

# The response of periglacial landscape to Late Pleistocene active thrusting

Evidence at the Po Basin-Northern Apennines hinge (Lombardy, Italy)

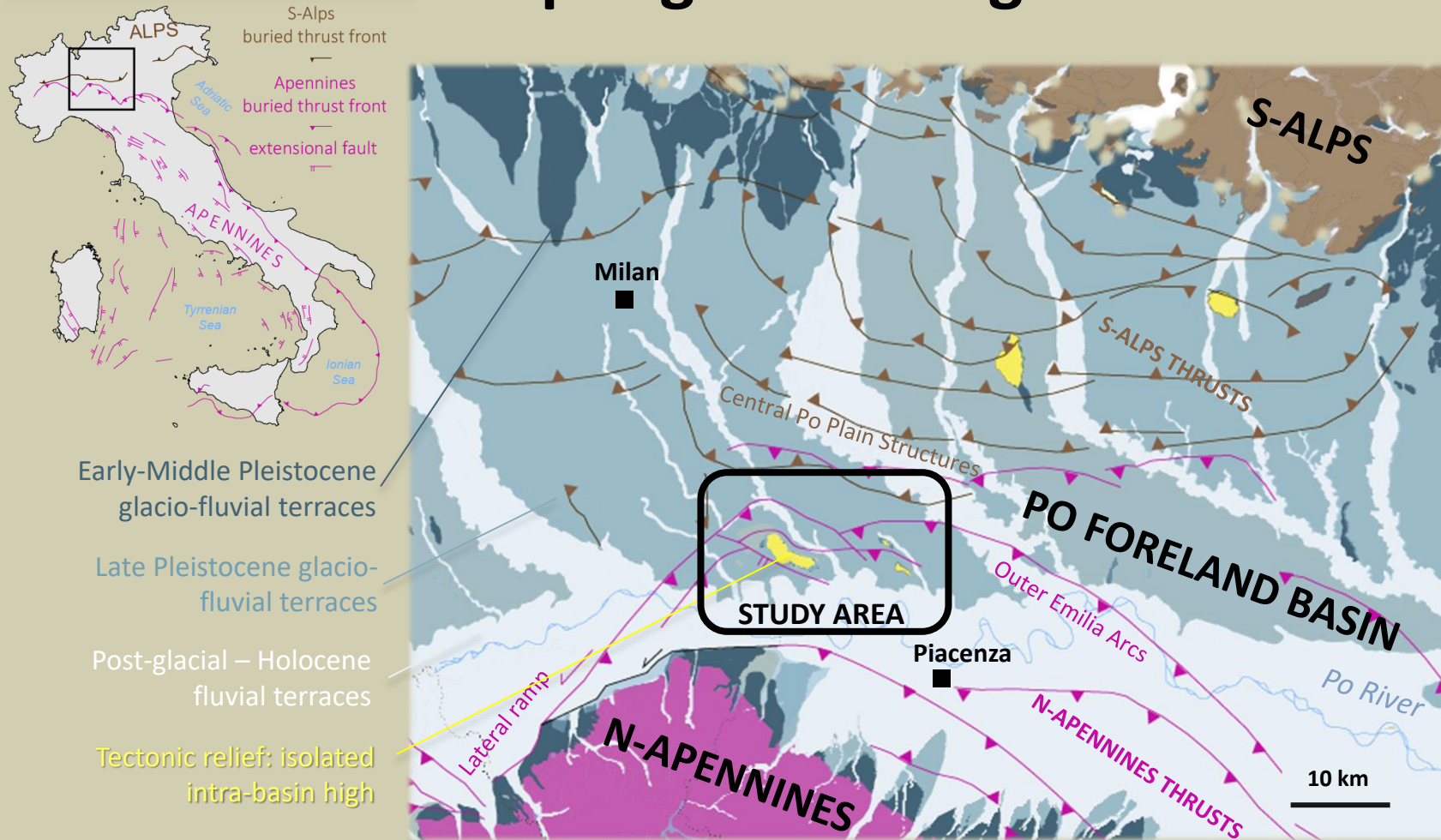
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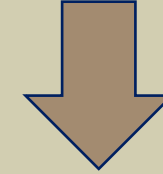




# The southern periglacial margin of the Po foreland basin



Climate-controlled sediment flux from the glaciated alpine side



**DEBATED:**  
Evidence of **Late Quaternary** tectonics on the **stratigraphic and landscape evolution?**



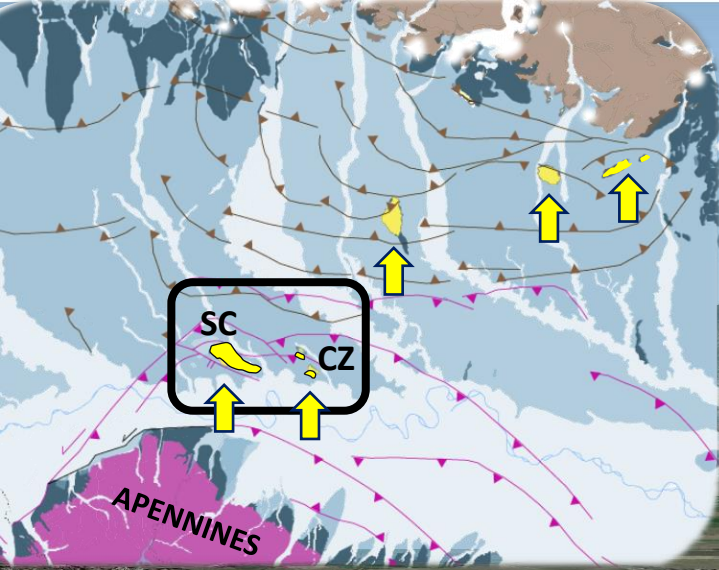
Polyphase Apennine northward thrusting

The palimpsest landscape and stratigraphic architecture of the Quaternary Po foreland basin record the tectonic pulses of the N-Apennines fold-and-thrust belt (the southern basin floor and active structural margin) and the glacial dynamics on the Alps (the northern basin floor and margin).

Deciphering the nature, hierarchy and timing of landscape-changing increments at the Po Basin-Apennines hinge helps to describe the Late Quaternary tectonic modulation of landscape response to glacial cycles.



# Key-sites: intra-foreland basin tectonic reliefs



ACTIVE MOUNTAIN RANGE

*Apennines*

QUATERNARY FORELAND BASIN

*Po Plain*

INTRA-BASIN TECTONIC RELIEF

*San Colombano high*

**Focus is on the culminations of Apennine ramp-folds,** the San Colombano (SC) and Casale-Zorlesco (CZ) isolated reliefs, which elevate above the terrace orders of the latest Pleistocene-Holocene plain.

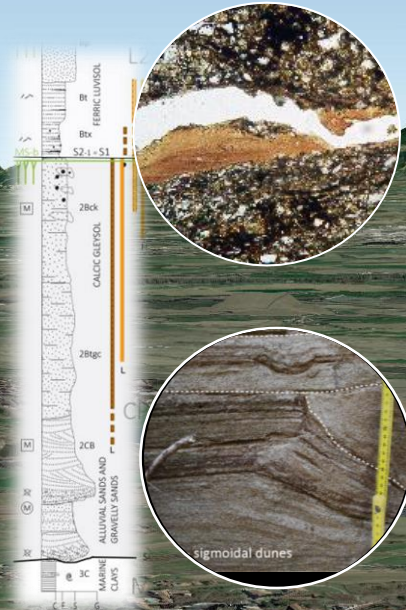
These selected key-sectors:

1) **expose** unconformities, morphological surfaces and stratigraphic units otherwise buried in the adjacent plain sectors; 2) show the involvement of Quaternary, alpine-sourced littoral, alluvial and glacio-fluvial succession in Apennine **folding and faulting**.

North



# Methodology: an integrated approach



1

Different-scale surveys:

- geomorphological
- stratigraphic
- structural
- sedimentological
- geopedological

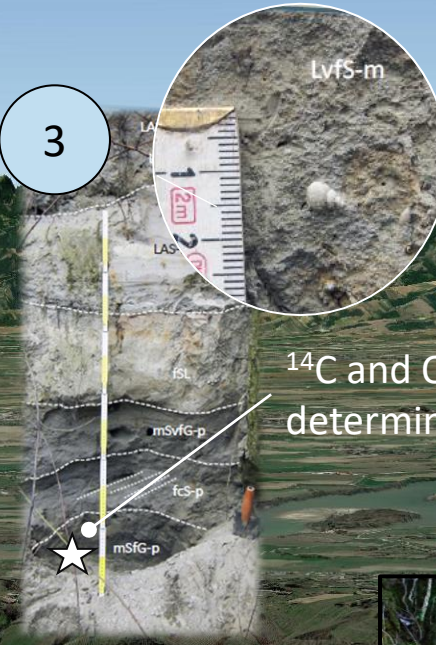
2

Morpho-structural analyses

3

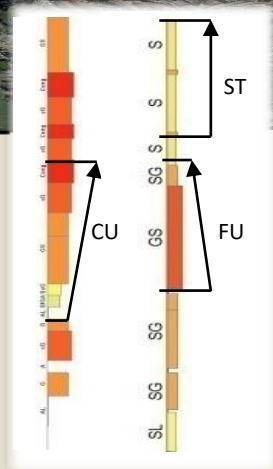
$^{14}\text{C}$  and OSL age determinations

> 120 outcrops



4

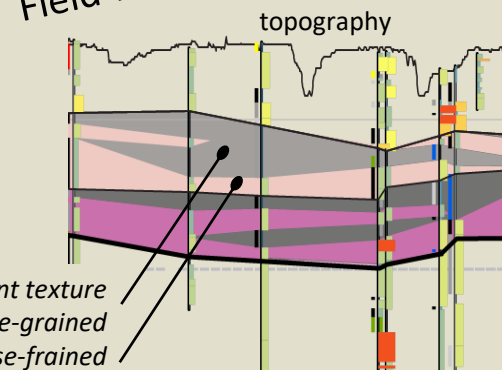
GIS-based digitization and normalization of borehole logs, based on ad-hoc built facies Code



5

Subsurface hierarchic correlation based on borehole logs and geophysical images

Sediment texture  
- fine-grained  
- Coarse-frained

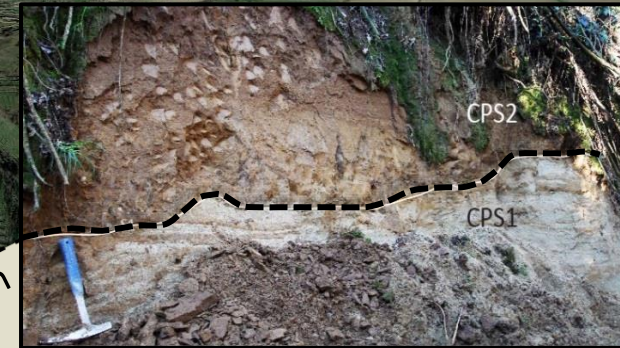


Field-based physical correlation

6

Data integration: incremental history of thrust-controlled periglacial landscape

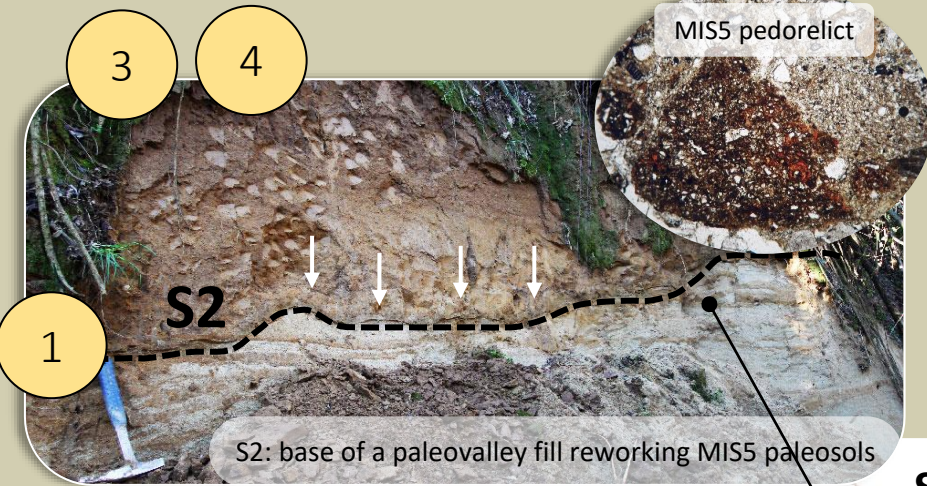
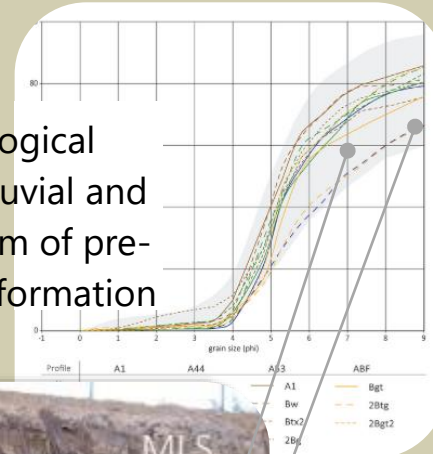
> 540 subsurface data





# Syndepositional tectonics

1) Location of unconformable stratigraphic vs. conformable morphological boundaries, 2) pinch-out and cross-cut relationships among glacio-fluvial and alluvial sedimentary bodies, 3) uplifted paleovalley fills, 4) cannibalism of pre-existing alluvial clastics, 5) colluvial wedges and 6) soft-sediment deformation structures.



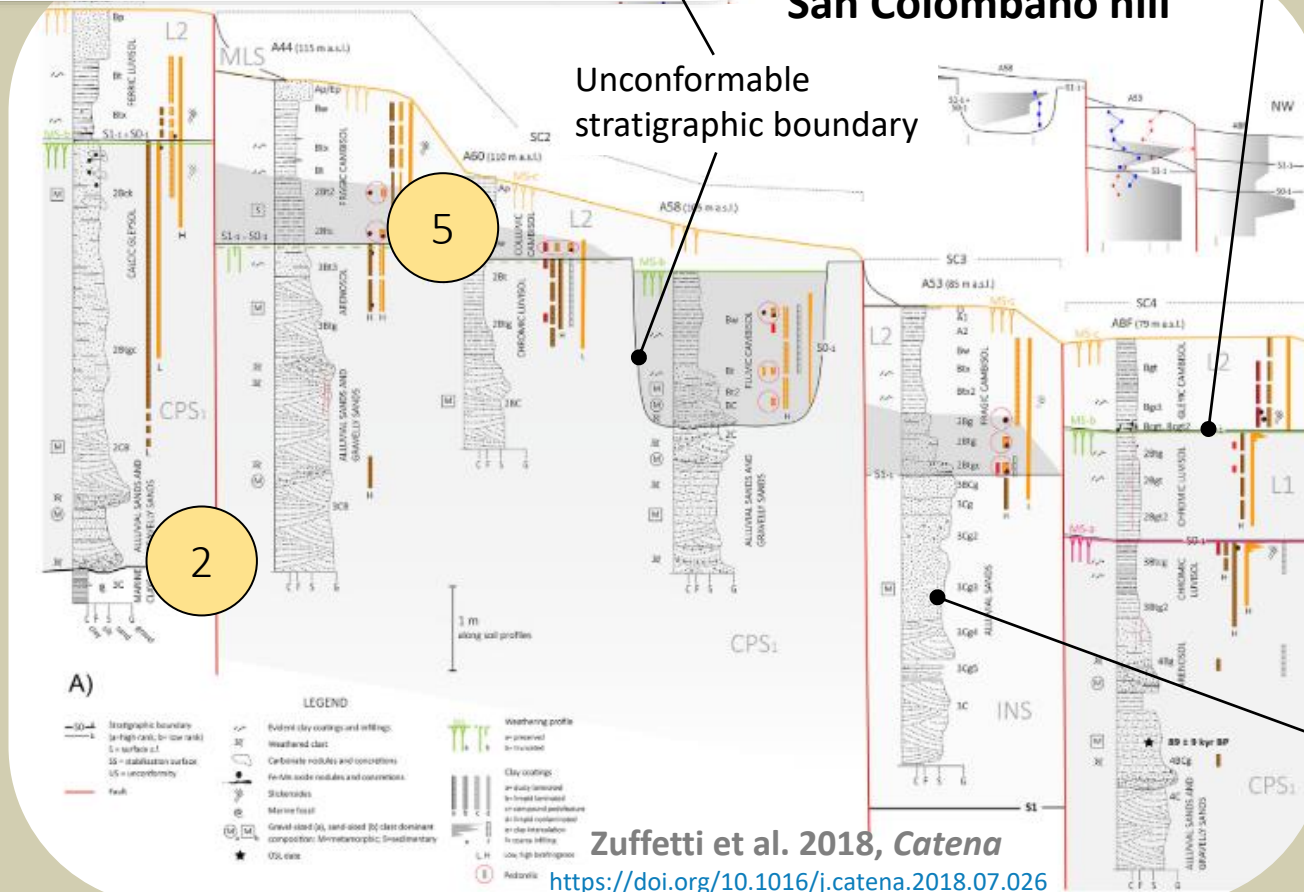
Conformable morphological surface



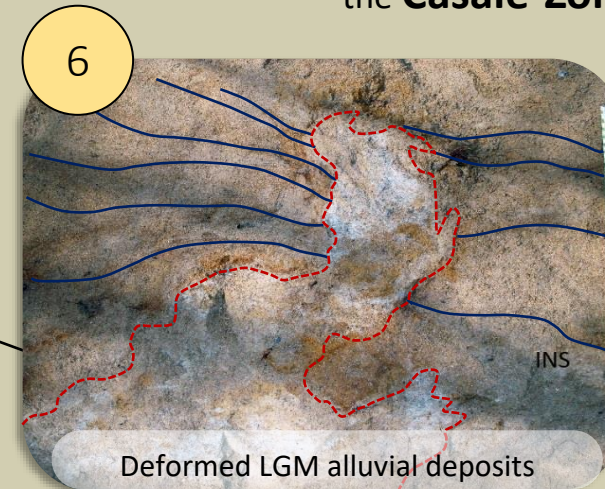
MIS2 and MIS4 loess deposits

## San Colombano hill

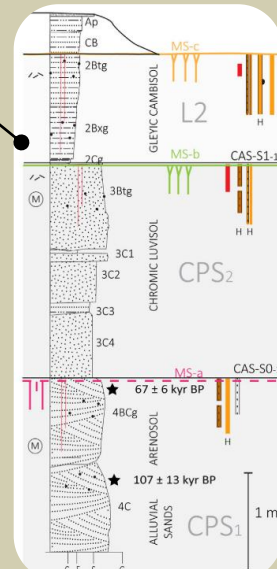
Unconformable stratigraphic boundary



Comparable evidence crop out at the **Casale-Zorlesco hills**



Deformed LGM alluvial deposits



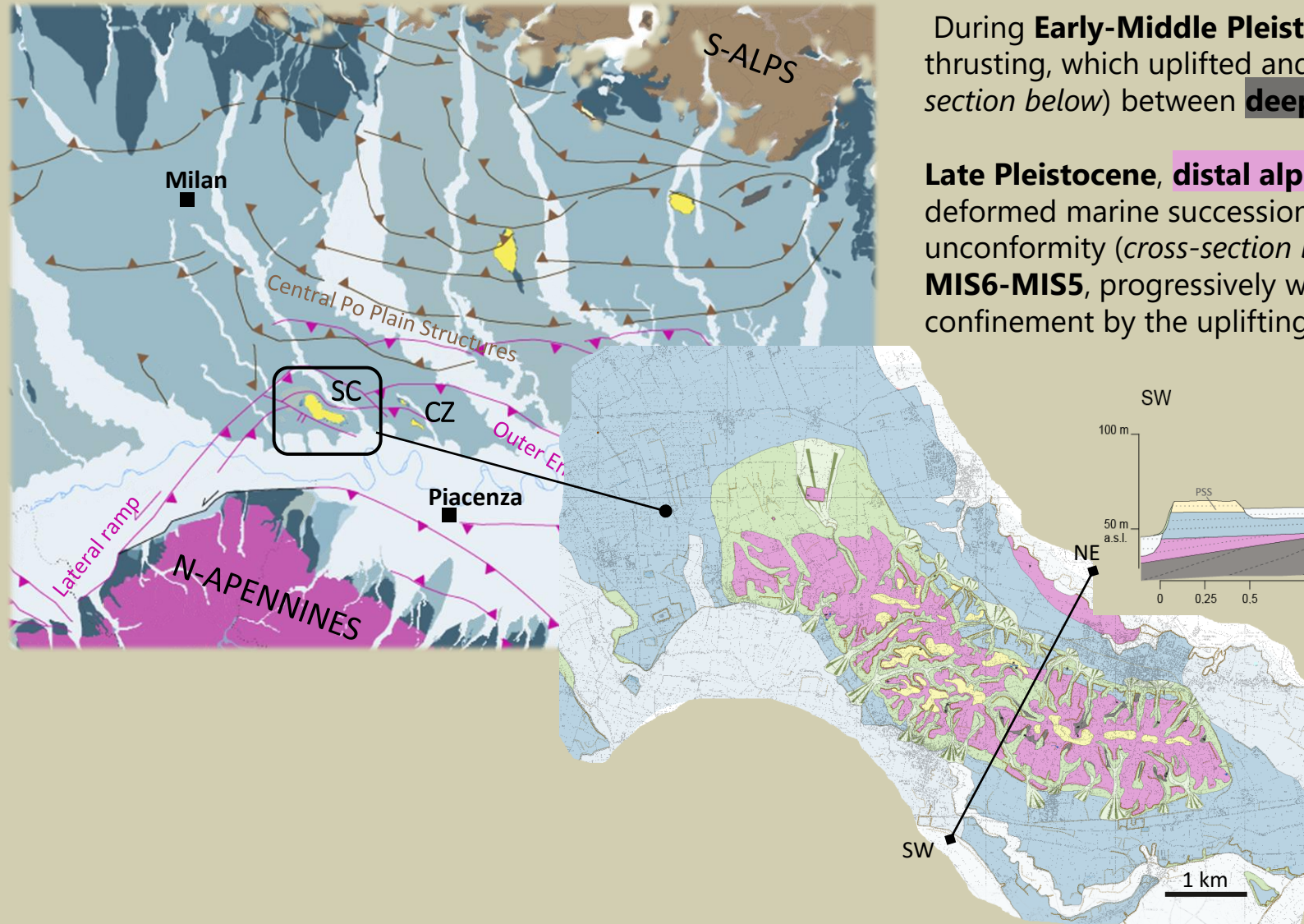
Zuffetti et al. 2018, *Catena*

<https://doi.org/10.1016/j.catena.2018.07.026>



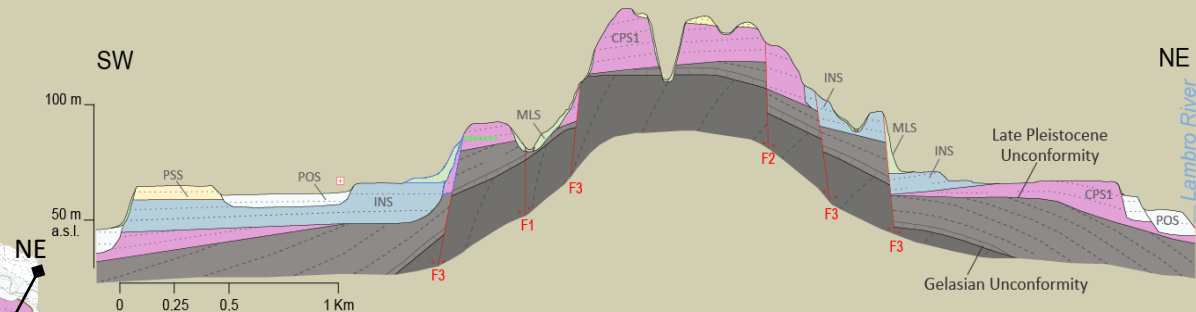
# Integration of data:

## incremental history of thrust-controlled periglacial landscape



During **Early-Middle Pleistocene**, the SC-CZ ramp anticlines underwent thrusting, which uplifted and folded the Gelasian regional unconformity (*cross-section below*) between **deep-marine** Miocene and **littoral** Calabrian formations.

**Late Pleistocene, distal alpine-sourced glacio-fluvial units** terraced the deformed marine successions giving origin to the composite Late Pleistocene unconformity (*cross-section below*). These units, time-constrained by OSL data to **MIS6-MIS5**, progressively wedge-out and amalgamate S-wards, suggesting confinement by the uplifting ancestors of the present-day hills.

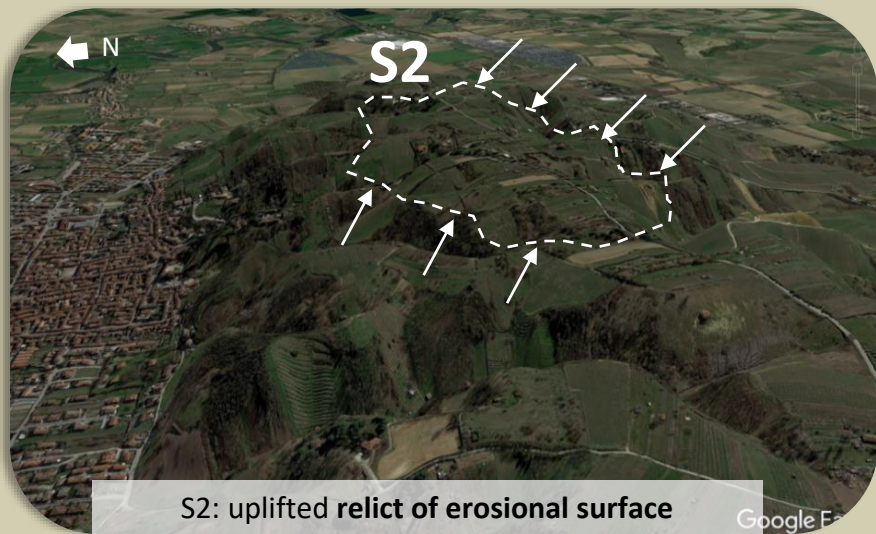


GEOLOGICAL UNITS	
Holocene	fluvial
Late Pleistocene	colluvial and torrential fan
	loess
	distal glaciofluvial
Calabrian	littoral

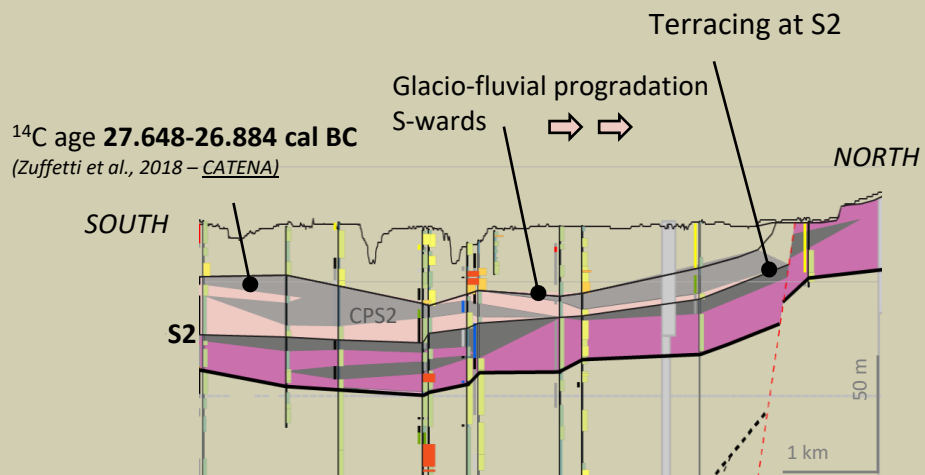


# Integration of data:

## incremental history of thrust-controlled periglacial landscape



-- Figure 2 --



-- Figure 1 --

**MIS4 glacio-fluvial system**, fed from the Verbano-Lario glacial amphitheaters, **fringed-out** above a western uplifted culmination (Figure 1), while a braided glacio-fluvial system flowing South from the central-eastern Lario amphitheater, terraced the eastern subdued structural highs. Relicts of the corresponding **planation surface** are uplifted at the present-day eastern SC and CZ hilltops (Figure 2). On the uplifted proto-hills, Late Pleistocene glacial-interglacial periods are registered by **polycyclic loess-soil sequences** (Figure 3-A). Relicts of syn-tectonic paleovalley fills (Figure 3-B), valley diversions, polygonal facets, alignments of windgaps and hanging valleys, suggest that differential uplift and wrenching occurred, plausibly driven by slip along the eastern dextral lateral ramp of the SC structure.



-- Figure 3 --

Zuffetti et al. 2018, *Catena*

<https://doi.org/10.1016/j.catena.2018.07.026>



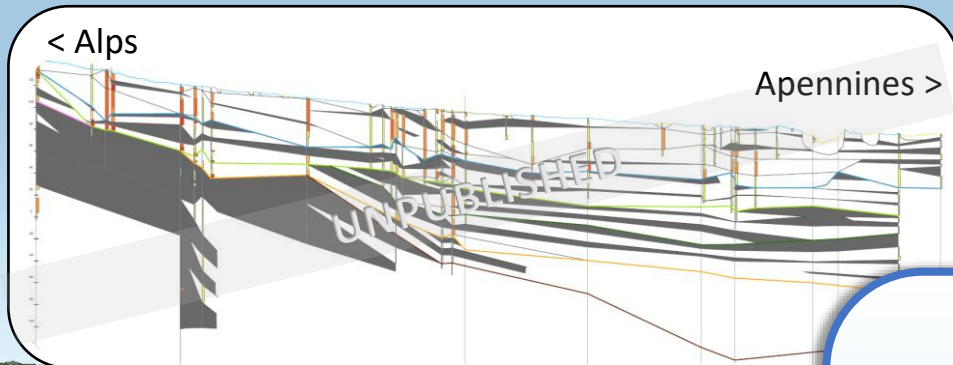




# Ongoing & Future research plan

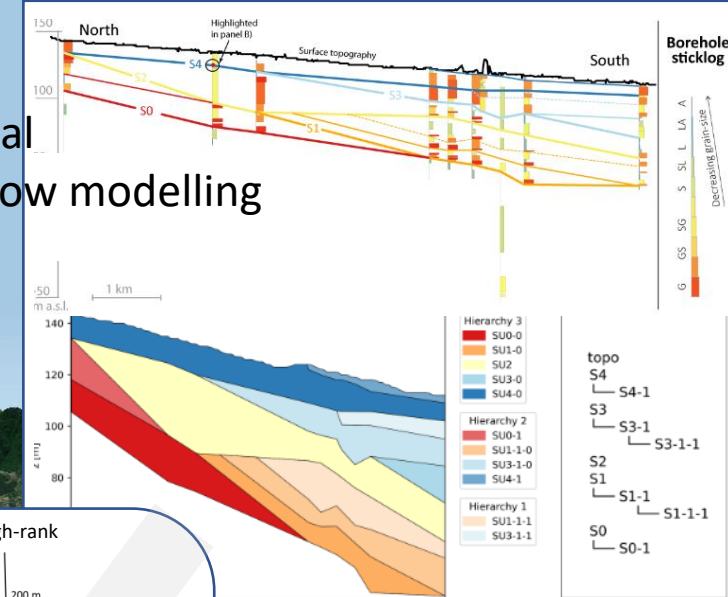
## A QUATERNARY PO BASIN EVOLUTION

- Morpho-structural evolution of the Po Basin-Apennines-Southern Alps system
- Implications for seismic hazard assessment
- Implications for hydrostratigraphic modelling



## B 3D (4D) QUANTITATIVE MULTISCALE MODELS

- Stochastic hierarchic models of alluvial stratigraphy constrained by local and regional geo-history
- Implications for numerical groundwater and heat flow modelling



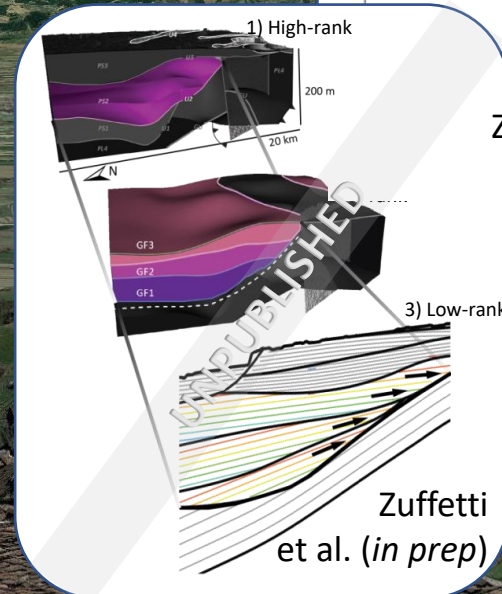
Zuffetti et al. 2020, *Computers and Geosciences*, in press)

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et al. (in prep)