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Structure and kinematics of the reactivated Bicorb-Quesa diapir (Eastern Prebetics, Valencia)

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Abstract: The combined analysis of the Bicorb-Quesa diapir internal structure and the surrounding Mesozoic cover allows to recognize the main characteristics of the Eastern Prebetics as well as to make a new and unique evolutionary model of a squeezed and later reactivated diapir. Specifically, this work points out: 1) the Bicorb-Quesa diapir was generated during the Early Miocene due to the movement of a basement normal fault ENE-WSW oriented and dipping towards the NNW, 2) the diapir was squeezed during the Serravalian due to the displacement towards the NNW of the Jurassic-Cretaceous cover located in the footwall of the basement fault, and 3) the diapir was reactivated cutting the faults and thrusts previously generated.

Keywords: Betics, salt tectonics, diapir, inversion tectonics, Keuper, Valencia.

The interest in salt tectonics has increased during last years, as demonstrated by the large amount of papers published. Nevertheless, most of them are based on geophysical methods, analog models or numerical models, while just a few are based on field data, usually focusing in one of these two aspects: the internal structure of the diapir (e.g. Richter Bernburg, 1987) or the overburden structure (e.g. De Ruig, 1995; Rowan *et al.*, 2003). The excellent outcropping conditions of Bicorb-Quesa diapir allow analyzing both aspects and, consequently, elaborating a structural and evolutionary model.

The Bicorb-Quesa diapir is located SW of the Iberian Peninsula, in the most external Prebetic thrust sheet (Fig. 1). The so-called Carroig sheet is formed by a Jurassic-Cretaceous para-autochthonous cover detached on the Late Triassic evaporatic rocks (Keuper). The structure is relatively simple; it consists of a kilometre scale sub-horizontal platform cut by two nearly perpendicular families of normal faults, ENE-WSW and NNW-SSE oriented. These faults limit a narrow system of grabens, the axis of which is usually perforated by elongated diapirs formed by Keuper evaporites and clays. Locally, the grabens are filled in by Miocene sediments that were accumulated synchronously to the diapir formation.

This work illustrates the geometric and kinematic characteristics of one of these graben systems perforated by a diapir. This allows recognizing not only the main features of the diapir of the region but also developing a new and unique model about the evolution of a squeezed and later reactivated diapir.

Cover and basement structure of Bicorb-Quesa zone

The Bicorb-Quesa diapir is elongated following a general ENE-WSW trend. It is approximately 12 km long and 1.5 km wide; the diapir is flanked by Bicorb Half-graben to the north and the Quesa Half-graben to the south; both half-grabens are filled in with Miocene rocks (Fig. 1).

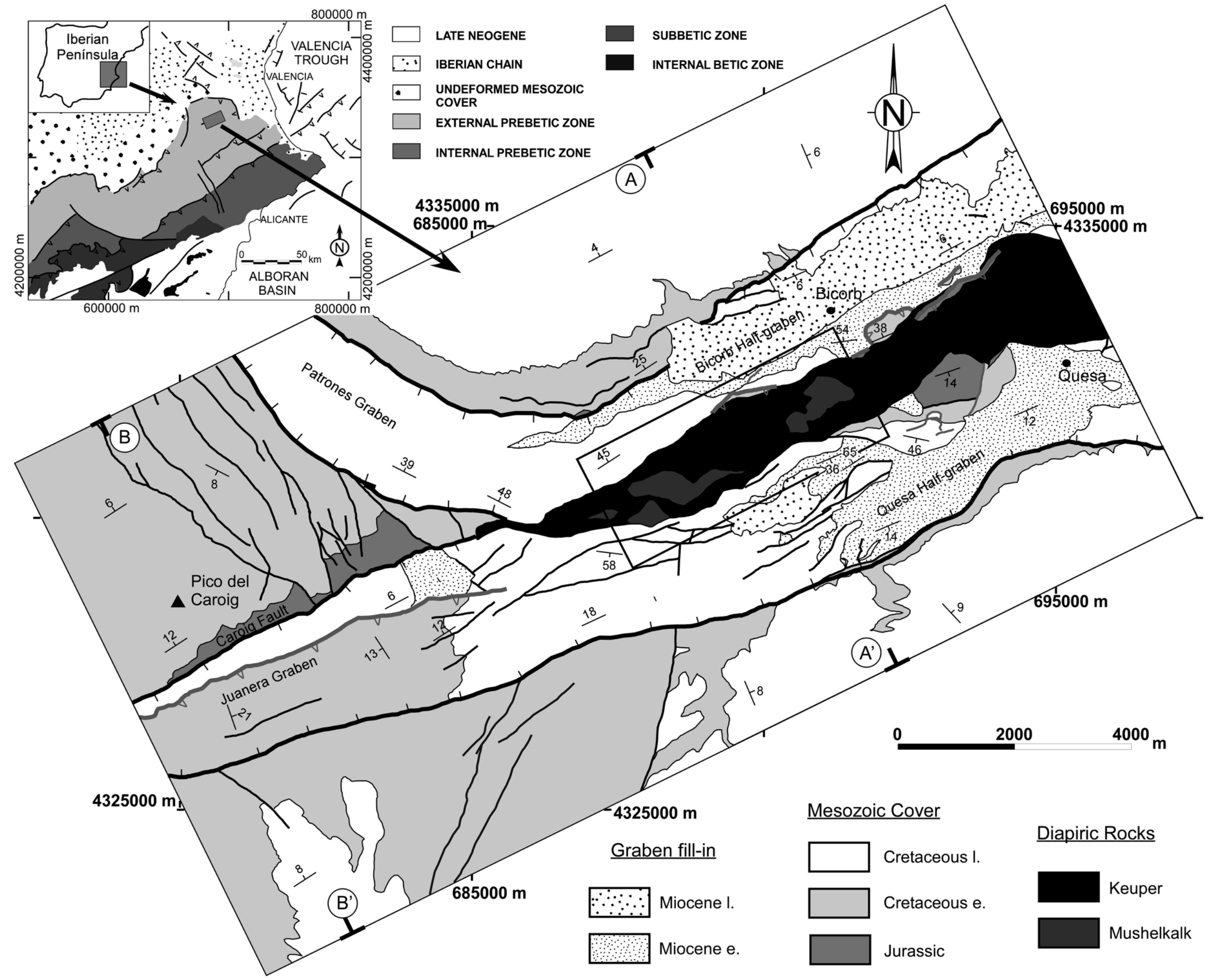

Figure 1. Geological map of the study area. Heavy black outline: the extensional faults, gray: contractive faults (mainly inverse faults). AA' and BB': situation of the geological cross sections in figure 2; black box: map represented in figure 3. The coordinates are in UTM, located in Fuse 30 with European Datum 1950.

The Bicorb Half-graben (Fig. 1), is limited at the NW by two normal faults with an accumulate throw of more than 1 km. In outline, its structure corresponds to a north-northwestwards tilted Mesozoic block which layer dips increasing towards the diapir, reaching values of 50-60º (Fig. 2). This tilted block is overlaid by Miocene discordant materials that show angular and progressive discordances and sedimentary characteristics that denote a synchronous deposition according to a polyphase growth of the diapir (Roca *et al.*, 1996). Close to the diapir, both the infill rocks and the Mesozoic cover are cut by a NNW directed thrust cut by the diapir walls (Fig. 2).

The Quesa Half-Graben (Fig. 1) shows a more complex structure. It is formed by a set of south-southeastwards tilted blocks limited by a normal fault with less throw than the one seen in the Bicorb Half-graben (600 m; Fig. 2). The Miocene sedimentary infill is thinner and there are not important thrusts affecting neither Miocene nor the Mesozoic cover.

Besides these differences, magnetotelluric data (Rubinat *et al.*, 2008) show that the Mesozoic sequences are thicker north of the diapir and the Variscan basement is located deepest in this zone than south of the diapir. These characteristics indicate that the Bicorb-Quesa diapir stands above a normal basement fault ENE-WSW oriented (Bicorb-Quesa Fault) that sinks the NNW block. This fault was active during the Mesozoic.

The western termination of the Bicorb-Quesa diapir coincides with an abrupt change in the Mesozoic

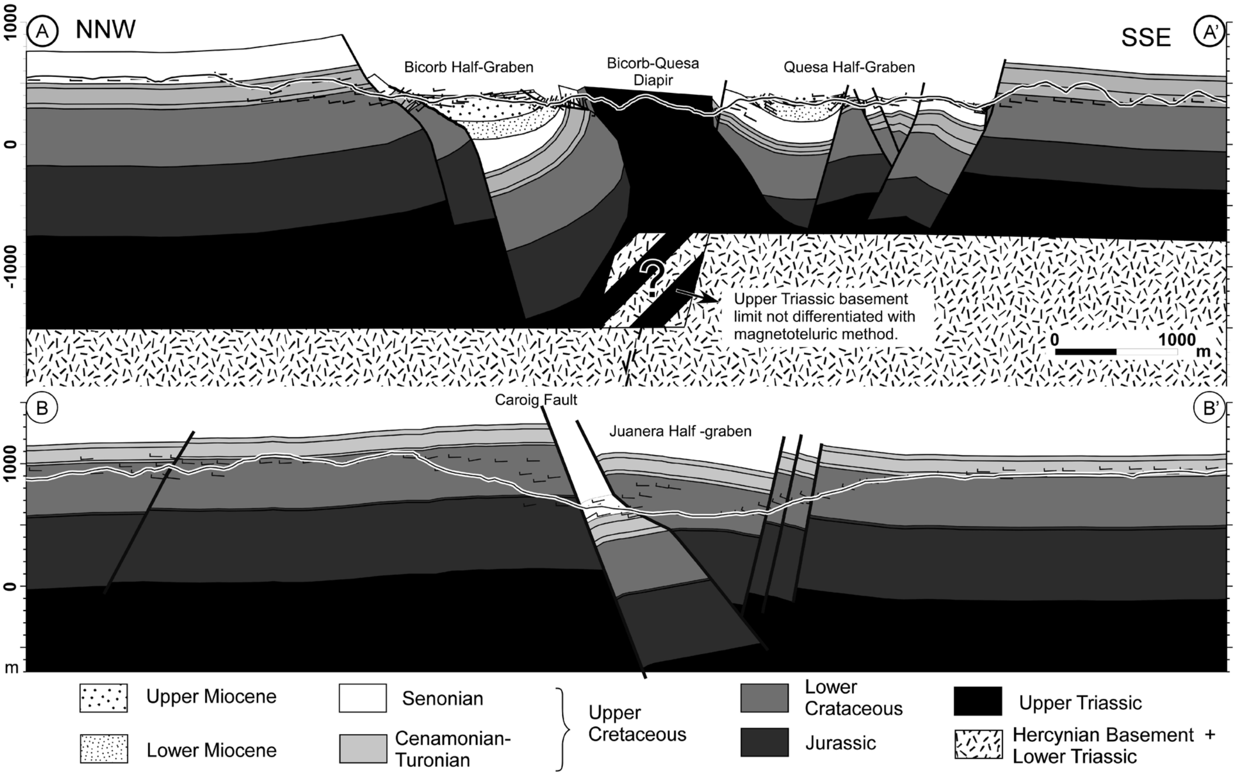

Figure 2. Geological sections AA' and BB' across the diapir and Bicorb-Quesa grabens systems. The geometry at depth in the cross-section A-A' is based on Magnetotelluric data (Rubinat *et al.*, 2008).

cover structure. From this point to the west: 1) Los Patrones Half-graben, NNW-SSE oriented, relieves the Bicorb Half-graben, and 2) the prolongation of Quesa Half-Graben (La Juanera Half-graben) appears limited by a large normal fault dipping southwards which is located in continuity with the diapir termination (Figs. 1 and 2). This fault, called Carroig Fault, presents a throw larger than 1000 m and generates a tilting of its hangingwall towards the NNW. In this zone, reverse faults affecting the Miocene rocks have been recognized, preserved in the most depressed parts of Juanera Half-graben (Fig. 1). Regarding the structure at depth, given the absence of geophysical data, the geometry of the Mesozoic cover (being topographically highest to the north than to the south of the Carroig Fault) suggests the presence of a basement fault ENE-WSW oriented, sinking SSE, unlike the Bicorb-Quesa Fault.

Diapir internal structure

The Bicorb-Quesa diapir is formed by Keuper evaporites and clays, and upper Muschelkalk dolomite layers (Fig. 3). The stratigraphy of these materials is well known (Ortí Cabo, 1974) and includes several petrological units clearly distinguishable and widely outcropping along the diapir. The internal structure of the diapir is characterized by the presence of:

- Folds parallels to the diapir walls (ENE-WSW) locally showing inflections and changing their orientation to WNW-ESE. The axes are plunging towards the walls in the closing areas.

- Folds oriented NNW-SSE, perpendicular to the diapir direction.

- Shear zones parallel to the walls of the diapir that denote different speeds of diapiric ascent.

- A thrust cut by the diapir walls. The thrust sheet had been displaced northwards, placing an overturned serie of upper Muschelkalk and Keuper rocks over a normal polarity serie of Keuper folds.

These characteristics of the internal structure suggest that upper Muschelkalk and Keuper rocks were affected by recumbent folds cut by thrusts before the rise of present diapir. Folds and shear zones mainly suggest that the speed and magnitude of diapiric ascent of the

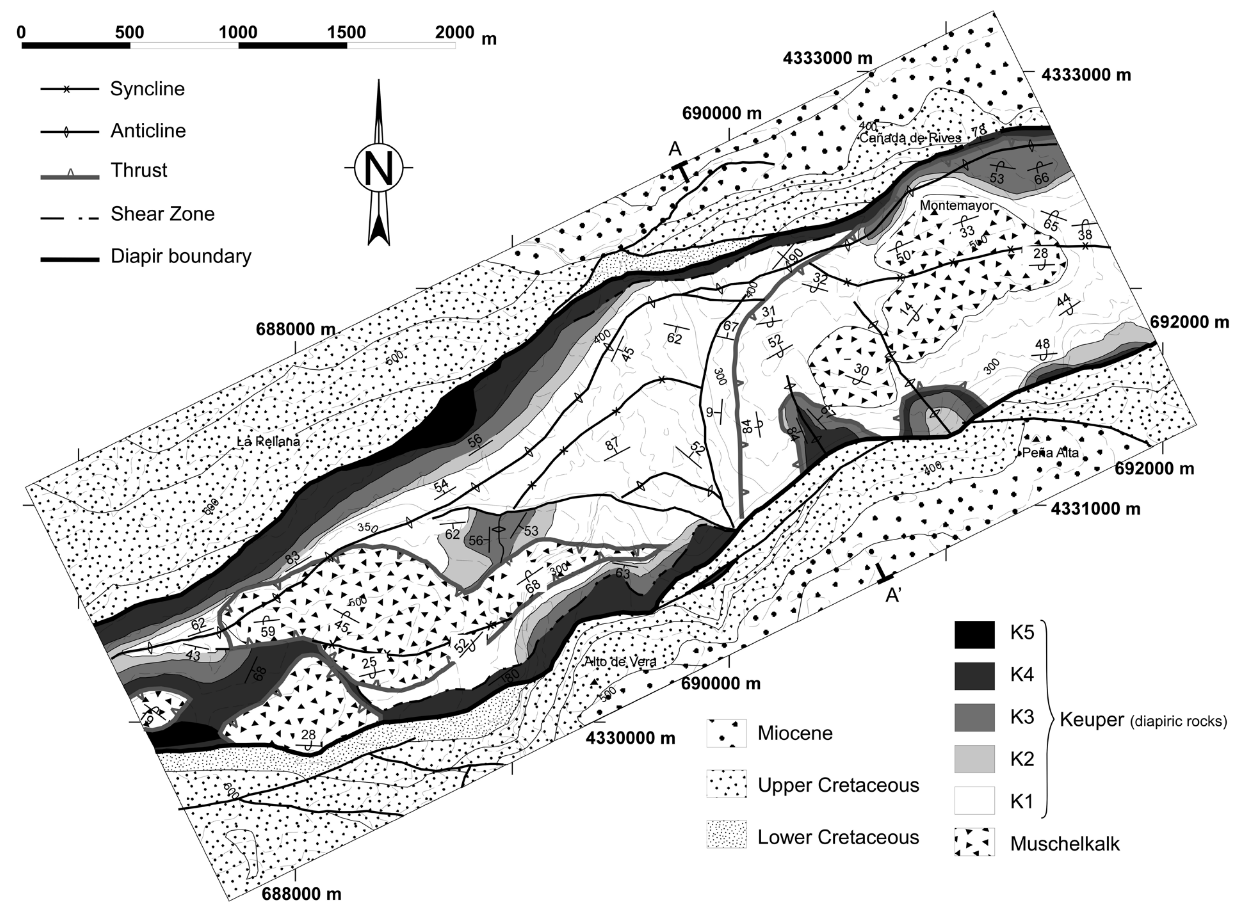

Figure 3. Detailed geological map of the internal structure of Bicorb-Quesa diapir in its central sector (see location in figure 1). The coordinates are in UTM, located in Fuse 30 with European Datum 1950.

diapiric rocks has not been constant throughout neither in longitudinal nor transverse orientation.

Conclusions

The structural characteristics of both the Mesozoic cover and the diapir, combined with the data already published (Roca *et al.*, 1996) denote that:

1) The Bicorb-Quesa diapir is generated by the motion of a normal fault oriented ENE-WSW and dipping north-northwestwards that was already active in the Mesozoic. This fault was reactivated during early Miocene, and generated the thinning of the overlying overburden (Mesozoic cover) favoring diapiric Keuper rocks rise. The withdrawal towards the diapir of these rocks produced the development of the Bicorb and Quesa half-grabens. These half-grabens are bounded by major faults dipping towards the diapir and could be interpreted as equivalent to the rim synclines that form in more ductile overburdens. During this stage, westwards of the diapir, the Juanera half-graben was also generated by the movement of a normal fault dipping towards SSE.

2) During the Serravallian, the zone was affected by a contractive deformation produced for the Betic orogen that generated north-northwestwards compression of the Mesozoic cover located southwards of the diapir and the Carroig fault. This compression caused the formation of recumbent folds and thrusts in its basal detachment level (Keuper + Muschelkalk) and produced the closing of Bicorb-Quesa diapir and later on the formation of thrust sheets that placed the south flank over the northern flank. Westwards, the Carroig basement fault truncates the continuity of the basal detachment level acting as a barrier for the propagation of deformation. The displacement of the cover is accommodated by a reverse

fault producing hangingwall north-northwestwards displacement.

3) After the contractive deformation, there was a reactivation of Bicorb-Quesa diapir; this rise cut previous thrusts and folds.

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