C-21 **CONTROL OF THRUST PROPAGATION ON TURBIDITE SEDIMENTATION**

ANDREA ARTONI, DAVIDE DI BIASE, EMILIANO MUTTI

and ROBERTO TINTERRI

*Parma University, Dipartimento di Scienze della Terra,
Parco Area delle Scienze 157/A, 43100 Parma, Italy*

In foreland basins, the deep and narrow trough which forms adjacent to the thrust front is commonly termed foredeep, and, until the orogenic wedge is not significantly uplifted and emerged, the trough is characteristically filled in with axial turbidites sourced from fluvio-deltaic systems located in emerged areas of adjacent orogens where substantial tectonic uplift has already occurred. In such basins, turbidites form huge sedimentary prisms exposed for hundreds of kilometers parallel to local structural axes as, for example, in the Apennines, the western Alps, the Carpathians, the Pyrenees, the Hellenides, and in many other orogenic belts worldwide. The concept of turbidites (Kuenen and Migliorini, 1950), the Bouma sequence (Bouma, 1962) and early facies and fan models (Mutti and Ricci Lucchi, 1972) were born in basin-fills of this kind.

During their early stages of development, foredeeps simply act as receiving basins without significant sediment contribution from the inner thrust front and the outer ramp which remain essentially submarine. Slumps, slides and olistostromes derived from these flanking features are the only significant contributions to the fill of the foredeep, especially along its inner margin. As long as the orogenic wedge remains essentially submarine and turbidites are thus derived from extra-wedge sources, foredeep turbidite sedimentation is primarily characterized by elongate depositional systems of basinwide extent composed of three basic elements: (1) large-scale submarine erosional features that act as conduits of turbidity currents, (2) sandstone lobes formed at the exit of these conduits, and (3) finer-grained basin-plain deposits formed in the distal part of the basin. Detailed correlation patterns established for a number of systems of this type show that individual turbidite beds and packets of beds are characterized by a remarkable sheet-like geometry along the axis of the basin over distances in excess of 100 km. Facies and inferred processes of these systems in their along-basin-axis expression have been amply discussed elsewhere (e.g., Mutti et al., 1999; Mutti and Tinterri, this volume).

In this paper, we will mainly focus on turbidite facies distribution patterns of foredeep basin-fills as observed in a general cross-current direction and on the overall vertical stacking pattern of these turbidite successions as related to thrust propagation with time. For reasons of convenience, the schemes of Fig. 1 and the following discussion focus on transects of foredeep basins dominated by the deposition of sandstone lobes.

As shown in Fig. 1, three broad facies associations define the fill of a foredeep basin in a cross-section perpendicular to the structural axis of the basin and therefore to the overall paleocurrent direction. The inner facies association occurs in the general thrust front region and is characterized by thick-bedded and massive sandstone facies, commonly amalgamated or containing thin mudstone partings. These sandstone bodies are generally characterized by a lenticular geometry due to their deposition in structural depressions or in broad channels, and are associated with slope mudstones, chaotic deposits and thin-bedded and fine-grained turbidites. The axial facies association, which represents the volumetrically predominant type of sediment in the fill of the foredeep is characterized by cyclically stacked sandstone lobes with remarkable tabular geometry. The outer facies association is expressed by the onlap of the axial sandstone lobes against the flexural ramp. We interpret these facies associations as primarily related to the asymmetric cross-sectional geometry of the basin and therefore to the control exerted by the local topography on turbidite sedimentation.

On a considerably smaller scale, and primarily on the basis of laboratory experiments and numerical modeling, Kneller (1995) has emphasized the importance of topography in producing variations in the flow of turbidity currents, causing flow acceleration (accumulative flows) or deceleration (depletive flows) in space. On a much larger scale, foredeep basins provide a spectacular and very convincing example of this kind of control. In the inner foredeep zones, the complex local topography produced by thrusting and faulting generates reflections, deflections, and collapse of turbidity currents and particularly forces their dense basal portions (cohesionless granular flows of Mutti et al., 1999) to deposit thick-bedded massive sandstones. Locally, flow acceleration may develop along topographic constrictions resulting in extensive channelling. These processes control turbidite deposition near the thrust front and in more internal, thrust-generated marginal basins still fed from the main axial system. The axial foredeep zones can be viewed as primarily dominated by deposition from turbidity currents flowing across an essentially relief-free basin floor. In these zones, turbidite systems display characteristic cyclic stacking patterns expressed at different hierarchical scales and essentially recording similarly cyclic processes (tectonism, relative sealevel variations, and climate) in the source areas (see Mutti et al., 1999 for details). The outer foredeep zones record the interaction between axially-flowing turbidity currents and the gently sloping flexural ramp. Abrupt facies changes and onlap terminations against the bounding slope are the most characteristic features produced by this interaction.

Fig. 2 shows how the progressive thrust propagation toward more external regions controls the overall vertical stacking pattern of foredeep turbidites. Forward thrust propagation

Fig. 1. Structural and depositional setting of a foreland basin. The transect crosses the foredeep basin dominated by the deposition of turbidite sandstone lobes. Facies associations are largely controlled by basin topography.

essentially results in an overall thickening-upward trend produced by the concomitant migration of the inner foredeep zone toward the basin axis with time. However, periods of tectonic relaxation and enhanced subsidence, as well as out-of-sequence thrusting, may produce more complex stacking patterns in which inner zones may locally recede, being overlain by "transgressive" axial deposits (see Fig. 1).

The foredeep sedimentation comes to an end when the uplifted orogenic wedge is sufficiently emerged to provide a source for the development of laterally-derived turbidites and associated fluvio-deltaic systems. Laterally-derived turbidites are usually deposited at shallower depth than that of the former foredeep. Clearly, the development of models to predict sandstone distribution patterns in turbidite foredeep basins is a challenge for future research in the circum-

Fig. 2. Progressive thrust propagation toward the outer zone (A) and related vertical stacking pattern of foredeep turbidites (B).

Mediterranean region. This research will necessarily involve an integrated approach combining detailed stratigraphic, sedimentological and structural analyses.

References

- Bouma A.H. (1962) - *Sedimentology of some flysch deposits, a graphic approach to facies interpretation*. Elsevier Co., Amsterdam, 168 pp.
- Kneller B. (1995) - *Beyond the turbidite paradigm: physical models for deposition of turbidites and their implications for reservoir prediction*. In: A.J. HARTLEY and D.J. PROSSER (Eds), *Characterization of Deep Marine Clastic Systems*, Geol. Soc. Spec. Publ., **94**, 31-49.
- Kuenen Ph.H. and Migliorini C.I. (1950) - *Turbidity currents as a cause of graded bedding*. Journ. Geol., **58**, 91-127.
- Mutti E. and Tinterri R. (2000) - *Facies and processes of turbidite systems*. This volume
- Mutti E. e Ricci Lucchi F. (1972) - *Le torbiditi dell' Appennino settentrionale: introduzione all'analisi di facies*. Mem. Soc. Geol. It., **11**, 161-199.
- Mutti E., Tinterri R., Remacha E., Mavilla N., Angella S. and Fava L. (1999) - *An introduction to the analysis of ancient turbidite basins from an outcrop perspective*. A.A.P.G., Continuing Education Course Note Series, **39**, 61 pp.