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Submarine Orogenic Front Forming Inside Foredeep Basin: The Control of the Salsomaggiore Anticline on the Middle Miocene Sedimentation (Northern Apennines, Italy)

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During the formation of the Northern Apennines collisional orogen, an Oligocene-Miocene submarine fold and thrust belt, with the associated foredeep and wedge-top basins, were forming; these basins were filled by sediment-gravity flows mainly sourced from emerged alpine mountain chain to the north and minor sources from the south (Fig. 1).

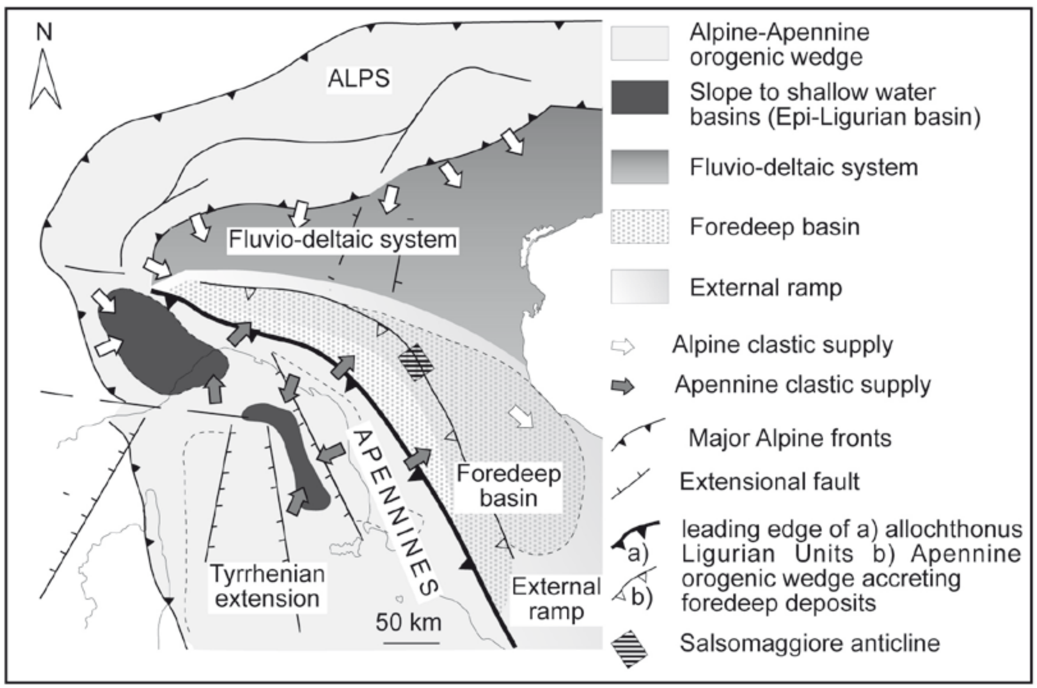

Fig.1: Paleogeographic reconstruction of middle Miocene northern Apennine foreland basin. (Modified after Mutti et al., 2002)

During middle Miocene, the Salsomaggiore anticline was forming at the leading edge of the Apennine submarine orogenic wedge (Fig. 1). In fact, the present days and outermost Cortemaggiore front (Fig. 2 upper left corner) started to form in late Miocene (Toscani et al., 2006; Artoni et al., 2007 and reference therein); whereas, new field evidences suggest that the Salsomaggiore front was present and active during middle Miocene. Thus, the middle Miocene Salsomaggiore front can be considered a divide between foredeep basin to the northeast and wedge-top basin to the southwest. In late Miocene, the anticline was buried underneath allochthonous units made of (Fig. 2): 1) tectonically stacked Ligurian units (remnants of the ocean basin and oceanic accretionary prism formed since Cretaceous to Paleogene) and epi-Ligurian shelfal to shallow water deposits of late Eocene to Messinian wedge-top basins; 2) a chaotic unit that reworks Ligurian and epi-Ligurian units and that was emplaced during the Messinian (intra-Messinian chaotic unit - IMCU) (Artoni et al., 2004). Afterward, the allochthonous units were eroded away in response to the progressive shortening and uplift; then, the frontal structures of the Northern Apennines orogenic wedge emerged during the Pleistocene. In the Salsomaggiore area, the erosion exhumed the middle Miocene sand-rich deposits that now crop out in the footwall of a tectonic window (Fig. 2a) and on the southwestern limb of the Salsomaggiore anticline (Fig. 2b).

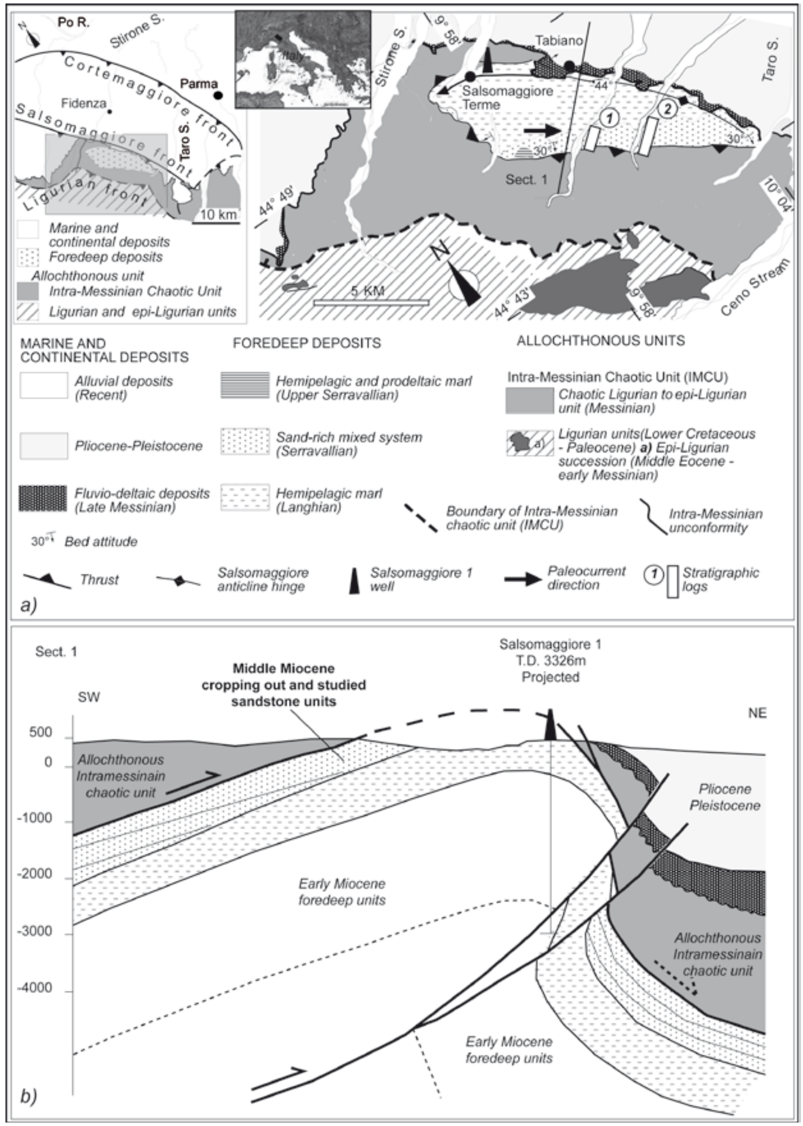

Fig. 2: a) Geological sketch map of the Salsomaggiore tectonic window and Salsomaggiore anticline in the footwall. (modified after Artoni et al., 2004) b) Cross section across the Salsomaggiore tectonic window.

The Salsomaggiore anticline is a fault-propagation fold (Toscani et al., 2006, Artoni et al., 2007; Picotti et al., 2007) that constitutes a 50km long arcuate front; the major structure of the Emilia Apennine foothill. The SW-dipping thrust does not emerge and the thrust's tip is around 3 km depth with imbricate-splays that both affect and are sealed by younger Pliocene-Pleistocene marine and continental deposits. The thrust prosecutes to around 8 km depth and it involves Mesozoic carbonate rocks. In the Salsomaggiore tectonic window, the footwall Salsomaggiore anticline crops out as an upright open anticline, while overturned and folded Miocene rocks are reported in public well (Salsomaggiore 1 T.D. 3326m); deformations ahead of the thrust's tip are very often represented by cropping out backt-hrusts, on the forelimb, and extensional faults, on the backlimb.

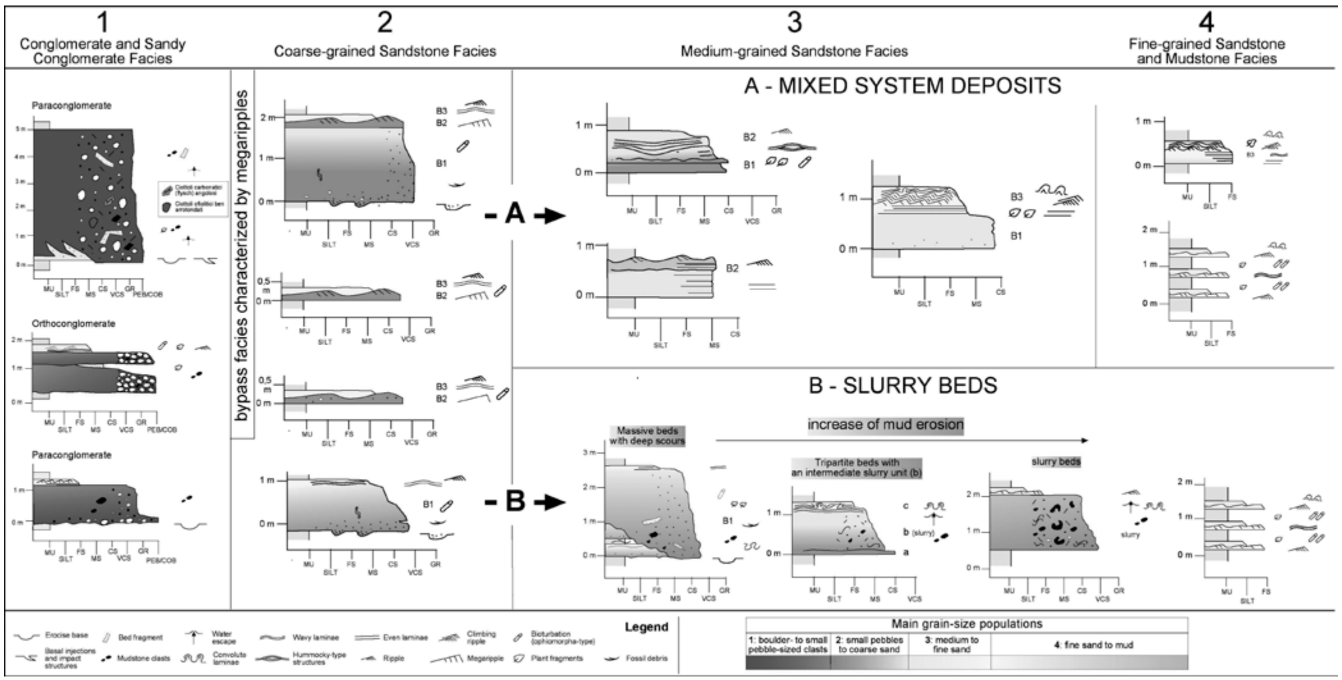

Fig. 3: Facies tract of mixed system deposits (A) and slurry beds (B) in Serravallian sand-rich unit of Salsomaggiore anticline. See text for more details.

On the southwestern limb of the Salsomaggiore anticline, Serravallian sandstone bodies crop out and form a wedge that is 800m thick, to the SE, and thins out to zero toward NW. A detailed stratigraphic and sedimentological analysis has been and is being carried out inside this sedimentary wedge. The first results of this study, based on the measuring of two stratigraphic logs for about 700m, reveal that the wedge has a sharp and unconformable lower contact onto the underlying Langhian hemipelagic marls; locally, onlap surface can be observed at outcrops. Then, this sedimentary wedge has an overall coarsening upward trend; six sand-rich, mainly massive sandstone units become three toward NW confirming the unconformable onlapping relationships. The Serravallian sand-rich deposits are characterized by immature massive sandstone in which hummocky-type structures, shell debris and ophiomorpha-type bioturbations can be recognized (Fig. 3). These sedimentary characteristics, together with the geological setting, allow to interpret Serravallian sand-rich deposits as mixed systems type B (sensu Mutti et al., 2003 their fig. 10), i.e. transitional deposits between fluvio-deltaic and turbidite systems characterized by immature, marginal and poorly efficient turbidite-like systems formed seaward of but adjacent to feeder delta complexes. However, only within the more distal and downcurrent log 2 (Fig. 2), it appears tripartite beds with an intermediate slurry or debrite units, i.e. silty and/or muddy sandstone with poor sorting, often with liquefaction structures and mudstone clasts (Fig. 3B). These types of beds, typical of distal depositional elements, have been always interpreted as being related to the progressive mud erosion occurring upcurrent (Ricci Lucchi & Valmori, 1980 and reference therein). Recently, high resolution stratigraphic and sedimentological studies performed by Muzzi Magalhaes and Tinterri (2009) in the Marnoso-arenacea (Langhian-Tortonian, Northern Apennines) show clearly that the debrite/slurry beds mainly occur inside stratigraphic units deposited close to intrabasinal and structurally-controlled highs and depressions. These morphological features of the sea bottom create slope gradient changes that favour both decelerations and mud erosion; both two processes have to be invoked for the formation of the slurry beds. Consequently, type B mixed deposits and slurry/debrite beds could be considered expressions of two different degrees of basin confinement related to tectonic control (Tinterri & Muzzi Magalhaes, 2009).

The preliminary results of the work in the Salsomaggiore area are in agreement with the results of the studies carried out in the Marnoso-arenacea with a similar basin settings. Therefore, we can conclude that the middle Miocene Salsomaggiore anticline was a submarine ridge at the front of the Apennine orogenic wedge (Fig. 1), a divide between wedge-top basin and deeper foredeep basin. The ridge was created by the growth pulses of the anticline and it seems to affect the deposition of the sand-rich bodies that have to flow on a modifying bathymetry: after the folding event, debrites/slurry beds were deposited down-current and away from the anticline's hinge, confirming further that bathymetric highs and lows are needed to favour the formation of these types of beds. On the contrary, when folding pulses are absent and sea bottom is relatively flatter, typical mixed systems deposits filled structurally confined wedge-top basin and they could spread over the anticline's hinge zone. The ongoing work will also be addressed to explain the observed sedimentary facies tracts as a response of variable flow's efficiency with respect to the basin's geometries.

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