Study of the Oligocene Sediments in the SW Boundary of Les Avellanes Diapir (NE Spain)

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Abstract

The interpretation of the detritic Eocene–Oligocene sediments located at the SW margin of Les Avellanes Diapir (South-Central Pyrenees) allows for recognizing the advance and emplacement of a salt glacier during their sedimentation. Six (6) lithostratigraphic units have been identified as superimposed in the stratigraphic sequence recording the salt extrusion and advance. Units 1 to 4 record a southwards prograding alluvial fan system transporting detrital components from the diapir that must be exposed during this stage. Over a paleo-relief formed atop the alluvial fan system, the unconformable overlying unit 5 is a rubble zone made by a breccia of diapir rocks, which indicates the extrusive advance of the glacier. Finally, unit 6 belongs to the salt glacier, which flows toward SE and overlies all the upper Eocene–Oligocene succession.

Keywords

Diapirism • Pyrenees • Keuper • Salt glacier • Halokinetic sequences

1 Introduction

Sedimentary sequences in diapir margins serve as a proxy for understanding diapiric history (Hudec & Jackson, 2007). These studies can be especially useful in diapiric provinces inside orogenic belts where compression could reactivate previous salt structures, usually producing salt extrusion and controlling the contractional structures' location, type, and geometry (Rowan et al., 2012).

The South-Central Pyrenean fold and thrust belt is a thin-skinned imbricated thrust sheet sequence decoupled over the Upper Triassic evaporites during the Late Cretaceous to Oligocene. Here, pre-contractional salt diapirs of Triassic rocks are relatively common, affecting the syn-contractional deposits (Saura et al., 2016). Among them, the Les Avellanes Diapir (Serres Marginals, NE Spain) crops out in the central part of the Serres Marginals thrust sheet, which is formed of a syn-orogenic Upper Cretaceous to Oligocene unconformably overlaying the pre-orogenic Triassic to Jurassic succession. Les Avellanes Diapir is composed of evaporites (gypsum at the surface, halite, and anhydrite at depth), siltstones and carbonates of the Keuper facies, dolostones of the facies Muschelkalk, and dolerites.

Along its SW margin, north of *Os de Balaguer* village (Fig. 1), these diapir rocks overlie the syn-contractional detrital Eocene–Oligocene sediments with a contact that has been historically interpreted as a thrust (Pocoví, 1978). This contribution aims to: (1) decipher the precise nature of this contact and (2) better understand the evolution of the Les Avellanes Diapir during the sedimentation of the syn-contractional Eocene–Oligocene sediments. Furthermore, this exceptional outcrop presents an excellent opportunity to study Les Avellanes Diapir and other deformed diapirs in contractional settings (e.g., Zagros, Alps).

2 Methods

To characterize and interpret this outcrop, a field campaign was carried out in an outcrop located North of *Os de Balaguer* town. Sedimentary and structural data have been mapped in detail, and a stratigraphic section has been done. From these data, six lithostratigraphic units have been

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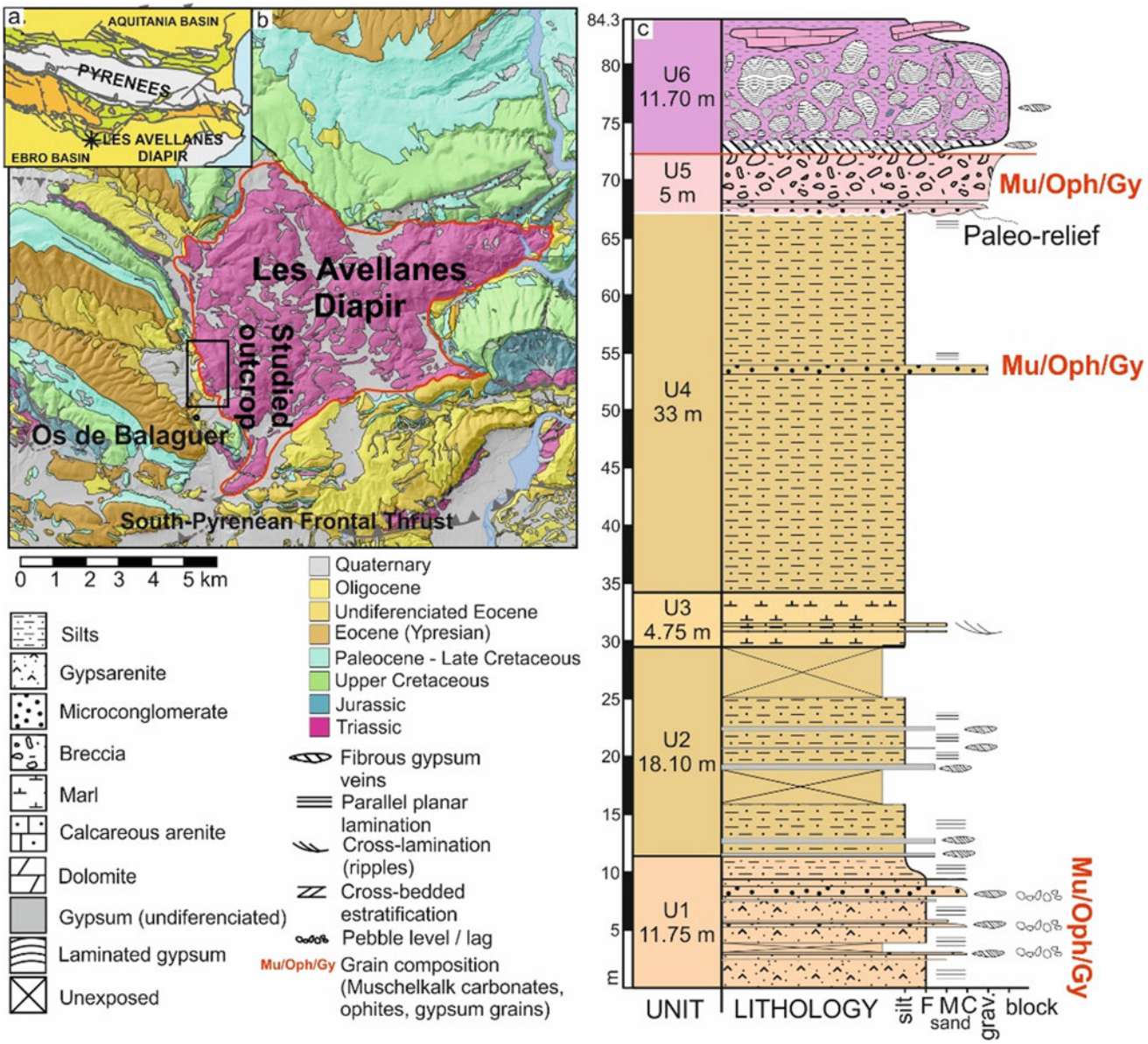

Fig. 1 **a** Eastern Pyrenees map with the approximated location of Les Avellanes Diapir. **b** Regional map of Les Avellanes Diapir. **c** General and in-detail stratigraphic sequence of the studied Eocene–Oligocene sediments

distinguished and correlated laterally and vertically. Each unit has been analyzed from a sedimentological and structural point of view, assigned to a diapiric or depositional environment, and interpreted to unravel the iaper evolution.

3 Stratigraphic Sequence

The studied syn-kinematic sediments onlap the underlying *Alveoline Limestones* (Ilerdian, Ypresian) toward the W-SW. The first lithostratigraphic unit (Fig. 1), U1, is composed of an alternation of fine parallel laminated gypsarenites and lithic arenites, intercalated with dm tabular microconglomerate layers in a thickening upwards sequence. U2 corresponds to silts intercalated with dm tabular alabastrine gypsum layers. U3 is a marly succession with cross-laminated calcareous arenites. U4 is mainly composed of reddish laminated silts intercalated with dm tabular beds of lithic arenites. These four units change laterally and vertically to the NW, first into an alternation of coarse sand with conglomerates, which further evolves into large-scale cross-bedded conglomerates and finally into massive conglomerates. Clasts consist of Muschelkalk carbonates, dolerites, gypsum, minor Illerdian limestones, and other carbonates. U5 unconformably overlies a paleo-relief located above U4. This upper unit is represented by a mud-supported, poorly sorted, inverse-graded breccia

composed only of pebble to boulder components of Muschelkalk carbonates, dolerites, and gypsum clasts. Forest planes made of oriented pebble levels are recognized at the base of the breccia. A net contact can be observed between U5 and the uppermost megabreccia of U6. This megabreccia comprises dm to m gypsum boulders, gypsum vein fragments, and dm blocks of Muschelkalk carbonates, usually located atop the deposit, floating in a fine matrix.

4 Units Interpretations and Halokinetic Implications

The presented lithostratigraphic units can be interpreted to recognize stages related to diapirism. U1 to U3 were deposited in a sabkha to salt pan environment that progressively evolved into a carbonated lacustrine/palustrine margin. U4 is interpreted as mudflats located at the distal part of an alluvial fan system that prograde toward the S-SW. The grain composition, facies distribution, and geometries of units 1 to 4 point that one of the source areas is Les Avellanes Diapir which had to be exposed a few kilometers to the NE. Later, an erosion stage occurred, as indicated by the paleo-relief filled by the breccia of U5. Breccia components are exclusively derived from the diapiric rocks and deposited in a very proximal position. The inverse grading indicates increasing energy which a gradually closer source area could explain. The uppermost gypsum megabreccia (U6) can be interpreted as the remains of an extruded salt mass in which highly soluble minerals (e.g., halite) have been dissolved, leaving gypsum and carbonate blocks floating in a fine-grained matrix (allochthonous diapiric breccias, (Hearon et al., 2015)). This salt extrusion most likely occurred at the iaper boundary and advanced toward S-SW as a salt glacier.

The erosion of this salt glacier produced the syn-halokinetic sedimentation of U5 at its frontal areas, which was later unconformably overlaid by the advancing salt glacier. Breccias under allochthonous salt bodies have also been recognized in the Gulf of Mexico, referred to as *rubble zones* (Rowan, 2017). The precise nature of these breccias is still being discussed, and thus, the importance of this work.

5 Conclusions

The studied syn-kinematic sediments, located at the SW margin of Les Avellanes Diapir, record the S-SW advance of a salt glacier over a breccia generated from its erosion, transport, and sedimentation. The salt-sediment boundary constitutes the net base of this glacier and is not a fault. The subsalt breccia filled a previous paleo-relief, developed over an alluvial fan's detrital sediments. This depositional system transported diapiric materials, demonstrating that the diapir was already exposed.

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References

Hearon, E., IV., Rowan, G., Giles, A., Kernen, A., Gannaway, E., Lawton, F., & Fiduk, C. (2015). Allochthonous salt initiation and advance in the northern Flinders and eastern Willouran ranges, South Australia: Using outcrops to test subsurface-based models from the Northern Gulf of Mexico. *Bulletin AAPG, 99*, 293–331.

Hudec, M., & Jackson, M. (2007). Terra infirma: Understanding salt tectonics. *Earth Science Reviews, 82*, 1–28.

Pocoví, A. J. (1978). Estudio geológico de las Sierras Marginales Catalanas (Prepirineo de Lérida). *XIII ACTA GEOLÓGICA HISPÁNICA, 3*, 73–79.

Rowan M. G. (2012). An overview of allochthonous salt tectonics. In Soto, J. I., Flinch J. F., & Gabor T. (eds.), *Tectonics and hydrocarbon potential, permo-triassic Salt Provinces of Europe, North Africa and the Atlantic Margins,* (pp. 97–144). Elsevier.

Rowan, M. G., Giles, K. A., Roca, E., & Arbues, P. O. F. (2012). Analysis of growth strata adjacent to an exposed deepwater salt diapir, Northern Spain. In *AAPG Annual Convention Program*.

Saura, E., Ardèvol i Oró, L., Teixell, A., & Vergés J. (2016). Rising and falling diapirs, shifting depocenters, and flap overturning in the Cretaceous Sopeira and Sant Gervàs subbasins (Ribagorça Basin, southern Pyrenees). *Tectonics,* 35, 1–25.