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Anatomy of a carbonate resedimentation within the Latest Turonian - Earliest Coniacian South-Provencal Basin

M. FLOQUET * J. HENNUY*
*Centre de Sédimentologie - Paléontologie, CNRS, UMR 6019, Université de Provence, Place Victor Hugo, 13331 Marseille Cedex 03.
e-mail : mfloquet@newsup.univ-mrs.fr

1. INTRODUCTION

In ancient sedimentary series, it is rare to find all components of resedimented units from their proximal pole up to their distal ones. The main reasons are that : 1) such units develop widely while it is uncommon to have available outcrops of their whole extent and 2) the depositional areas of these units often pertain to orogens where sedimentary series are folded and faulted and consequently very discontinuous so that it is difficult to reconstruct geometries and anatomies of resedimentations.

But carbonate resedimented units, visible in their whole extents, exist in Middle Turonian *pro parte* to Early Coniacian series of South-Provencal Basin (SPB). Detailled analysis of one of these units, dated of the Turonian-Coniacian boundary, allows us to defined its exact geometry and anatomy, and subsequently to determined more easily the controlling factors of its genesis. The best knowledge of such a unit could make of it a geological model useful for subsurface exploration, as it may be a potential reservoir.

2. OBJECT

During Middle Turonian to Early Coniacian times, SPB was narrow and E-W elongated and probably formed the northeastern closure of the marginal Lion Basin *sensu* Stampfli (1993). It was linked to the northern border of the Pyreneo-Provencal Rift which connected the Atlantic oceanic domain to the west and the Valaisian one to the east (figure 1). A carbonate platform (CPF) developed to the north of SPB while a Massif was emerged southwards (figure 2). Two kinds of deposits occured in SPB : autochtonous and allochtonous. The autochtonous deposits are quartzose calcarenites that formed under mainly W-E trending currents in circalittoral environments of lower shoreface to upper offshore. Allochtonous deposits are, on one hand, terrigeneous resedimentations of deltaic foresets and bottomsets coming from the southern Massif and, on the other hand, carbonate resedimentations that originated from the northern CPF (Hennuy & Floquet, 2000).
Five carbonate resedimentations, called RSC1, 2, 3, 4 and 5, are evolutive gravity flows, each of them including slope breccias, mass-flows and turbidites. In this paper we analysed only RSC3 because it is the most representative of all units as it shows the maximum of evolutive gravity flows components, in the same way than Shanmugam et Moiola synthetic sketch (1995, fig.2, p.480).

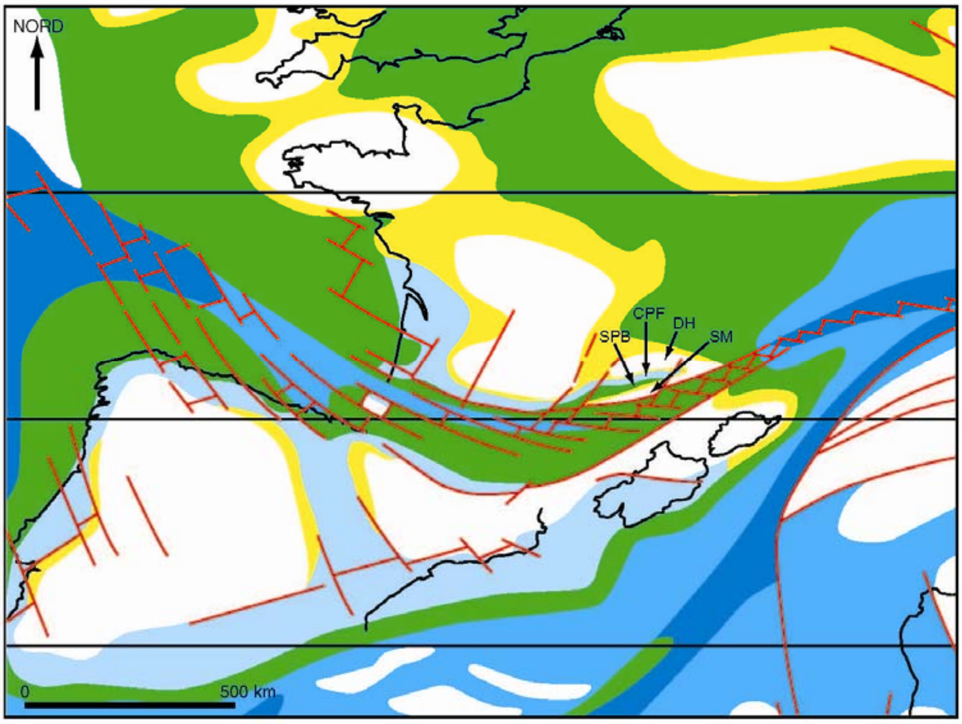

Figure 1 : Paleogeographic map of Southwestern Europe during Latest Turonian times. White : lands; yellow : coastal (mainly terrigeneous); light blue : carbonate platforms; green : outer shelf; medium blue : deep marine; dark blue : oceanic crust; CPF : South Provencal Carbonate Platform; SPB : South Provencal Basin; DH : Durancian High; SM : Southern Massif. Interpreted and drawn from Stampfli (1993) and Philip & Floquet (2000).

3. GEOMETRY

RSC3 crops out particularly in the BSP northern part, at CPF border along an almost continuous belt of about 25 km long from the east to the west and 0 to 500 m wide from the north to the south, *i.e.* over about 3.5 km^2. As it is 20 m thick in average (maximum 25 m), its outcropping volume reaches 0.07 km^3.

Local outcrops of RSC3 exist in the BSP southern part (Massif du Soubeyran southwest and Mont Caumes southeast) so that RSC3 deposited likely everywhere in SPB (figure 2). In this case, its calculated volume should be of about 3 km^3.

4. ANATOMY

RSC3 shows 4 distinct facies from the base to the top : 1) an unorganized or chaotic coarse breccia (0 to 20 m thick), 2) an organized breccia (3 to 15 m thick), 3) quartzose and glauconitic calcarenites (5 to 10 m thick) and 4) calcisiltites (0 to 1 m thick). These 4 facies grade vertically and lateraly from one to another one (figure 3).

Vertical organization

1) The unorganized and coarse breccia is very heterometric and polygenic. Its components are essentially limestones coming from CPF, except some quartzose, glauconitic and calcarenitic elements concentrated at the base and reworked from the underlying autochtonous unit.

The components originating from CPF include olistoliths ranging from very coarse block and exceptionally fine slab, to boulders and granules, according to Blair & McPherson classification (1999). All components have a random arrangement within the matrix. This latter is made of quartzose and glauconitic calcarenites which comprise microfauna typical of circalittoral environments.

2) The components at the top of unorganized breccia show a crude fining upward and thus pass to the organized breccia facies. This one is arranged in 2 to 4 depositional sequences, each of them coarsening up at its base and then fining up and 70 to 80 cm thick. These sequences are amalgamated in a fining up and thining up greater single sequence.

3) The quartzose and glauconitic calcarenites, in which the CPF calcareous grains dominate, are stacked in fining up and thining up beds separated by thickening up (0.1 up to 2 cm) marly and silty layers, so that they form a fining up and thining up sequence.

4) The fining upward of the calcarenites leads to the calcisiltites facies which contains some fine quartz, coaly plant remains, numerous sponge spicules and planktonic foraminifera. It shows horizontal laminations at its base and wavy laminations of asymetric current ripples (1 cm amplitude and 8 cm wavelenght). The first biological tracks appear in these calcisiltites.

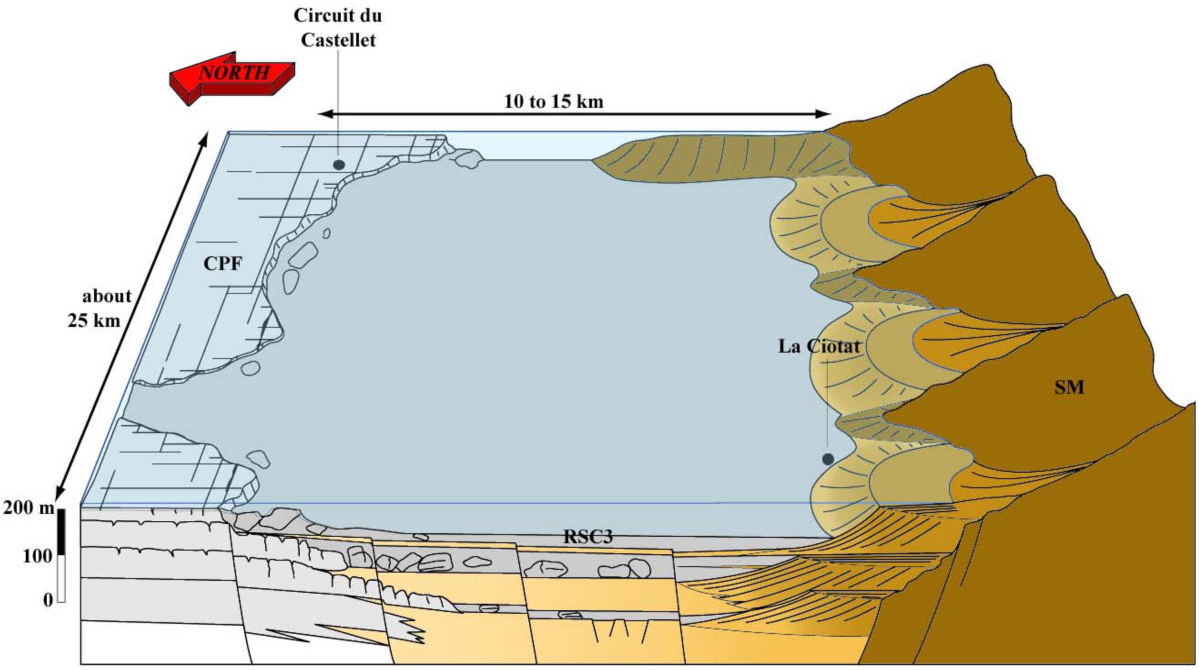

Figure 2 : Paleoenvironmental reconstruction of SPB at the time of RSC3 deposition.

Lateral organization

RSC3 exhibits an overall fining as well as better sequential arrangement from its northern proximal pole to its southern distal pole. The unorganized coarse breccias constitute 80% of RSC3 volume in the proximal pole for 30% in the distal one. Most olistoliths and the biggest ones are located directly against a scarp which constitutes the CFP border. At the opposite, the thickest development of calcisiltites is situated towards the distal pole.

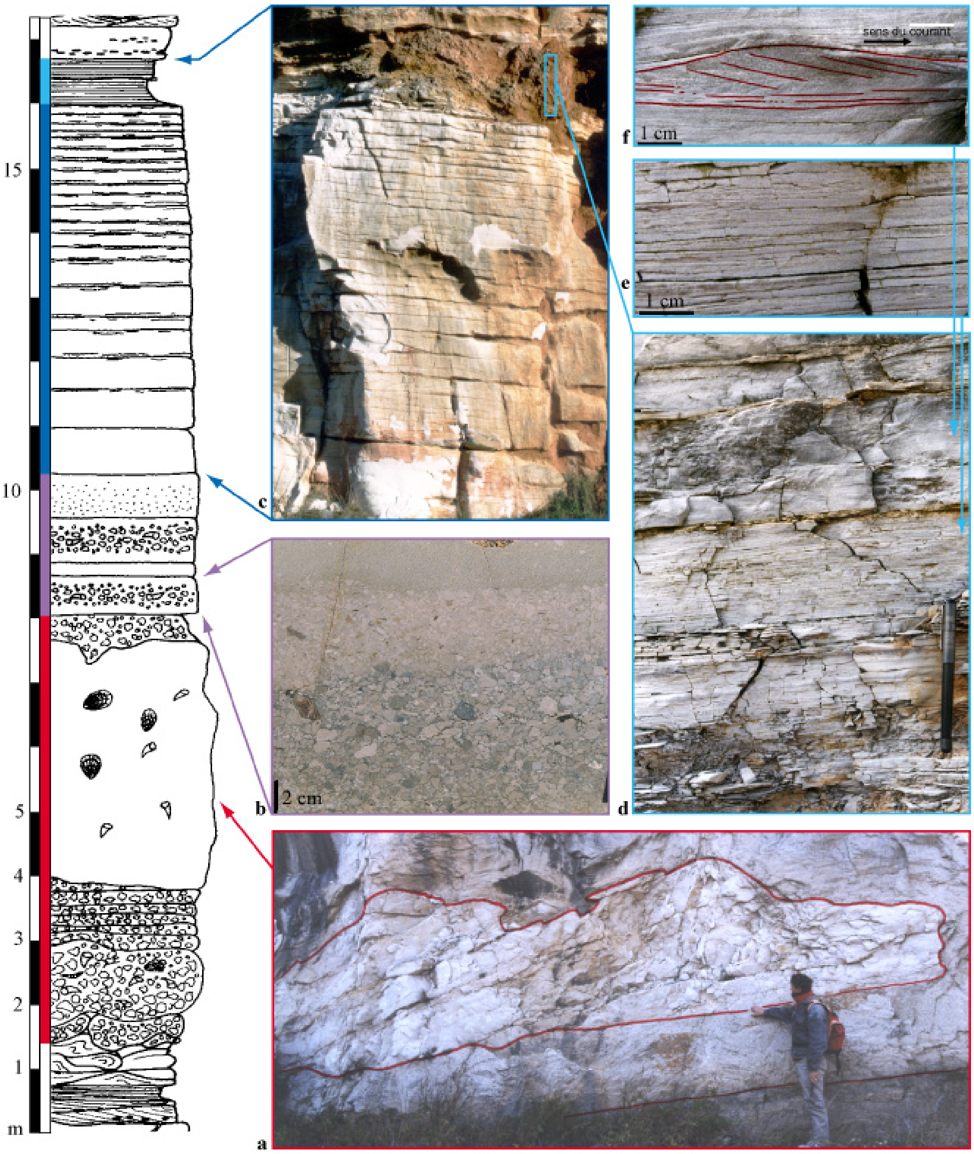

Figure 3 : Typical section and photographs of the 4 facies of RSC3 evolutive gravity flow. a) underlined in red: the unorganized breccia including an olistolith; b) underlined in mallow : the organized breccia; c) underlined in dark blue : the fining up and thining up horizontally laminated calcarenites; d) to f) underlined in green : the laminated calcisiltites with details of the lower horizontal laminations and of the upper ripple laminations. a) forms the basal debris-flow and b) to f) constitute the megaturbidite.

5. DEPOSITIONAL PROCESSES

RSC3 geometry and anatomy correspond to the evolution of a gravity flow according to several processes.

Along the CPF scarp, the unorganized breccia, probably accumulated in submarine environment, is a typical slope deposit (slope apron). The olistoliths, just detached from CPF, settled after sliding on the slope. The other components deposited after collapse and fall down.

Distally, the unorganized breccia is regarded as a result of mass-flows (clast supported cohesive debris-flows) that originated from the slope deposit. Slumps are very rare and restricted to soft sediments, while most calcareous components were already hardened before remobilization.

Each sequence of the organized breccias is considered as a high density turbidite. Its coarsening up base is a result of a very concentrated laminar flow. Its fining upward main part is a result of a less concentrated turbid current in which elements were transported in suspension (Postma *et al.*; 1988).

The fining and thining up calcarenites are regarded as deposits from laminar current following turbid surges. The lack of bioturbation between each simple depositional sequence (one fining up calcarenitic bed plus one thin marly layer) indicates how the succession of turbid surges and the stacking of turbidites occured quickly.

The calcisiltites are deposits of ripple tractive currents behind the turbid surges. Biological tracks indicates a sedimentation slowing down.

The stacking of the organized breccia, calcarenites and calcisiltites constitutes a Bouma sequence, restricted to its three basal terms *i.e.* the fining up Ta, the parallel laminations bearing Tb and the ripple laminations bearing Tc. This Bouma sequence, 15 m thick in average, and spread over the whole SPB can be called megaturbidite.

6. CONTROLLING FACTORS

Carbonate factory

The 3 km^3 calculated volume of RSC3 of which 90% of components come from CPF, the 20 m in average estimated thickness of RSC3 (maximum thickness of olistoliths), the 30 km known lenght of CPF, imply that the width of CPF reached at least 5 km. Such a CPF could develop easily in the concerned time span (within the Neptuni Zone, of 1.4 My duration according to Gradstein *et al.*; 1995) and according to the high carbonate production rate thanks to the rudists and other benthonic organisms proliferation in subtropical warm conditions.

SPB topography

RSC3 geometry and anatomy are defined by 1) the basin narrowness which impeded the resedimentation to spread out, this explaining the thickness, 2) an adequate depth (estimated at 100 m), 3) the northern bordering scarp which provided the olistoliths, 4) the deltaic foresets of the southern border which had constrained the megaturbidite to wedge out.

Tectonics

Tectonics probably originated :

1) the initiation of gravity-flows owing to seism and resulting in RSC3, so that this latter is called seismobreccia in the proximal pole and seismoturbidite (*sensu* Mutti *et al.*, 1984 and Shiki *et al.*, 2000) in the distal pole;

2) the creation and play of CPF scarp by faulting or flexuration;
3) the remobilization of RSC3 in the form of slumps and olistoliths in the distal pole.

Relative sea level changes

An initial relative sea level lowstand probably led to CPF emersion and to the preparation of detrital material. Then, a relative sea level rise related to tectonic subsidence induced the reworking of this material and the deposition of RSC3 in SPB.

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