Long-lasting diapir growth history in the Basque- Cantabrian basin (Northern Spain): a review

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Abstract

The Basque-Cantabrian basin is located in northern Spain in the westernmost part of the Pyrenees. It is a Mesozoic rift, inverted during the Tertiary. In this basin, a subsiding deep-water depocenter, called the Basque Trough formed during the Early Cretaceous, in response to the opening of the Bay of Biscay. In the Basque-Cantabrian basin, the Triassic salt-bearing red clays are exposed in several diapirs that display discordant contacts with the Mesozoic and the Tertiary successions, suggesting a long-lasting halokinetic growth at regional scale. The synthesis of previously published works, together with the analysis of the geological maps from the Spanish geological survey (IGME) as well as the building of new structural cross-sections, allows reviewing the history of halokinesis in the basin. At least four distinct areas may be defined according to the paleogeographical locations of the diapirs: the northern and southern margins of the Basque Trough, and the southern and eastern areas of the Basque-Cantabrian basin. In the northern margin of the Basque Trough, the Bakio and Gernika diapirs mainly recorded an Aptian-Albian growth history, although older and younger growth cannot be ruled out. These diapirs were growing in relatively deep-water environments and created some paleo-highs where isolated carbonate platforms developped. In the southern margin of the Basque Trough, the Villasana de Mena, Orduña, Murguía diapirs recorded an Early Cretaceous to Late Turonian growth evolution. These diapirs were growing in relatively shallow-water environments at the shelf of the southern margin. In the southern area of the Basque-Cantabrian basin, the Salinas de Rosío and Salinas de Añana diapirs recorded a Cretaceous salt growth in a shallow-marine to continental environment and the Tertiary reactivation during the inversion of the basin. The Salinas de Rosío diapir shows a salt glacier overlying the adjacent Tertiary Villarcayo Syncline that displays a mini-basin shape with a strong thinning of the Tertiary succession toward its margins. In the eastern area of the Basque-Cantabrian basin, five diapirs (Estella, Alloz, Salinas de Oro, Ollo and Anoz) are aligned along the Pamplona fault, that represent a Cretaceous transverse fault bounding the Basque Trough to the east. The Tertiary succession covers the older units masking the possible Cretaceous salt growth evolution. However, strong thinning of the Tertiary succession toward these diapirs together with the lateral facies changes highlights the Tertiary reactivation of these structures during the basin inversion. The compilation of all these data allows creating a geological chart that depicts the evolution of the salt structures through time and in the different areas of the Basque-Cantabrian basin.

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Introduction

Diapir growth in the Basque-Cantabrian basin is known since the 1950s with the pionner work of Lotze (1953) and there is an abundant old literature about diapir growth in the area (e.g. Kind, 1967; Brinkmann & Logters, 1967; García-Mondéja & Robador, 1987; Serrano & Martínez del Olmo, 1990). A renewed interest for this basin occurred as halokinetic sequences have been described around the Bakio diapir (Poprawski et al., 2014 & 2016). The aim of this work is to provide a modern synthesis of these old works, usually hard to acces and published in German or Spanish languages, and to depict the diapir growth history of the basin, using new structural cross-sections through 10 salt bodies.

Geological settings

The Basque-Cantabrian basin is an inverted rift, located in northern Spain in the western Pyrenean realm. Triassic gypsum and red clays forming the salt bodies are the oldest Mesozoic deposits of the basin. Jurassic to Late Barremian strata correspond to thin, fluvial, alluvial and shallow marine rocks. Aptian to Middle Albian units are represented by Urgonian carbonate platforms and lateral deeper marly deposits. During Late Albian a major depocenter (the Basque Trough) formed in the center of the Basque-Cantabrian basin. This depocenter was bounded to the south by the Villasana de Mena-Orduña-Murguía diapirs line. It was bounded to the north by the Landes Massif, a basement block presently located offshore. The Basque Trough was filled by siliciclastic turbidites (Black Flysch Group) during Late Albian to Cenomanian and by calcareous turbidites from Late Cretaceous to Eocene. In the margins, siliciclastic shallow marine (Valmaseda Fm.) and fluvial sediments (Utrillas Fm.) deposited during Late Albian to Cenomanian and carbonate platforms dominated from Late Cretaceous to Eocene. The inversion of the basin started from Campanian and probably culminated during Miocene. Oligocene lacustrine limestones and Miocene continental conglomerates and sandstones mainly deposited in the Villarcayo Syncline and Miranda-Urbasa Syncline, in the southern part of the Basque-Cantabrian basin.

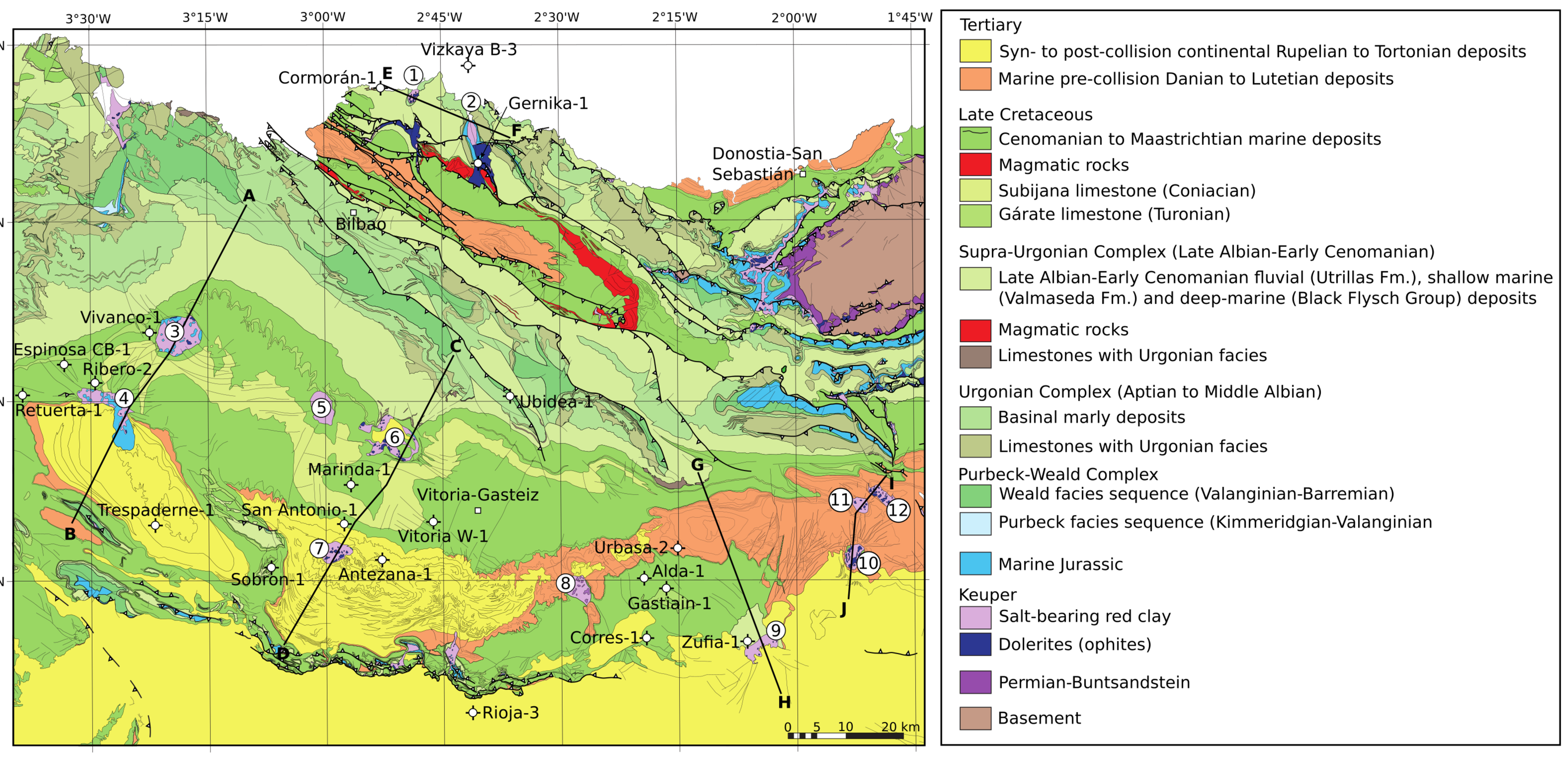

Figure 1: Geological map of the Basque-Cantabrian basin built by Ábalos (2016) from the IGME and EVE maps (Spanish and Basque geological surveys) and location of the sections presented in this work and the wells used for section building. The main salt bodies of the basin are numbered as following: 1, Bakio; 2, Gernika; 3, Villasana de Mena; 4, Salinas de Rosío; 5, Orduña; 6, Murguía; 7, Salinas de Añana; 8, Maeztu; 9, Estella; 10, Salinas de Oro; 11, Ollo; 12, Anoz.

Diapirs of the southern margin

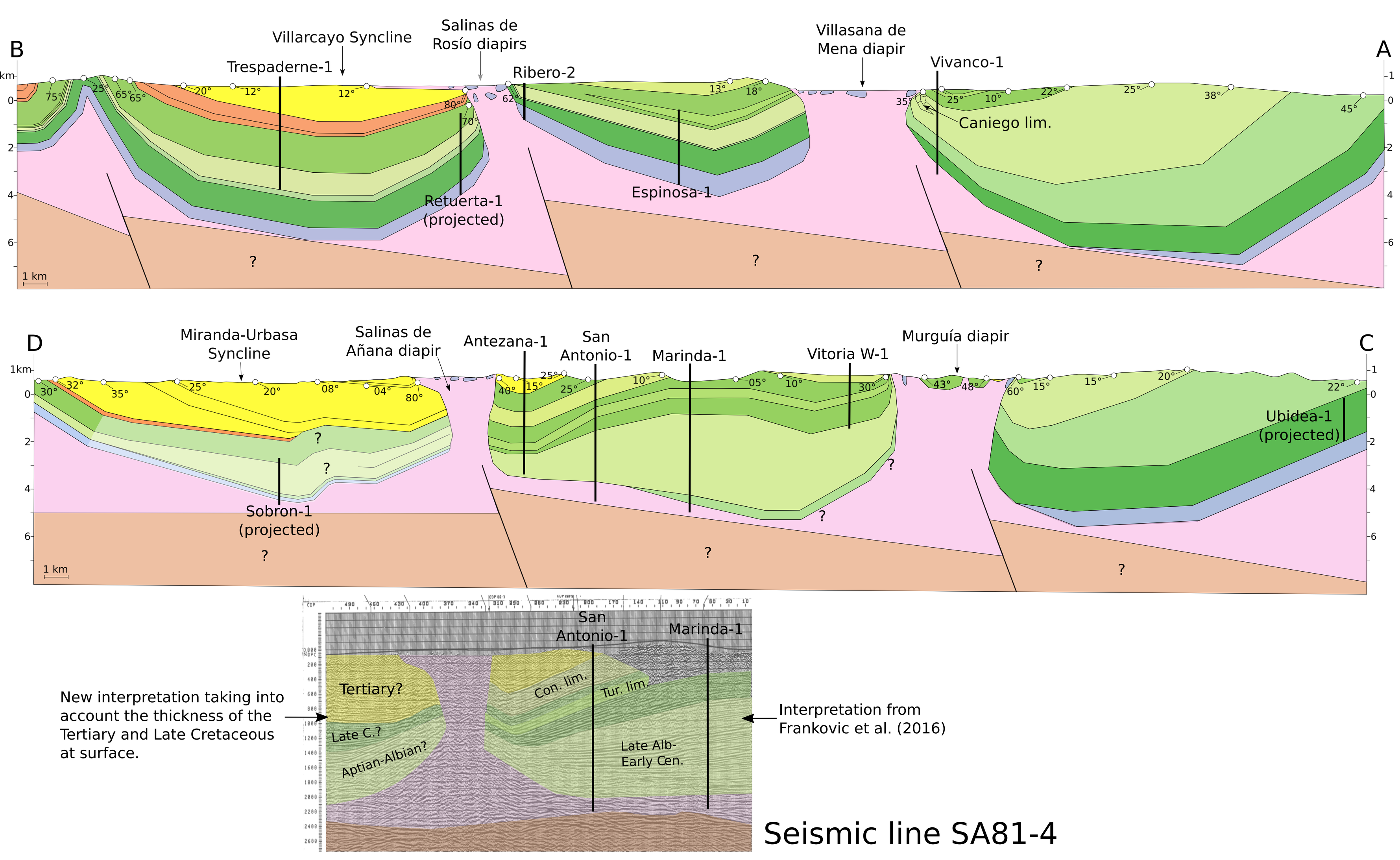

Figure 2: New structural cross-sections through the Villasana de Mena and Salinas de Rosío diapirs (section A-B) and through the Murguía and Salinas de Añana diapirs (section C-D). Same colors than the geological map (fig. 1). In the section A-B, the lower orange strata represent the Paleocene and the upper one the Eocene-Oligocene. The section A-B has been built using the data from Meiburg et al. (1984) and Hernaiz-Huerta & Pond (2000), south of the Salinas de Rosío diapir. Meiburg et al. (1984) documented a thinning of the Turonian to Miocene units, angular unconformities and a salt glacier interbedded with the Miocene deposits in the southern flank of the Salinas de Rosío diapir. The section C-D takes into acount the geometries at depth extracted from the seismic line SA81-4 (IGME) for the Salinas de Añana diapir. The ages of the reflectors in the line SA81-4 are those proposed by Frankovic et al. (2016) in the northern flank of the diapir, while a new interpretation is proposed for the southern flank. The wedge geometry in the southern flank of the Murguía diapir is documented in Abalos et al. (2003). The small synclines (Campanian units) top of the Murguía diapir are assumed as a part of the diapir roof that subsided inside the salt. For both sections, geometries at depth are corroborated by the seismic lines of Serrano & Martínez del Olmo (1990).

Diapirs of the northern margin

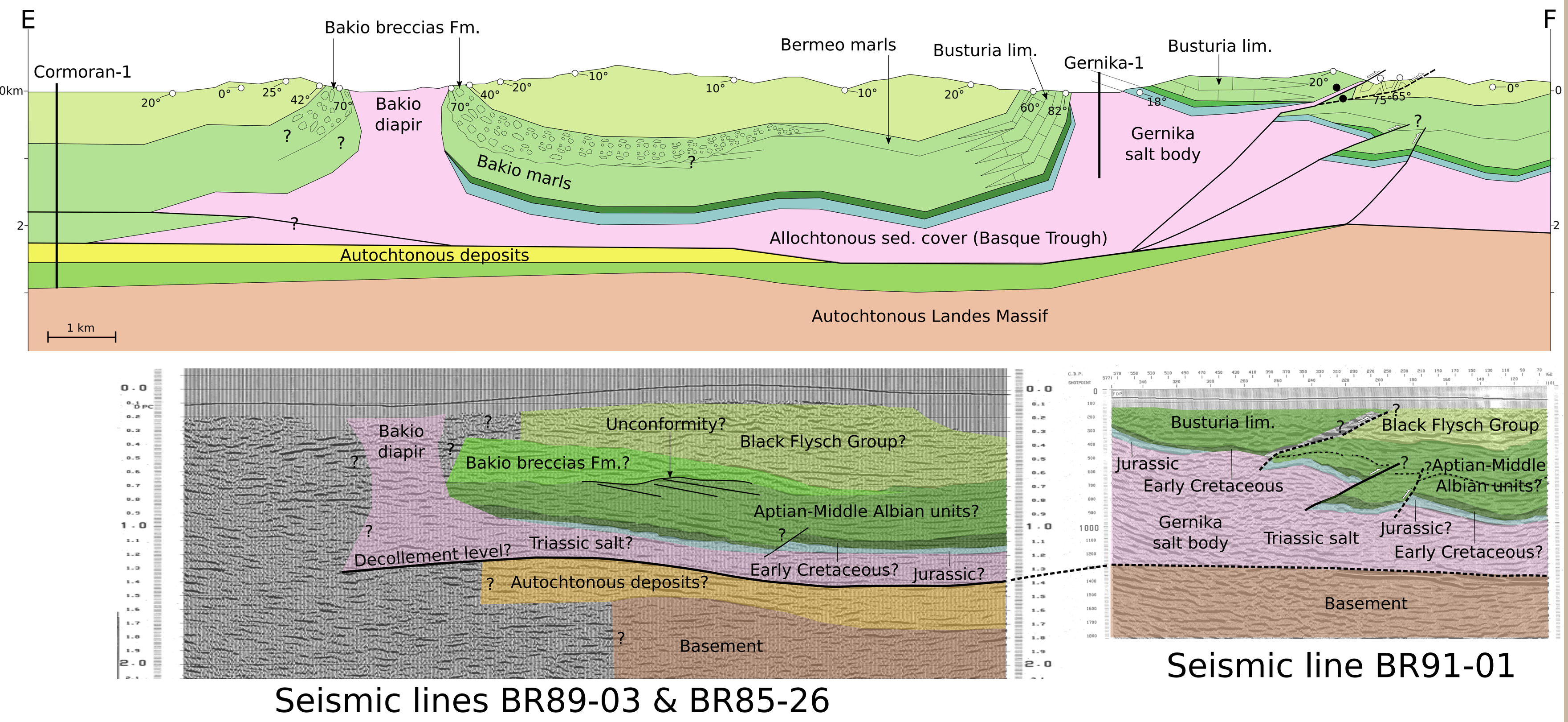

Figure 3: New structural cross-section through the Bakio and Gernika diapirs. Same colors than the geological map (fig. 1). The section has been built including the data of the Cormoran-1 and the Gernika-1 wells. Geometries at depth are inferred from the seismic lines BR89-03 & BR85-26 and BR91-01 (IGME). The ages of the reflectors in the line BR91-01 are assumed from surface data, as Jurassic to Middle Albian units exposed east of salt outcrops match with the reflectors. By contrast, in the lines BR89-03 & BR85-26, there is no direct connexion of reflectors with surface data, thus their ages are highly interpretative. The Cormoran-1 wells suggest that the sedimentary cover and the diapirs are transported toward the north, above the Landes Massif. The salt played as a decollement level (strike view on this section). Possible lateral facies changes in the Aptian-Middle Albian units (García-Mondéja & Robador, 1987) have been added on the section. The inferred angular unconformity on the seimsic lines BR89-03 & BR85-26 may correspond with the unconformity of the Bakio breccias Fm. overlying the Bakio marls unit, exposed at surface (Poprawski et al., 2014 & 2016).

Diapirs along the Pamplona transfert fault

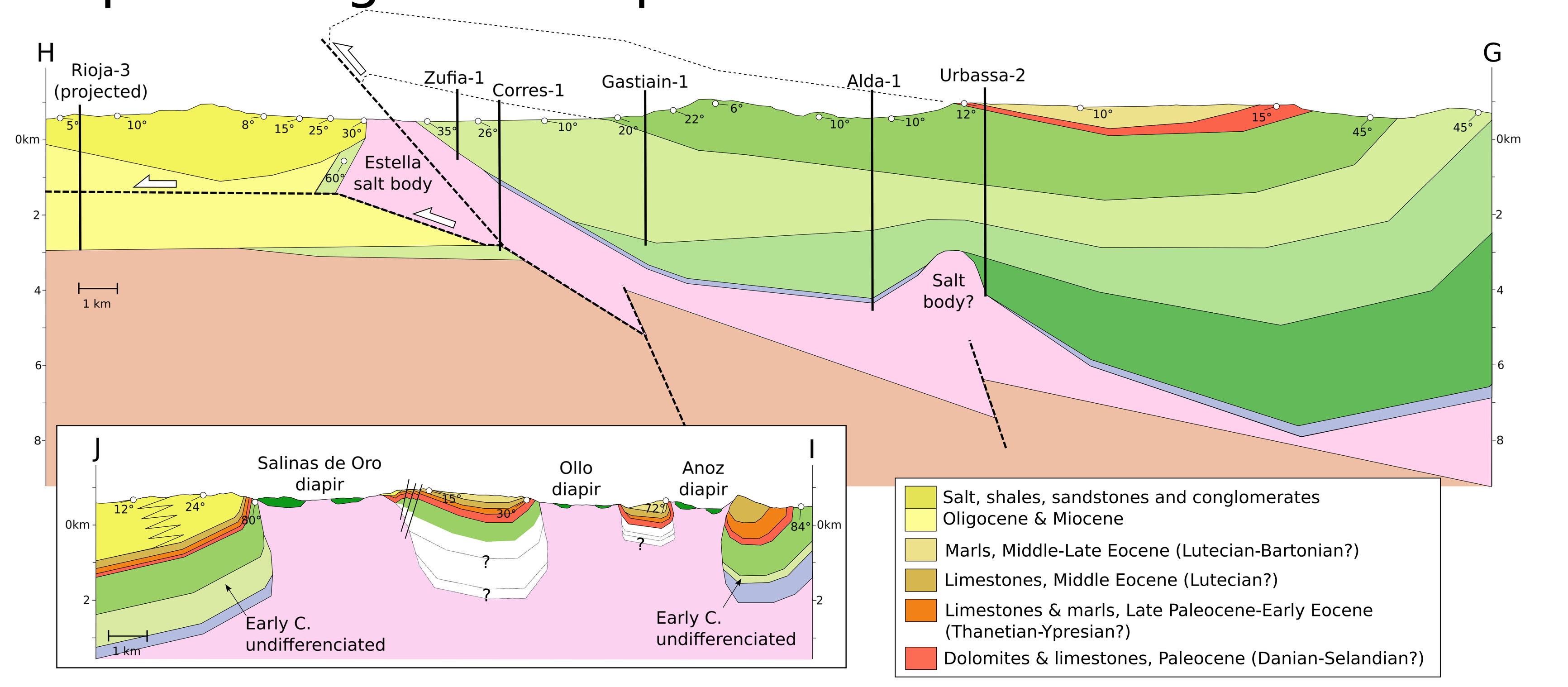

Figure 4: New structural cross-sections through the Estella salt body (section G-H) and through the Salinas de Oro, Ollo and Anoz diapirs (section I-J). Same colors than the geological map (fig. 1), except for the Tertiary units (see the local outline for Tertiary). The section G-H has been built using the data of Larrasoaña et al. (2003). They showed that the Estella salt body may correspond to a salt anticline thrusted southward above the South Pyrenean basal thrust. This suggests a Tertiary (Miocene?) activation as a salt diapir piercing the anticline hinge. An early (Cretaceous) growth cannot be ruled out as the Early Cretaceous units possibly thin toward the Estella salt body. Cretaceous strata are thick west of the Pamplona fault (Salinas de Oro, Ollo and Anoz diapirs line) and relatively thinner to the east, thus the Pamplona fault is considered as a normal Cretaceous fault. During the shortening, the Pamplona fault played as a transfert fault between two different thrust sheets moving southward and controlled by the different Cretaceous thicknesses. The reactivation of fault probably induce growth of the Salinas de Oro, Ollo and Anoz diapirs during Tertiary (section I-J), as documented by Kind et al. (1967).

Synthesis

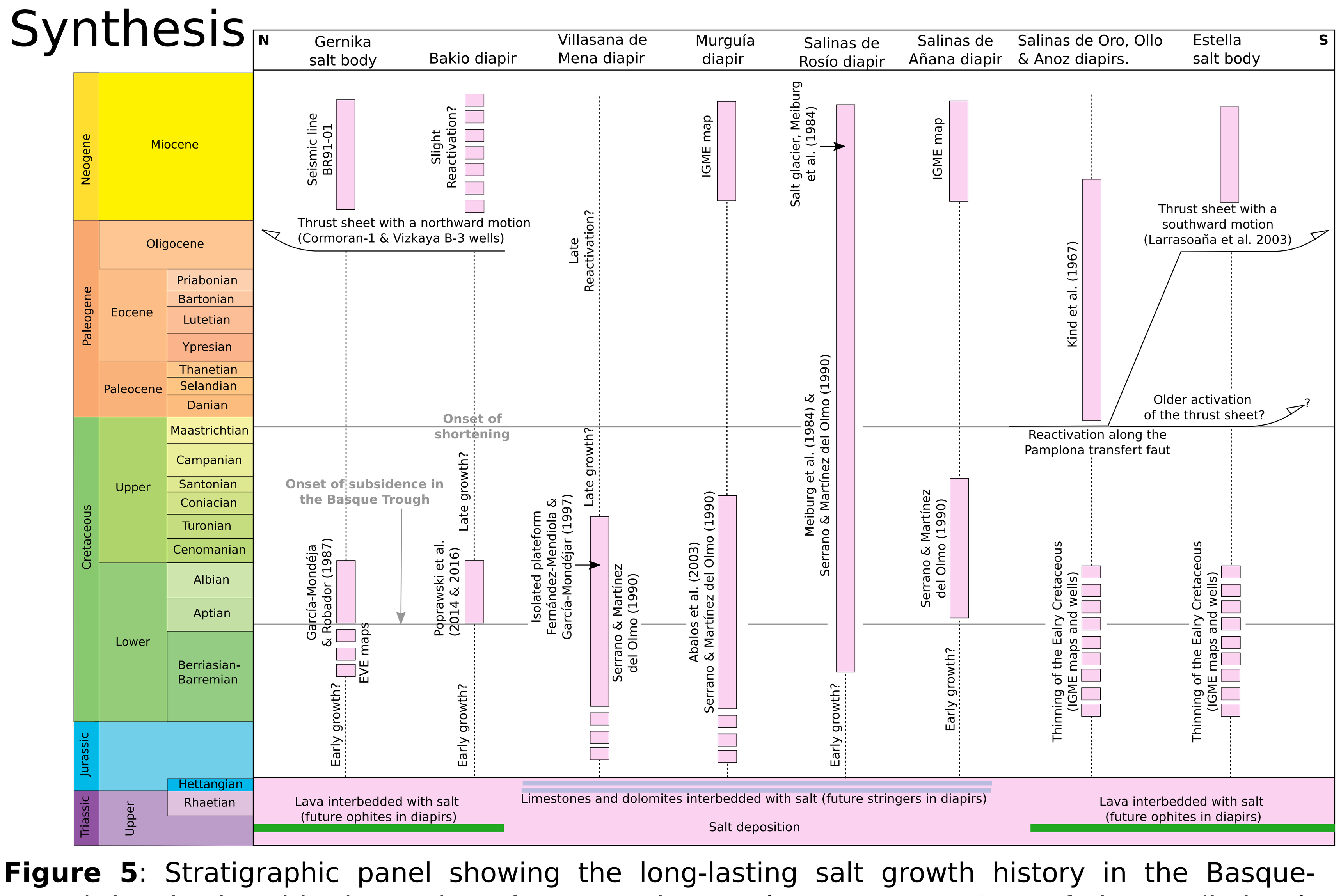

Figure 5: Stratigraphic panel showing the long-lasting salt growth history in the Basque-Cantabrian basin with the main references about salt structures. Most of the studied salt structures were active during the Aptian-Albian, when the subsidence occured in the Basque Trough. These structures have been reactivated by the shortening, during Tertiary.

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