Platform sedimentation and collapse in a carbonate-dominated margin of a foreland basin (Jaca basin, Eocene, southern Pyrenees)

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ABSTRACT

The Eocene Jaca basin is a foreland basin with well-exposed carbonate platforms in the distal margin. This margin underwent alternating periods of stable platform growth and platform drowning. Periods of drowning were accompanied by large-scale collapses with generation of shelf-edge truncations and resedimentation of carbonate megabreccias into a terrigenous turbiditic trough. These features caused a stepped retreat of the platforms and are related to episodic variations of tectonic loading in the hinterland and correlative flexural bending of the distal basin.

INTRODUCTION

Foreland basins typically show cross-sectional asymmetry of sedimentary units and progressive migration of depocenters. At the hinterland margin, the sedimentary input from the emergent orogen produces a clastic wedge, which is commonly redistributed along the basin axis. In marine foreland basins, the distal (cratonward) margin of the basin may be the locus of either terrigenous or carbonate sedimentation. When climatic conditions favor carbonate production, the sedimentation rates may balance the subsidence and permit the growth of platforms (Read, 1980; Pigram et al., 1989).

We present here a tectonic-stratigraphic model for the evolution of the carbonate-dominated distal margin of a turbiditic foreland basin from the southern Pyrenees. This model accounts for margin retreat with periods of aggradational platform growth coupled with episodes of drowning and collapse, which are related to an episodic distribution of the thrust loads in the hinterland.

STRATIGRAPHIC FRAMEWORK OF THE JACA BASIN

The Jaca basin (Fig. 1) was an Eocene marine foreland basin of the southern Pyrenees that today is exposed in the orogenic belt. During Ypresian and Lutetian time, the Jaca basin was an east-west elongated trough filled with a thick turbidite wedge (Hecho group; Mutti, 1984). The basin was bordered to the north (hinterland) by the active Lakora and Eaux-Chaudes basement thrust sheets (Labaume et al., 1985; Teixell, 1992) (Fig. 1). To the south (distal margin) the trough was flanked by carbonate platforms (Puigdefàbregas and Souquet, 1986; Barnolas et al., 1991). The main episodes of displacement of the thrust sheets can be dated at their continuation in the South Pyrenean cover thrusts (e.g., Cotiella, Mt. Perdido and Larra thrusts; see also Barnolas et al., 1991).

Turbiditic Succession

The restoration of structural cross sections through the Jaca basin (Teixell, 1992) reveals the preserved turbidite wedge to be 50 km wide and 4500 m in maximum thickness (Fig. 2). The turbidite sedimentation lasted ~9–10 m.y. (Ypresian–late Lutetian), indicating compacted sediment accumulation rates of up to 45–50 cm/ka. The turbidite wedge displays a south-directed onlap (Labaume et al., 1985), in accordance with the advance of the thrust loads toward the foreland.

The Hecho group includes terrigenous turbidites and thick carbonate megabreccia sheets. Terrigenous turbidites were fed axially by deltaic shelves located to the east, on top of a thrust unit (Tremp-Graus basin, Fig. 1).

Southern Carbonate Platforms

In the distal margin of the basin, there are three main platform stratigraphic units (Barnolas et al., 1991). The lowest of the platforms ("Alveolina limestone" in the Pyrenean literature) is of early Ypresian (Ilerdian) age, the middle (Boltaña limestone) is late Ypresian (Cuisian) in age, and the uppermost platform (Guara limestone) is Lutetian. Their thickness and extent is shown in Figure 2. The platform deposits consist of predominantly skeletal grainstones (made up of large foraminifera tests such as *Alveolina*, *Nummulites*, and *Assilina*), and nodular wackestones and marlstones. The facies distribution conforms to a low-relief carbonate ramp, with skeletal facies in the inner part, that grade to finer grained facies in the outer part. The deposits result from stacking of shallowing-upward sequences, having individual thicknesses from 10 to 30 m.

Considering the relative position of the three units, it is evident that they are arranged in a forelandward-retreating pattern. Despite the ramp-type facies associations, the preserved geometry of the platforms is characterized by flat bank tops and steep erosional edges.

Platform Truncations and Drowning Discontinuities

Each of the platforms is cut basinward by erosional truncations. These truncations are in the subsurface in most of the Jaca basin, but they are exposed in outcrop at some key localities. The lowermost platform is cut to the north by a truncation onlapped by the lower part of the Hecho group (north of Villanua; Labaume et al., 1985). The most evident truncation is that of the middle (Boltaña) limestone, which ends along a large-scale surface that can be mapped in the Boltaña anticline area (Fig. 3). The platform truncation extends basinward for at least 9 km, cutting down for 800 m into upper Ilerdian deposits. The Hecho turbidites onlap this surface. The Lutetian (Guara) platform is also cut by an erosional surface that is exposed southeast of the Boltaña an-

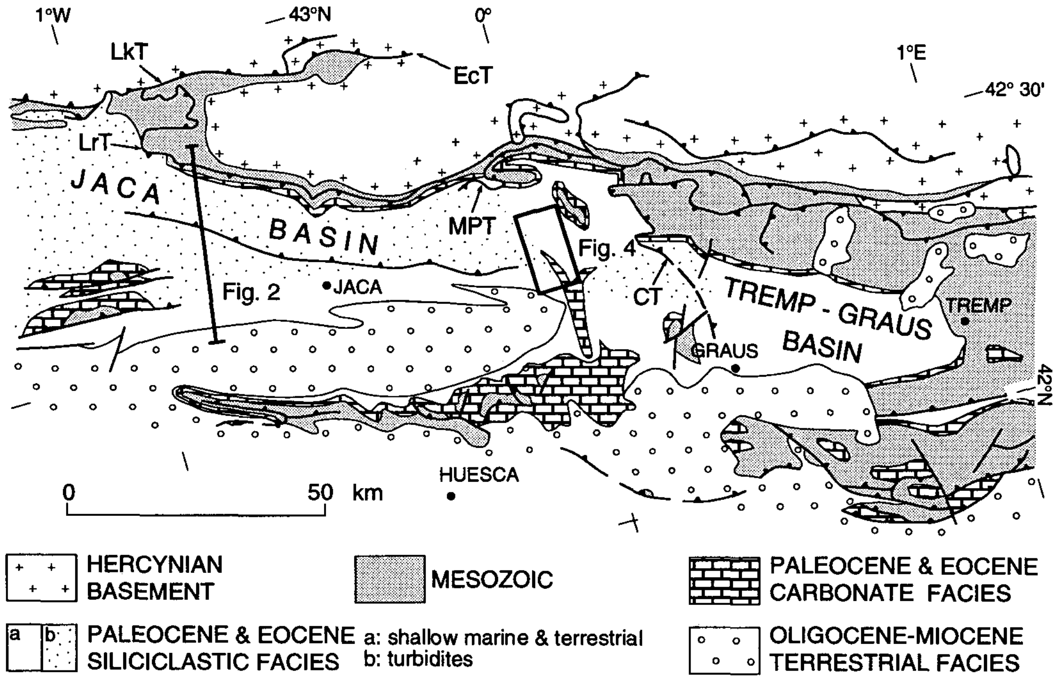


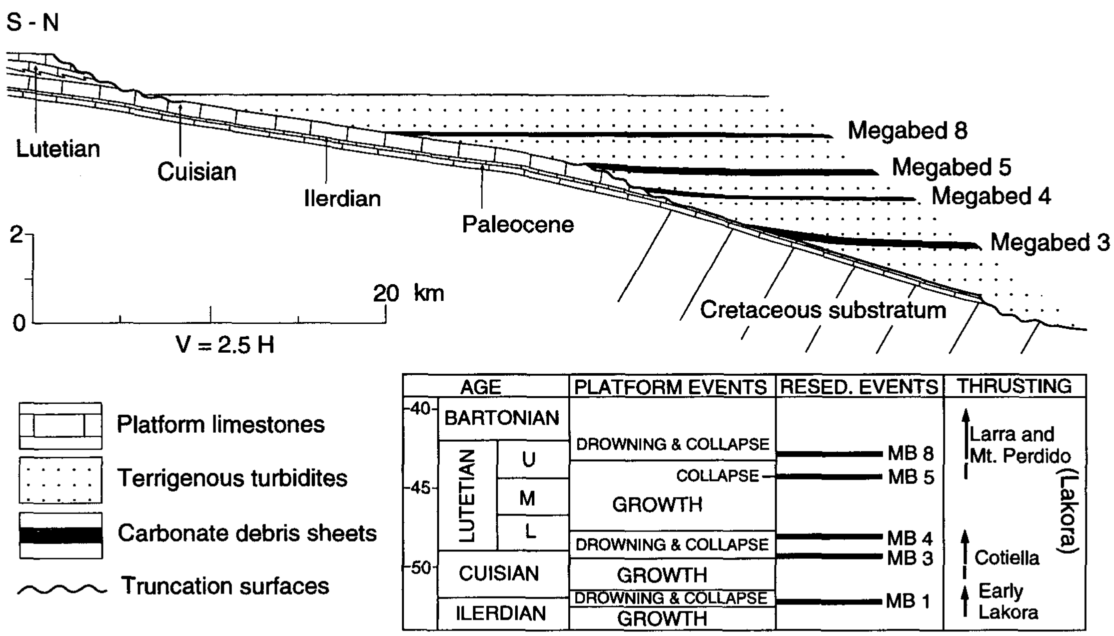
Figure 1. Geologic sketch map showing setting of Jaca basin in south-central Pyrenees. LkT—Lakora thrust; EcT—Eaux-Chaudes thrust; LrT—Larra thrust; MPT—Mt. Perdido thrust; CT—Cotiella thrust.

ticline (Barnolas et al., 1991). However, in this locality, accretionary slope facies are preserved below the truncation, which may have been removed by erosion at the mentioned outcrops. Comparable erosional truncations were described by Playford (1980), Mullins and Hine (1989), and Steward et al. (1993), among others, and have been interpreted as large-scale failures or collapses of the carbonate platform margin.

The truncation surfaces in the study area pass landward into apparent conformities. These conformities, at the top of each carbonate platform, display a drowning sequence ("drowning unconformity" in the sense of Schlager, 1989). The shallow-water limestone grades abruptly into a thin sequence of fine-grained glauconite limestone and marl, but occasionally small pinnacle reefs developed on the drowned surfaces. These facies are overlain by terrigenous turbidites.

The truncation surfaces show no evidence of emergence or subaerial exposure (e.g., karstification, pedogenic diagenesis). By contrast, the vertical succession (i.e., from limestone to turbidite) indicates a deepening of the depositional profile. These features suggest that the overall drowning of the platform area and the shelf-edge collapses are genetically related.

Each successive truncation is found to the south of the previous one (Fig. 2), resulting in a stepped onlap-type margin in the sense of James and Mountjoy (1983). The retreat can be estimated to be ~52 km. The shelf-edge truncations and the drowning surfaces of the bank top join in a basinal discontinuity that separates the retreating carbonate facies of the distal basin margin from the onlapping clastic wedge (turbidites). On the basis of a restored cross section, the average



	AGE		PLATFORM EVENTS	RESED. EVENTS	THRUSTING
-40-	BARTONIAN				
	LUTETIAN	U	DROWNING & COLLAPSE	MB 8	Larra and Mt. Perdido
-45-		M	COLLAPSE GROWTH	MB 5	(Lakora)
		L	DROWNING & COLLAPSE	MB 4 MB 3	Cotiella
-50-	CUISIAN		GROWTH		
	ILERDIAN		DROWNING & COLLAPSE GROWTH	MB 1	Early Lakora

Figure 2. Relations between onlapping deep-water turbidite wedge and backstepping carbonate platforms of distal basin. Main carbonate megabreccia beds interbedded with turbidites are shown. Sketch is based on restoration of balanced cross sections (Teixell, 1992). Table shows links between main sedimentary and tectonic events. Episodes of maximum convergence, based on age of leading-edge cover thrust sheets, are indicated.

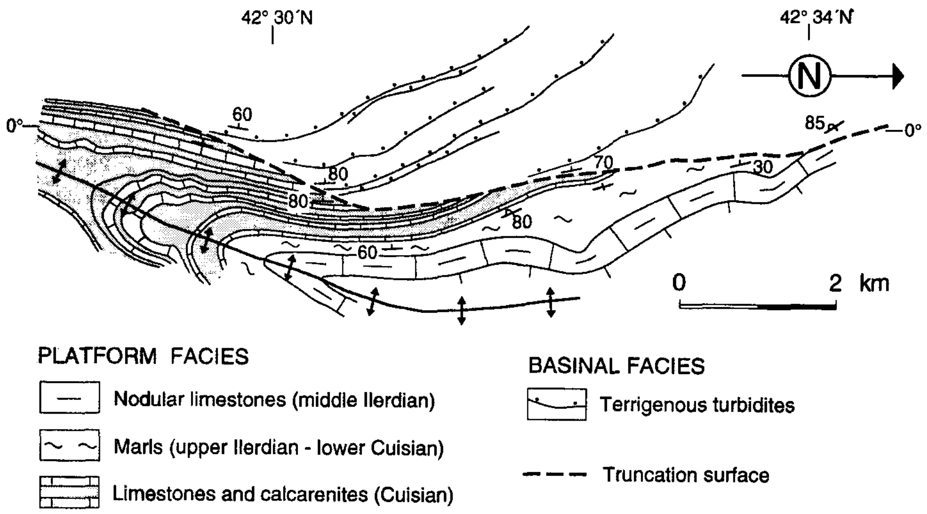


Figure 3. Geologic sketch map of western limb of Boltaña anticline showing truncation surface of Cuisian (lower Eocene) platform and onlap of turbiditic facies on this surface. Anticline postdates these sedimentary features, and map view provides cross-sectional image of carbonate margin.

onlap angle of the turbidite wedge over the discontinuity can be estimated to be about 4°–6°.

Carbonate Megabreccias Within the Turbidites

The thick megabreccias of the Hecho group, referred to in the literature as "megabeds" or "megaturbidites," are composed of resedimented platform and slope material, all of Eocene age (Johns et al., 1981; Labaume et al., 1985). In some cases, clasts derived from more than one of the carbonate platforms described above have been recognized in a single megabed. There are eight main megabeds in the Hecho group. Their individual thickness varies from a few metres to a maximum of 200 m, and they contain tabular limestone clasts up to 500 m across. On the basis of calcareous nannoplankton, the third megabed (MB3) was attributed to the uppermost Cuisian (zone NP14), whereas the overlying ones were dated as Lutetian (zone NP15) (Labaume et al., 1985). It is thought that each of them results from a single catastrophic mass-wasting event (Johns et al., 1981).

Although these megabreccias are key features to understanding the evolution of the basin, their origin and provenance are controversial, in part due to the absence of clear paleocurrent indicators. Most authors proposed a northern source for these beds, from hypothetical platforms (now eroded away) sitting on top of the active thrust sheets of the hinterland margin of the basin (Séguret et al., 1984; Labaume et al., 1985). On the contrary, a southern provenance is evidenced by the following criteria: (1) northeast-directed flute casts in the calcarenite part of one of the largest megabeds (megabed 5), (2) the locally observed northward-fining and thinning trends (megabed 3), (3) coexistence of at least the youngest megabeds with siliciclastic turbidites bearing south-directed paleocurrent indicators, and (4) the erosional nature of the contacts between the megabeds and the onlapped carbonate platforms of the southern basin margin (see Teixell, 1992, p. 74–78 for full discussion). The integration of these features with the erosional truncations of the carbonate platforms leads us to interpret the megabeds as resedimented units from the platform collapses, and to include them in a general model for the evolution of the distal Jaca foreland basin.

GEODYNAMIC MODEL FOR THE EVOLUTION OF THE CARBONATE DISTAL MARGIN

Retreat of the carbonate platforms of the distal margin of the Jaca basin and their onlap by the basinal turbidite wedge are consistent with flexural bending and depocenter migration characteristic of foreland basins. In the literature, other examples of stepped onlap margins have been related to the existence of periods in which carbonate production cannot balance sea-level rise because of abrupt increments of tectonic subsidence (Playford, 1980; Schlager, 1989; Mullins et al., 1991). However, megabreccia shedding from low-relief carbonate platforms has also been attributed to tectonic activity (Hine et al., 1992).

In the Jaca basin, the backstepping geometry resulted from the combination of stages of platform growth and of platform drowning. Platform drowning was accompanied by large-scale collapses of the margin, which can locally cut down into a previous platform unit. Given the tectonic cause of the overall retreat of the basin margin, it is reasonable to relate the above-mentioned episodicity to a similarly episodic tectonic evolution of the basin. Taking into account the geodynamic setting, we propose an interpretative model that explains these sedimentary features.

The model consists of two phases of stratigraphic development, considering an episodic variation of the maximum thrust loading of the basin (Fig. 4). Comparable two-stage models were applied to nonmarine foreland basins by Heller et al. (1988). In the Eocene Jaca basin, which typifies a deep-marine foreland basin, periods of relative tectonic quiescence (low convergence rates) may have enhanced the aggradational

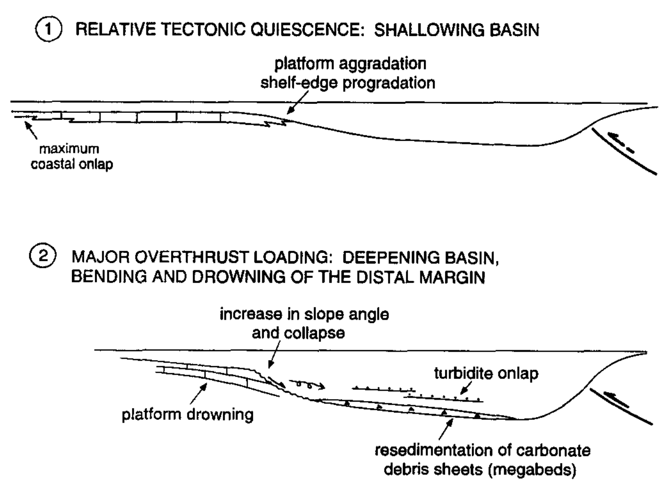


Figure 4. Geodynamic model showing two stages of development of Jaca turbiditic basin and its distal margin (see text for explanation).

development of shallow-water carbonate platforms in the distal margin, platforms that grade with continuity to the basin floor through accretionary slopes.

In periods of renewed thrust loading (or maximum rates of load advance), however, the bending of the lithosphere in the distal margin of the basin caused drowning and oversteepening of the platforms that were on that margin. These processes were accompanied by extensional collapse faulting that caused truncation of the platforms (Fig. 4). Associated with these processes, catastrophic resedimentation into the basin floor as base-of-slope aprons would produce large debris sheets (megabeds). During this phase, the carbonate bank top recorded a rapid vertical gradation to deeper water marls, authigenic minerals being indicative of low sedimentation rates. With the continued evolution of the basin, each drowned platform was subsequently onlapped by the migrating deep-water turbidite wedge, and carbonate sedimentation shifted further onto the foreland.

Thus, the main stratigraphic discontinuities and resedimentation events at the distal margin of the South Pyrenean foreland basin appear to be driven by local tectonic activity. We interpret the described distal erosions to result from drowning and platform collapse; we do not have evidence for forebulge uplift as documented in other foreland basins (i.e., Jacobi, 1981; Quinlan and Beaumont, 1984). The "basal unconformity" that underlies the onlapping clastic wedge in many foredeeps is not developed in the study area over a previous passive margin sequence; instead, the unconformity results from the amalgamation of drowning surfaces and related truncations on synorogenic carbonate sediments of the distal margin of the basin.

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