ACTIVE FOLDING IN A SUBSIDING SEDIMENTARY BASIN: A CASE STUDY IN THE PO BASIN (Northern Italy)

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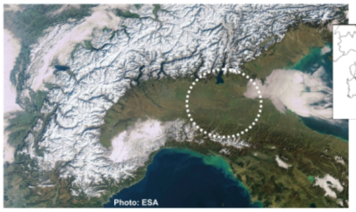
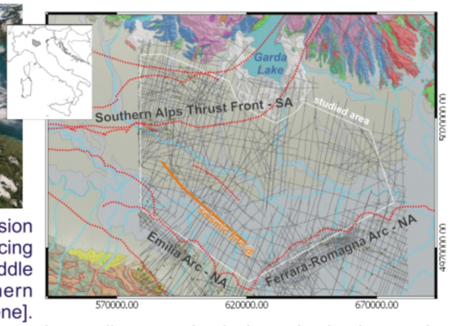
1 GEOLOGICAL FRAMEWORK





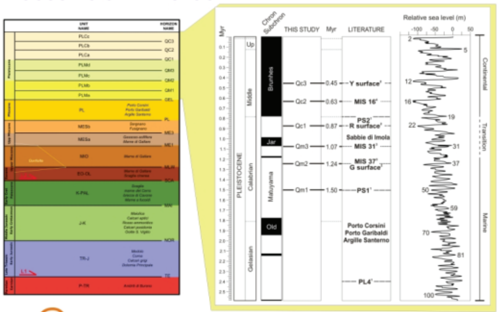
The Po Plain is the flat surface expression of the common foreland of two facing chains: the Southern Alps (SA) [Middle Eocene-Miocene] and the Northern Apennines (NA) [Oligocene-Pleistocene].
The most important tectonic phases can be easily recognized along the basin margins marked by the deformation and tilting of river terraces and of exposed syntectonic sediments; conversely their detection is particularly difficult in the central-distal part of the basin.

STRATIGRAPHIC SCHEME

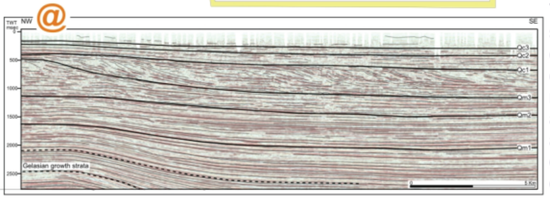
The stratigraphic scheme of the study area is based on the interpretation of a huge seismic dataset (12,000 km, provided by ENI S.p.A.), 136 well logs (●) and the correlation with the existing literature data that provide stratigraphic and magnetostratigraphic constraints.

During the Pleistocene the complex interaction of tectonic processes, sea-level fluctuations, climate changes, and sediment supply produced the filling of the basin with the progradation of the fluvio-deltaic system, from west toward east.

FOCUSING ON PLEISTOCENE



The shallowest and most recent part of the succession is characterized by a thickness ranging from a few hundred of meters up to 2 km and is made up of clastic deposits that recorded the last events of marine sedimentation in the basin; they are overlain by Quaternary deltaic and alluvial sediments deposited by the Po River and its main tributaries .



The prograding deltaic sedimentary wedge is characterized by clinoformal seismic reflectors that exhibit onlap and toplap geometries along the NA margin and downlap towards the depocenter .

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ACKNOWLEDGEMENT

GeoMol Assessing subsurface potentials of the Alpine Foreland Basins for sustainable planning and use of natural resources

The project GeoMol is co-funded by the Alpine Space Program as part of the European Territorial Cooperation 2007-2013. The project integrates partners from Austria, France, Germany, Italy, Slovenia and Switzerland. Further information on www.geomol.eu

Maesano F.E. & D'Ambrogi C.
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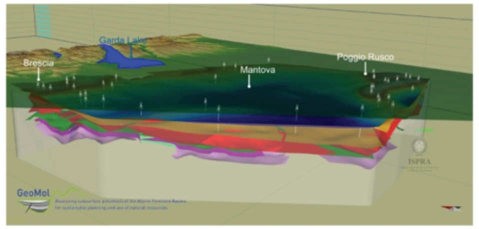
Italian Journal of Geosciences, 2015, doi: 10.3301/IJG.2015.17

RESEARCH TOPICS

A) Detect elusive syn-sedimentary folding signals related to compressive structures growing in general subsiding basins.
B) Discriminate sedimentary processes from regional signal of the foreland tilting and local tectonic signals.
C) Define a 3D modeling, decompaction and sequential restoration workflow to quantitatively analize the mutual relationships between folding and sedimentation.
D) Calculate the uplift rates of buried anticlines.

2 3D MODELING AND RESTORATION WORKFLOW

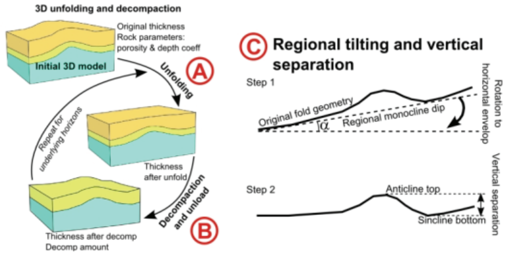


The methodological approach is based on the analysis of the 3D model built for the GeoMol Project that includes 15 horizons (top or unconformities) and more than 135 faults (thrusts and extensional faults).

The workflow consists of successive steps of unfolding and decompaction of the units bounded by unconformities mapped within the Pleistocene succession of the Mantova Monocline.
The aim of this methodology is to obtain a 3D picture of each horizon unaffected by the effects of sediment compaction and by the local and regional tectonic deformations recorded in the uppermost horizons.

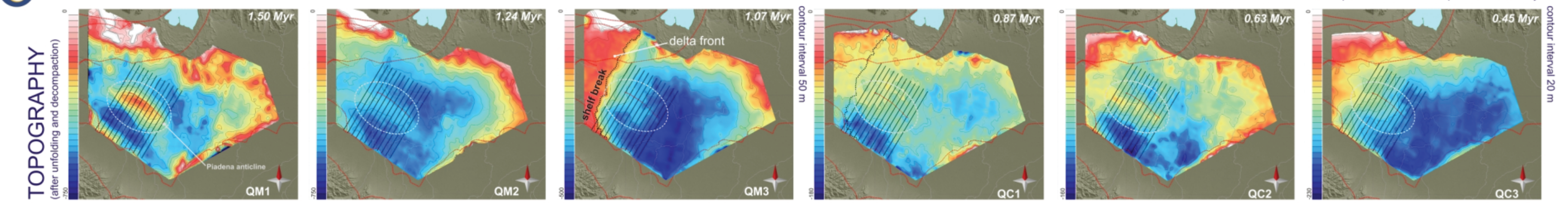
The procedure is subdivided into 3 steps:
A) Unfolding
B) Decompaction and unload
C) Removal of regional monocline dip

The maps of basin evolution and Pleistocene sedimentation rates are the results obtained after the first two steps.
Then the removal of the regional geodynamic signal related to the general flexure of the monocline has been considered to better analyze the evolution of synsedimentary tectonic features like growing anticlines (e.g. the Piadena anticline).

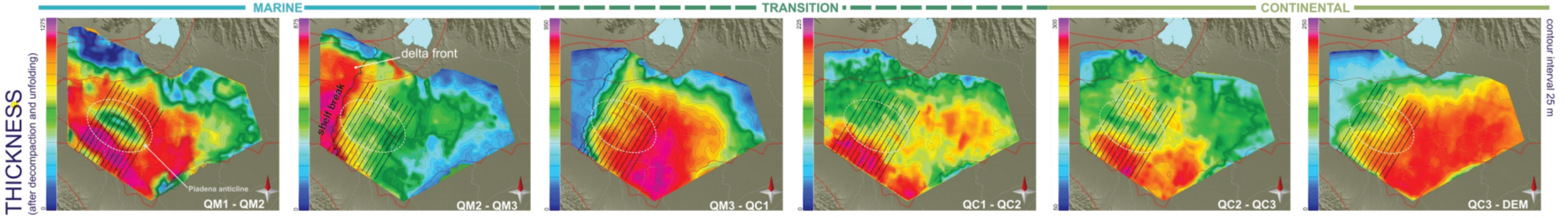


3 BASIN EVOLUTION & PLEISTOCENE SEDIMENTATION RATES

elevation values are not representative of the paleo bathimetry



MARINE — TRANSITION — CONTINENTAL



QM1 - QM2	QM2 - QM3	QM3 - QC1	QC1 - QC2	QC2 - QC3	QC3 - DEM
736.32	423.95 [W sector 111.94 - E sector 483.13]	428.31 [W sector 603.12 - E sector 389.21]	125.23	166.81	177.52

Average thickness metres (weighted mean)

SEDIMENTATION RATES CENTRAL PO BASIN

	Basin	W sector	E sector
Qc3-DEM	0.39 ± 0.05		
Qc2-Qc3	0.93 ± 0.16		
Qc1-Qc2	0.52 ± 0.11		
Qm3-Qc1	2.14 ± 0.21	0.56 ± 0.13	2.42 ± 0.22
Qm2-Qm3	2.49 ± 0.26	3.55 ± 0.33	2.29 ± 0.25
Qm1-Qm2	2.83 ± 0.19		

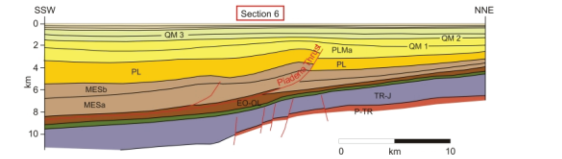
The sedimentation rates (mm/yr) are calculated from the average thicknesses

The average thickness values show a constant decrease from the Calabrian onward reflecting the general regressive trend of the sedimentary sequences related to the decrease of accommodation space and the progressive basin infilling.
Between QM3 and QC1 the complete infilling of the Central Po Basin changed the paleogeography of this area from a slope-to-basin to a coastal and continental shelf.

4 PIADENA ANTICLINE: COMPARISON OF TECTONIC AND SEDIMENTARY SIGNALS

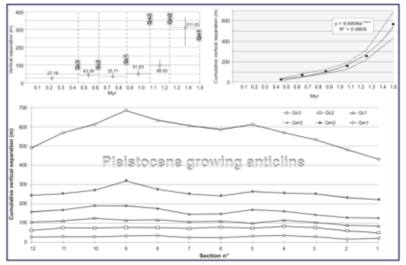
The Piadena anticline, a fault-propagation fold related to the Emilia arc activated in the Gelasian, represents a local positive signal (uplift) in a general subsiding context.

The thrust, NE verging, propagates in flat along a detachment inside the Miocene succession and forms a ramp in correspondence of a system of Mesozoic normal faults in the carbonatic succession. The thrust tip dislocates the base of Pliocene and Gelasian, but does not further propagates inside the Pleistocene succession.

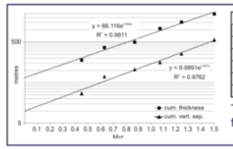


The ongoing activity of the fold during the Calabrian is recognizable thanks to the basin analysis: the QM1 horizon topography shows a clear anticline and its closures towards NW and SE; the thickness map QM1-QM2 indicates the presence of syntectonic growth strata.
The topographic evidences are still recognizable in the younger horizons, although less pronounced.

RESIDUAL VERTICAL SEPARATION



SEDIMENTATION vs UPLIFT RATE



	sedim rate (mm/yr)	uplift rate (mm/yr)
Qc3-DEM	0.40 ± 0.05	0.06 ± 0.05
Qc2-Qc3	1.04 ± 0.17	0.24 ± 0.12
Qc1-Qc2	0.54 ±0.11	0.15 ± 0.09
Qm3-Qc1	2.91 ± 0.25 #	0.26 ± 0.11
Qm2-Qm3	2.71 ± 0.28 #	0.58 ± 0.15
Qm1-Qm2	3.59 ± 0.21	1.20 ± 0.12

The sedimentation rates are calculated for the entire Piadena area or # sub-area.

12 sections, spaced 2.5 km, are obtained from the surfaces processed according to the steps A and B. In each section, for each restored horizon, the regional tilt toward SW is recovered by measuring the apparent dip angle (α) along the section and applying a rotation to reduce α to 0 (step C).
The obtained residual vertical separation gives a measure of the relative uplift related to the fold activity.
The vertical separation shows the maximum value in the Calabrian and then an exponential decrease.
The quantitative analysis on the sections highlights two relative maxima in the vertical separation (sec. 9 and 5) that can be interpreted as a clue for the possible segmentation of the thrust.
Despite the sediment supply is constantly one magnitude order greater than the vertical separation, our method allows to detect very weak folding signals and also to calculate uplift rates, from vertical separation values close to the resolution of the seismic profiles.

RESULTS

This methodological approach allows to discriminate and to have quantitative evaluation of both sedimentary and tectonic (folding) processes, also when very elusive.

A preliminary regional basin analysis (i.e. paleomorphology, sedimentation rates) is needed before approaching the study of folds, deemed to be active, located within the basin.

Active anticlines growth can be recognized and quantitatively analized also inside a general subsiding basin, using a 3D approach which take into account the differential compaction effects.