Synsedimentary diapirism in the Cueva Formation at El Ribero sector, Burgos (Upper Cretaceous, Basque-Cantabrian Basin, Northern Spain)

Diapirismo sinsedimentario en la Formación de Cueva en el sector de El Ribero, Burgos (Cretácico Superior, Cuenca Vasco-Cantábrica, Norte de España)

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RESUMEN

En este trabajo se aborda el análisis secuencial y tectosedimentario de las dolomías de la Formación de Cueva (Turoniense sup.- Coniaciense inf.; 80 m. de potencia máxima) que afloran en el sector de El Ribero (Burgos, norte de España). La unidad consta de bancos carbonatados de hasta 30 m. de potencia que normalmente son masivos, pero, en este lugar, presentan clinoformas que buzan en sentidos opuestos a partir de la zona central del diapiro de Rosío, dibujando una estructura domal en su conjunto. Las dolomías aparecen justo por debajo de una superficie de ruptura de primer orden (CSB, Límite Secuencial del Coniaciense) y se restringen a la zona de halocinesis. Su techo es plano, pero la base es de geometría irregular, lo que sugiere un movimiento descendente de los fluídos dolomitizantes. Como consecuencia de los pulsos diapíricos, se formaron varios horizontes de paleokarst con estructuras de colapso y cavidades rellenas por sedimentos laminados del tipo «cul de sac». Estos rasgos llevan a pensar que los movimientos diapíricos pudieron haberse producido sinsedimentariamente y fueron especialmente activos durante el tiempo de depósito de la Formación de Cueva.

Key words: *Upper Cretaceous, Basque-Cantabrian Basin, carbonate ramps, clinoforms, synsedimentary diapiric activity.*

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Introduction. Geological setting

After the widespread Cenomanian-Turonian anoxic event (Jenkyns, 1980) that marks the deepest deposition in the Castilian platform, a relative fall in sea-level occurred with the subsequent creation of shallow carbonate ramps, of which many have sedimentary ruptures. The upper Turonian-lower Coniacian series (Fig.1) in the Castilian platform domain (Feuillée, 1967) are represented from bottom to top by the Hornillalatorre, Cueva and Nidáguila Formations (Floquet *et al.*, 1982; Amiot, 1982; Floquet, 1991). Our interest is focused on the Cueva Formation (50-80 m., late Turonian-early Coniacian), which consists of well-bedded, fine to medium-grained biopeloidal packstone to grainstone, massively-bedded in the lower part (in one unit up to 30 m.) and more discretely in horizons of a few meters thickness towards the top. Fossils are not easy to identify, but corals, sponges, red algae, pectinoids, inoceramids, oysters (Pycnodonte) and some bioturbation (Thalassinoides) are frequent in the upper part of the unit. The presence of lituolids and miliolids was recorded among the foraminiferal content. Locally, the Cueva Formation is strongly dolomitized («El Ribero Member», IGME, 1978; Floquet et al., 1982). Although normally massive or poorly structured, the Cueva Formation exhibits progradational morphologies (clinoforms) in the vicinity of the Rosío diapir (El Ribero sector). The features mentioned above seem to be compatible with an open platform environment, which includes characteristics of tidal facies: bipolar cross-laminated and cross-bedded bioclastic calcarenites.

Stratigraphy and sequential analysis

The Cueva Formation is intensely dolomitized near the town of El Ribero (Figs.1 and 2), where the lateral and vertical changes from dolomitized to non-dolomitized rock are easily visible. Field and petrographic evidence reveal the existence of two first-order depositional sequences (DS1 and DS2, Fig.2), which resulted from major eustatic sea level changes. The lower part of the Cueva Formation is represented by the High Systems Tract of the lower sequence (CHST=Coniacian High Systems Tract), and the upper part of the unit (Ribera Alta Member) corresponds to the Transgressive Systems Tract of the upper sequence (CTST=Coniacian Transgressive Systems Tract). The boundary between CHST and CTST is a type-1 sequence boundary (Floquet, 1991) (CSB=Coniacian Sequence Boundary, Fig.2). Whereas the CHST consists of clinoforms prograding both to the north and south, the CTST is a top-lap sequence, which lies with angular unconformity upon the CHST.

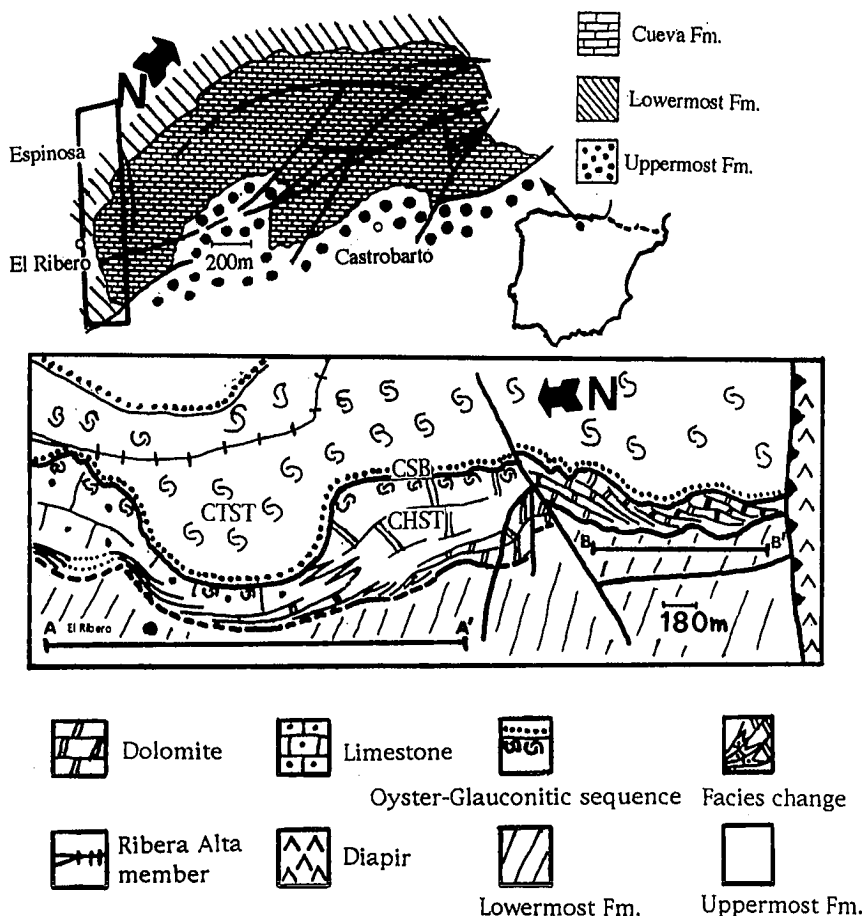Other minor sedimentary gaps also appear in the El Ribero section. Two

Fig.1.- Geographic location and geologic map of the Cueva Formation at El Ribero showing the stratigraphic sections A-A' and B-B'.

Fig. 1.- Localización geográfica y mapa de afloramientos de la Formación de Cueva en El Ribero. Se indican las secciones estratigráficas A-A' y B-B' de la unidad.

indicative of a small platform model related to diapir-originated highlands are present. Close to the diapir, several tens of meters of the sedimentary pile have been intensely dolomitized (Erkiaga et al, this volume), although sedimentary structures such as cross lamination and algal mats and fossils such as corals and briozoans, have been preserved. The lower limit of the dolomitized mass is irregular and easily visible at the south of El Ribero, whereas the upper limit is horizontal and follows the CSB sequence boundary. Dolomitization laterally disappears towards the north of the diapiric dome, not in a sharp manner, but accurately following the clinoform planes that may have allowed the circulation of dolomitic fluids. The northernmost dolomite facies appear as thin wedge-shaped pure dolomite horizons interbedded between thicker calcarenite beds. During the late CHST, several coral patch reefs developed, which have subsequently been largely dissolved, although some were partially preserved by silicification. The CSB sequence boundary at the top of CHST can be correlated with that of 88.5 my by Haq et al. (1988). The same limit has been referred to as SB-8 by Floquet (1992) and UC-10 by Gräfe & Wiedmann (1993) in wider areas of the Basque-Cantabrian Region.

The upper depositional sequence (DS2) outcrops as a subhorizontal calcarenite unit that unconformably overlies the clinoform system of the CHST. At the base of the shallowing-upwards cycles are poorly-structured limestone beds that vertically evolve to cross-laminated, cross-bedded and fossiliferous calcarenite beds. At the very top, shallowing features are still conspicuous: small quartz geodes and quartz-filled desiccation cracks in two particular horizons, which have been interpreted as two minor sedimentary gaps restricted to the El Ribero area. The most shallow horizons are marked by oyster concentrations very similar to those described for Urgonian sediments in the Basque Cantabrian Basin (Rosales, 1995). The transition to the upper Nidáguila Formation is represented by a thick calcarenite bed, bearing glauconite, and denotes a sharprise of sea-level, since this formation is marly and echinoderms and oysters are the most commonly preserved fossils. The host limestone largely consists of shallow marine packstone/grainstone bearing milio-

minor sequence boundaries outcrop very close to each other in the lower part of the Cueva Formation. Both boundaries have erosional features; the lower exhibits scour and fill surfaces and the upper reveals evidence for paleokarstification, such as vugs with laminated infillings and collapse structures. Fifteen metres below the CSB, a third minor sequence boundary has a smooth and flat upper surface, which bears cauliflower-type quartz geodes associated with anhydrite relicts. Such minor boundaries were not found in equivalent sections nearby, such as at Cueva and Bedón Mountain (Elorza and García-Garmilla, 1993,1995), which suggests that they may have had an origin related to local diapiric synsedimentary movements.

The base of the lower depositional sequence (DS1) contains the deepest marly facies of Upper Cretaceous sediments in the Navarro-Cantabrian domain (Hornillalatorre Formation),

and is topped by metre-scale shallowing-upwards cycles (early CHST). A scour and fill sequence boundary appears at the top of the last parasequence. Karstification affected the shallow deposits overlying this boundary and involved a vadose zone whose thickness can be estimated to be about 3.5 m. The late CHST is spectacularly developed and is characterized by clinoforms dipping towards both N and S (Figs.2 and 3). The HST carbonate body is tabular-shaped, with roughly parallel lower and upper boundaries, although opposite and variable inclinations in some places indicate tilting, possibly related to halokinetic movements of the adjacent Rosío diapiric zone (García-Garmilla and Elorza, 1991; Elorza et al., 1991). Some minor gaps in the clinoform system can also be detected.

A general carbonate ramp setting is likely for the Cueva Formation (e.g. Sarg, 1988), but features (clinoforms)
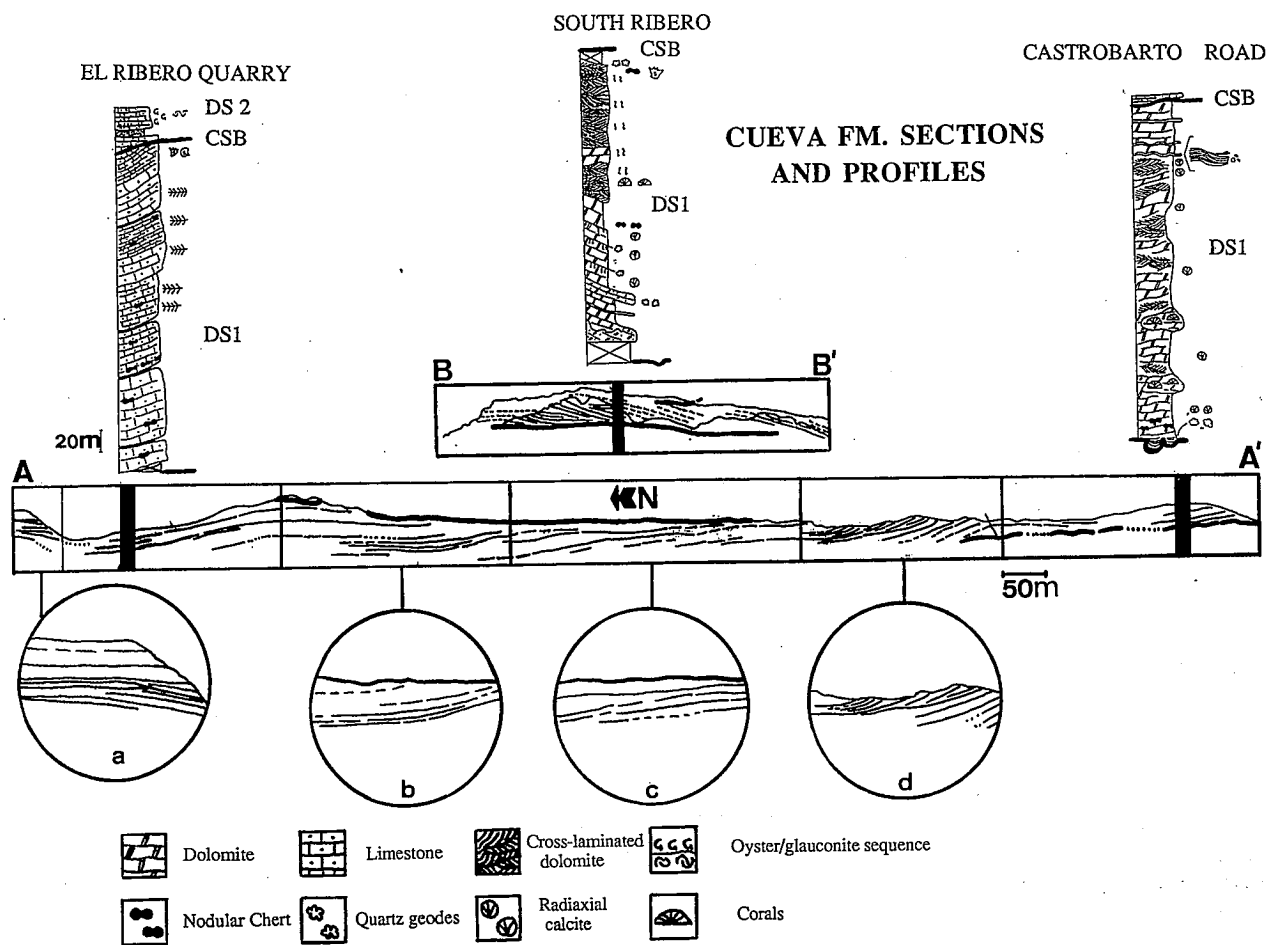
Fig.2.- The sections A-A' and B-B' of the Cueva Formation with indication of stratigraphic profiles and four detailed views (a, b, c, d) of concrete zones of the clinoforms (see text).

Fig. 2.- Secciones A-A' y B-B' de la Formación de Cueva con la localización de los perfiles estratigráficos, así como cuatro esquemas de detalle (a, b, c, d) de otras tantas zonas concretas de las clinoformas (ver texto).

lids, textularids, lituolids, echinoderm and mollusk fragments, red algae and very scarce vertebrate remains. Taken together, these findings suggest that organic frameworks could not keep pace with the rise in sea level, and that the arrangement of facies corresponds to a drowning-phase.

Geometry of carbonate bodies

Normally the Cueva Formation is composed of horizontal to subhorizontal massive banks up to 30 m in thickness. This character changes at El Ribero to prograding clinoform systems. Clinoforms are sigmoid to oblique, and generally dip about 5°, but may dip up to 10° near the diapir, as described by Gawthorpe and Gutteridge (1990) for the Dinantian in the UK. They exhibit in general a tabular geometry, having their upper and lower surfaces more or less parallel. The observations at the W of the studied area (Bedón Mountain) show the progradation of clinoforms towards the W. Overall, these observations suggest that the clinoforms assumed a dome-like structure having the central area just coinciding with the diapiric body (Fig.3).

Although the actual diapiric outcrop area is like an «L», the isobath maps (ENRESA, 1990) reveal that the Rosío diapir has an enlarged E-W domal shape. Just at the point «a» in Fig.2, contrary dips at local scale have been recorded suggesting depressions caused by differential halokinetic movements. As Fig.2 shows, the clinoforms become horizontal at points «b» and «c» in Fig.2, whereas the higher dip appears at «d». Higher dips indicate the predominance of aggradational stages in the behaviour of the platform, whereas the lower ones («b» and «c») should denote a significant progradation. The progressively more gentle dips towards the north of the studied area seem to prelude the relative fall in sea level marked by the Coniacian Sequence Boundary (CSB).

The complete set of clinoforms has a thickness close to 80 m and the progradation develops along 9 km. In spite of the fact that the number of collected samples is not enough at present, it seems likely that the organic build-ups (silicified corals) are installed at the upper part of the clinoforms, whereas the lower part is largely composed of bioclastic detrital sediments. Field observations support a model of «horizontal progradation» similar to that described by Bosellini (1984) for the Catinaccio platform (Triassic, Northern Italy), but on a much smaller scale.

Relations with synsedimentary diapirism

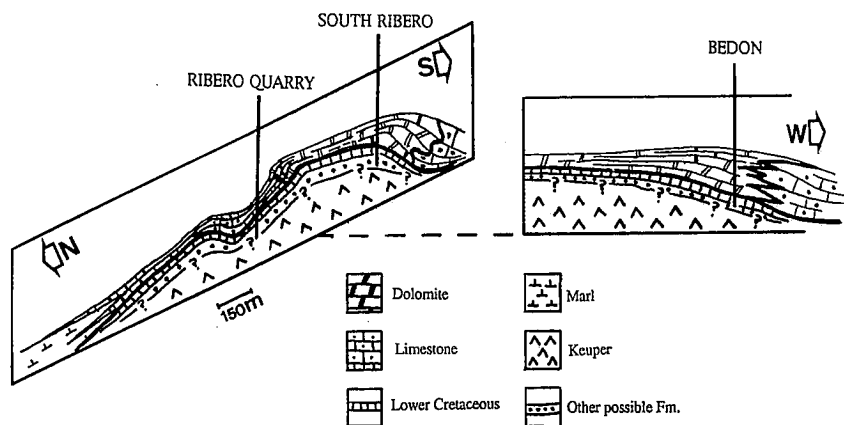The Cueva Formation carbonates were deposited in a widespread

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Fig.3.- Interpretative model of how the synsedimentary diapiric influences the progradational geometries. The position of the sections A-A' and B-B' is indicated.

Fig. 3.- Modelo interpretativo de la influencia diapírica sinsedimentaria sobre las geometrías de progradación. Se indica la situación de las secciones A-A' y B-B'.

carbonate ramp, but locally and close to the actual diapiric area of Rosío, the behaviour of the system was similar to a small platform. The observations at higher scale (Fig.3) seem to corroborate this point. The clinoforms in Western points (Bedón Mountain) clearly dip towards the W. This points to a general domal shape for the clinoforms as a whole.

Dolomitization and calcitization in the most emerged zones of the area of diapiric influence reveal diagenetic environments related to shallow marine followed by fresh-water meteoric domains. The presence of evaporitic nodules in such horizons reinforces the idea of a significant shallowing at this point (Erkiaga *et al*, this volume). In addition, dolomitization diminished towards the most distal areas of the diapir and appeared as wedges of infiltration in the northernmost places. Taking into account the opposite dips at El Ribero and the concentration of dolomite and meteoric calcite in the sediments at the diapiric zone, the most

probable mechanism invoked for the development of the Cueva Formation clinoforms could be associated with diapiric local uplifts, whose intensity and orientation may have varied over time, provoking contrary dips and topographic troughs on a minor scale. This is a unique sedimentologic and paleographic feature, which cannot be observed in other sections of the Cueva Formation along the Castilian platform.

Acknowledgements

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