small gypsum units accumulated along this margin, interbedded with siliciclastics and limestones.
*Gypsum rocks are secondary in outcrop given that all the units underwent deep (>500m) burial anhydritization.
*The marginal gypsum units are characterized by massive gypsum (bioturbated facies; Bs) with chert and meganodules.
*The meganodules and irregular masses of secondary gypsum (Mn), up to several meters in length, are randomly or horizontally distributed. A columnar arrangement is also observed (Ortí et al., 2007; Figure 5, Figure 6).

quarry near Sarral village (Sarral Gypsum unit)

Figure 5

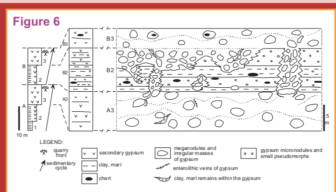


Figure 6

4 Characterization

GEOMETRY. Spherical, irregular or diffuse masses of anhydritized bodies (transformed to secondary gypsum in outcrop). Up to 5 m in diameter/length.

SPATIAL ARRANGEMENT. Stratiform and occasional subvertical disposals (columns or walls up to 6 m high).

RELATIONSHIPS WITH THE ASSOCIATED LITHOLOGIES. Embedded within the gypsum facies to which the meganodules and irregular masses replace or displace.

PALEOGEOGRAPHIC DISTRIBUTION. Mainly located in the marginal basin position.

TEXTURES OF THE SECONDARY GYPSUM. Mainly alabastrine texture (white and pure fine-grained gypsum)

6 Diagenetic model

*Facies of the precursor anhydrite very DIFFERENT from those of the sabkha setting
*Coexistence of meganodules with unaffected primary gypsum facies in several Miocene units→NO DEEP BURIAL DIAGENESIS
*Meganodules located in the margins of the endorheic basins→ related to PALEOHYDRAULIC SYSTEMS discharching into the marginal lakes (Figure 7)
*Deeply ascending groundwaters have been documented in the Quaternary hydrogeologic systems of the Iberian margin in the Ebro Basin (Sánchez Navarro et al., 1999): groundwater discharges through the Lower Liassic karstic aquifer (dolostones, limestones and Ca-sulphate beds), high mineralization (1-2 g/L), Ca-sulphate composition, common emergency T up 24°C (locally >40°C) (Figure 8)

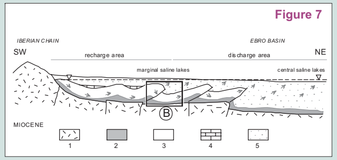


Figure 7

Figure 7: Paleohydrologic model. Modified from Sánchez Navarro et al. (1999)

1. Palaeozoic-Triassic
2. Triassic in Muschelkalk and Keuper facies
3. Early Jurassic-Cretaceous (Aptian)
4. Cretaceous (Albian)-Late Cretaceous
5. Tertiary (Late Eocene-Late Miocene)

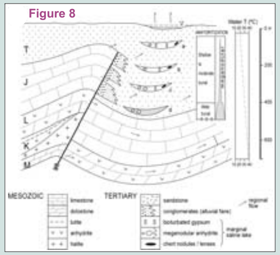


Figure 8

Figure 8: Anhydritization model

a. depositional facies
b-c. progressive development of anhydrite meganodules during shallow to moderate burial
d. gypsum-to-anhydrite conversion of the remaining gypsum during deep burial diagenesis

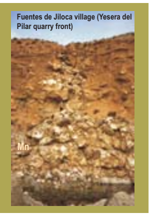
A progressive increase of the groundwater temperature at depth is suggested.

M. Muschelkalk (Middle Triassic)
K. Keuper facies (Upper Triassic)

5 Other occurrences

CALATAYUD BASIN (Miocene units, NE Spain)

*Intramontane basin located in the central part of the Iberian Range
*Evaporite unit (secondary gypsum in outcrop) intercalated within red lutites
*Large nodules (alabastrine secondary textures, stratiform and vertical arrangement up to 20 high, Mn) within the bioturbated gypsum (frequently presereved as primary gypsum; Pbs) and lutites layers

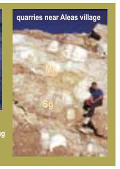


TREMP BASIN (Paleocene unit, NE Spain)

*Located in the allochthonous Central South Pyrenean structural unit
*Evaporite unit (secondary gypsum in outcrop) intercalated within red lutites
*Large nodules (0.5->1 m, alabastrine secondary textures) within laminated-to-banded gypsum facies

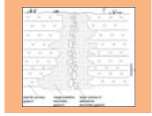
TAJO BASIN (Paleogene and Miocene units, central Spain)

*Intracratonic Tertiary basin
*Several evaporitic units, including gypsum-anhydrite, glauberite, thenardite and halite, associated to lutite beds
*Large nodules and irregular masses of secondary gypsum (Mn) replacing and displacing massive-to-laminated (Sg), selenitic and bioturbated gypsum facies (Ortí et al., 1992)



CARPENTRAS BASIN (Paleogene unit, SE France)

*Mazan Gypsum quarry
*Large nodules (0.5-1 m, alabastrine secondary textures in columnar arrangement) replacing primary selenitic gypsum facies
*Attributed to anhydritization by ascending circulation of chloride-brines in burial conditions (Truc, 1983)



7 Concluding remarks

*The textural characteristics of the secondary gypsum composing the meganodules and large irregular masses, which mainly appear in the marginal evaporite units of the Ebro Basin (and in a number of Iberian Tertiary basins) indicate that these diagenetic facies were originated as anhydrite.

*The characteristics of this mode of anhydritization are clearly different from those of the sabkha anhydrite; also, they have no relation with the anhydritization affecting totally the gypsum units during deep burial.

*The growth of these anhydrite meganodules occurred during shallow-to-moderate burial, displacing and/or replacing the host gypsum sediments prior to their complete lithification.

*The large-sized structures derived from this process suggest a continuous growth of the anhydrite during shallow-to-moderate burial, which is consistent with a slow ascending circulation from deep regional aquifers acting as anhydritizing fluids.