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Kinematic reconstruction of a thin-skinned, deep-water fold and thrust belt: the case of the Outer Tuscan Nappe (Umbria, Italy)

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Fold-and-Thrust Belts occur worldwide in a variety of tectonic settings. Most of them develop in a deepwater environment (Deep Water Fold-and-Thrust Belts, DWFTBs), at both continental passive and active margins, driven by gravity (near-field stresses) and tectonic forces (far-field stresses) respectively.

Here we present a multidisciplinary geological study of the Outer Tuscan Nappe (OTN), an imbricate thrust system in the Northern Apennines of Italy, emplaced in Early Miocene times in deep water environment. Despite the wide scientific literature, the geometry and the kinematic evolution of the OTN were never reconstructed in detail. Furthermore, its total amount of shortening and then its shortening rate, were never measured and calculated through proper restoration techniques.

The OTN involves a 2000 m thick, Late Cretaceous-Tertiary "Tuscan" succession, consisting of arenaceous turbidites (Macigno Fm.), overlying a thick level of marls and calcarenites (Scaglia Toscana Fm.), which form the major basal décollement of the imbricate system. Along this basal décollement, the OTN overthrusts eastward younger turbidite units (Mt. Rentella and Marnoso-Arenacea successions).

In this study we interpreted a set of 2D seismic reflection profiles calibrated with a deep borehole, crossing transversally (WSW-ENE) and longitudinally (NNW-SSE) the OTN. To better constrain the interpretation, selected controls of key outcrops was performed, mainly aimed at reconstructing: i) the actual transport direction during the OTN emplacement; ii) the position of the subsequent, NNW-SSE trending, extensional faults dissecting the tectonic wedge; iii) the role of transversal faults, longitudinally segmenting the thrust system.

Combining the aforesaid data, we drew an integrated 20 km long geological cross section showing the internal geometry of the imbricate thrust system, down to the main basal décollement. The integrated section was successively restored in 2D using the software MOVE (Midland Valley).

The integrated section shows a thin-skinned deformation, where the basal thrust becomes progressively shallower from W to E, from a depth of about 5 km to 1 km. Correspondingly, the reconstructed OTN tectonic wedge is up to 5 km thick in its western part, and tapers progressively eastward: these values are consistent with previous estimates, based on thermal burial data. The total measured shortening of the OTN imbricate thrust system is about 43 km, including 19 km of internal imbrication and, at least, 24 km of horizontal ENE-ward transport along the basal décollement. To this, we have to add 13 km of passive transport caused by the subsequent deformation of the underlying units (e.g., Mt. Rentella and Marnoso-Arenacea successions). The total percentage of internal shortening is 42 % (measured as an average value between the Macigno and the Scaglia Toscana formations).

Finally, we discuss the possible role of gravity in the evolution of this DW-FTB, generated in convergent settings, in an early collisional stage. The OTN geometry (e.g., high taper angle, close-range internal thrusts) and the high percentage of shortening are not characteristic of an exclusively gravity driven DWFTB therefore we think it should be interpreted as a Type 2b DWFTB (exclusively far-field stress-driven) based on the Morley's DWFTBs classification.