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# Tectonic and climatic control on Holocene sedimentation in minor mountain lacustrine basins: the Lake Moo case study (Northern Apennines, Italy)

Panoramic view of the Lake Moo plain (northern Apennines)

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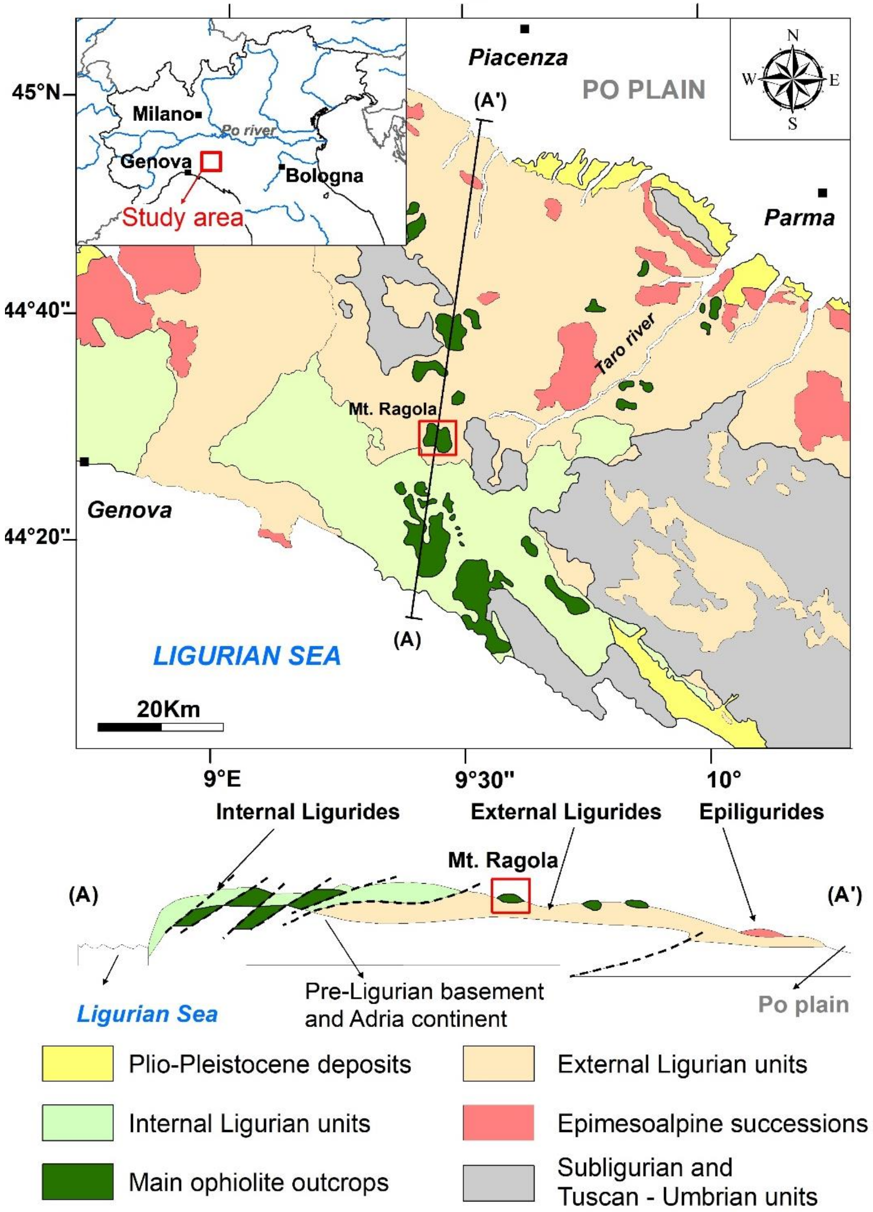



## Scope and purpose

- **Small-scale (1.2 km$^2$) lacustrine basin** in the upper Nure Valley (northern Apennines, province of Piacenza)
- Drainage system on **ophiolitic substrate** the Mt. Ragola massif (1712 m a.s.l.) and strongly deformed clayey complexes belonging to Ligurides Auctt. Maximum thickness of the ophiolite body is 20 m over an area of 29,5 Km$^2$, with its base dipping gently N–NE with a steepness of about 5%.
- **Multidisciplinary and multiscale approach to reconstruct the tectonic-climatic evolution of this sector during the Holocene.**

## Material and methods

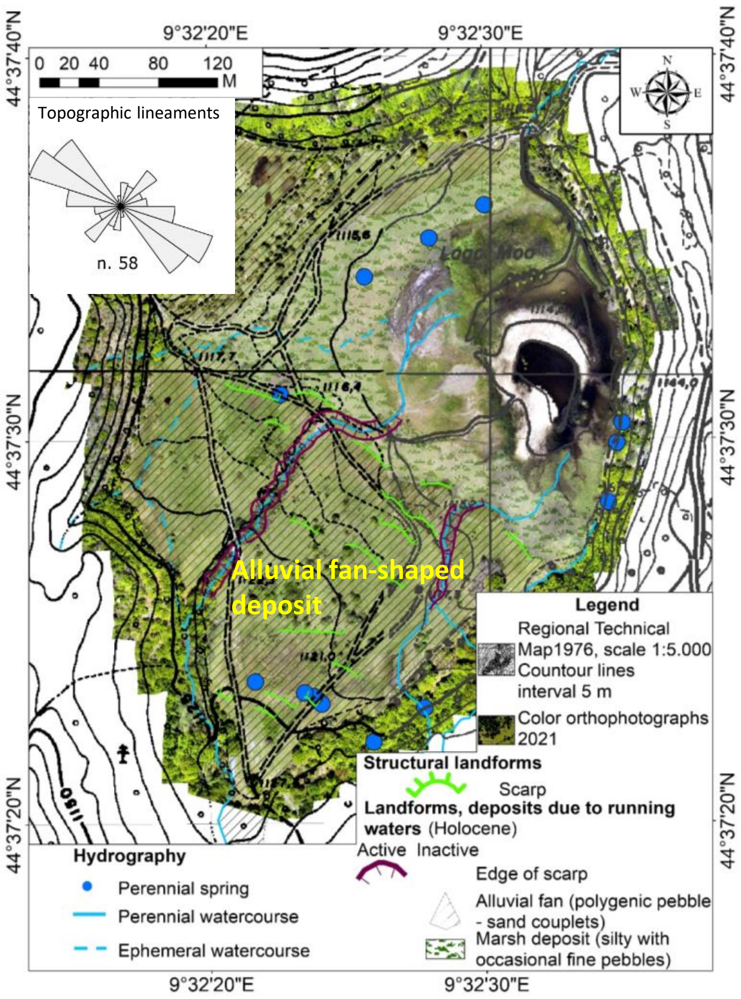
- Review of the historical archives acquired by the Geological, Seismic, and Soil Area;
- A new photogrammetric acquisition (Summer 2021);
- A geoelectrical survey (Autumn 2021);
- New undisturbed sediment cores;
- Chronostratigraphic framework based on radiocarbon data;
- Orthophotographs and DEM acquired by the Geological, Seismic, and Soil Area;
- Background geological data at the 1:10,000 scale, derived from the Emilia-Romagna Region database;
- Review of the national earthquake catalog to qualitatively identify possible relationships between epicentral clustering trends and structural patterns;
- Background data collection in collaboration with: Arpae-Simc, University of Parma (SCVSA) and Bologna (BIGEA).

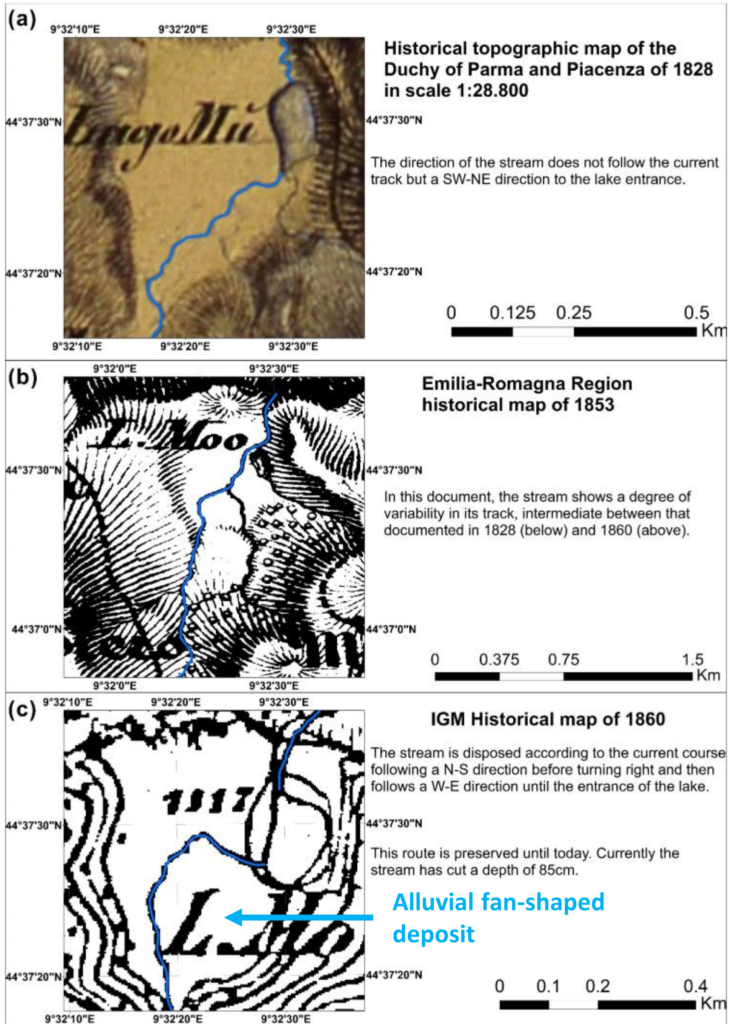
All territorial data are available in vector digital format, organized and managed in a database with ESRI 2018 AcrGIS.

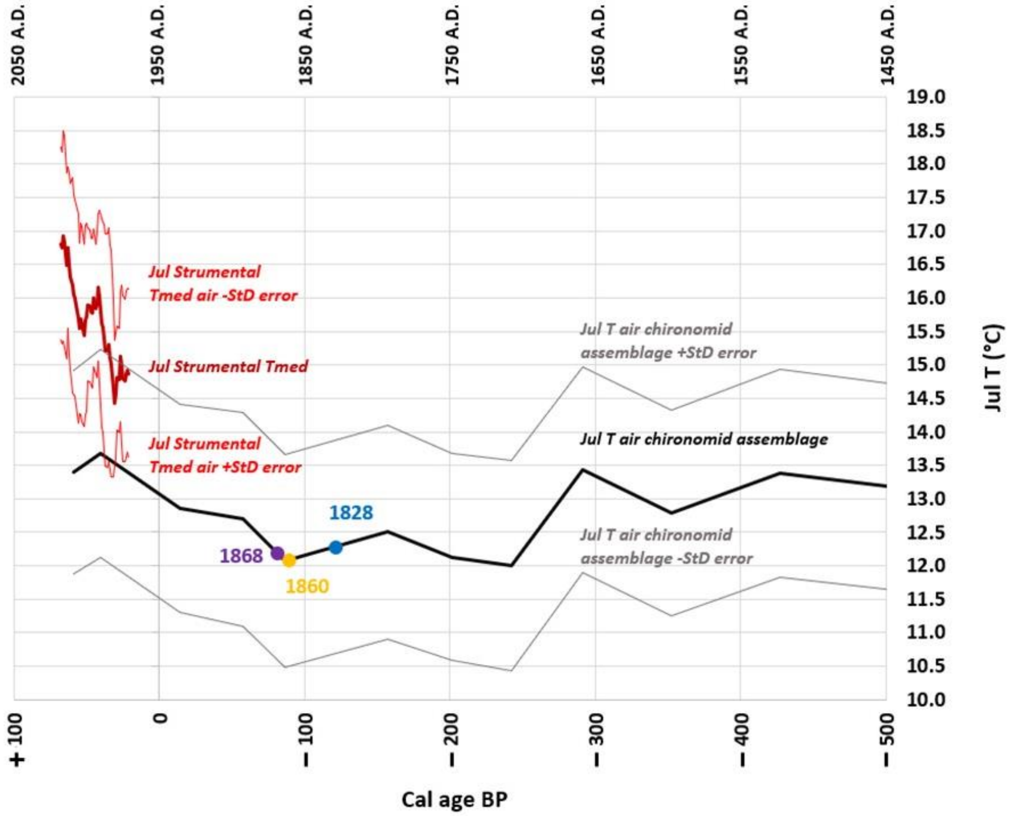
# Lake Moo: local surface analisys

The morphology of the Lake Moo plain is controlled by the **structural discontinuities** present in the ophiolitic bedrock with **two main orientations NW-SE and NE-SW.** In particular, the NW-SE set appears to share the most evident topographic expression, also coinciding with the front of the alluvial fan.

In the southern part, an **alluvial deposit** has been related, through the analysis of historical cartography, to the activity of several **ancient floods occurred during the last stage of the Little Ice Age**.



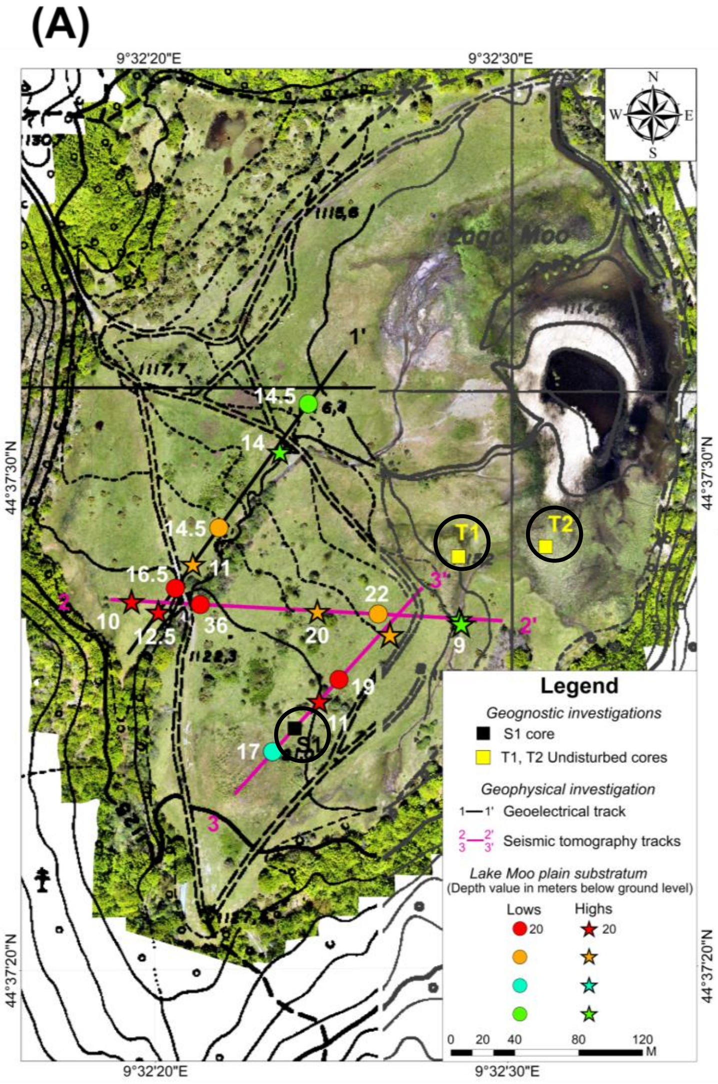




The black line shows the reconstructed temperature, while the gray lines are the specific estimated standard error associated with the temperature reconstruction based on chironomid assemblages from Samartin et al., 2017. The red line represents the July mean temperature (1971–2018) retrieved for the Verdarolo meteorological station of ARPAe-SIMC network Emilia-Romagna Region (11-year running average). The light red lines are standard deviation error.

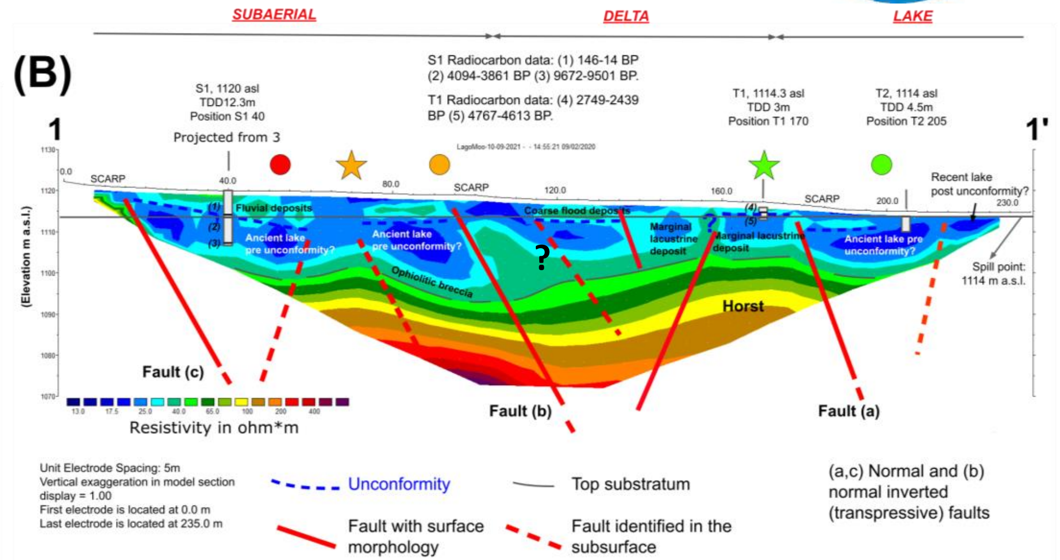
# Lake Moo: basin scale analisys

- **Contact between sediments and the bedrock** at maximum and minimum depths of about 25 and 5 m, respectively;
- **Complex physiographic profile with asymmetric morphological highs and lows** (shorter and steeper southern flanks compared to the northern ones).
- **Unconformity:** sharp and erosive contact at a depth of 4.5 m, marking transition from shallow lacustrine clayey deposits (resistivity values below 25 Ω × m), to a marginal lacustrine environment subject to flood deposits and subaerial very coarse sediments (resistivity values ranging between 25 and 40 Ω × m).
- **The structural discontinuities defining the subsurface framework are correlated in plan view with the NW–SE and NE–SW topographic alignments**, and are interpreted as aligned normal fault branches with local cumulative displacement of up to a few meters and a lateral extension of up to hundreds of meters.
- **Such faults** are arranged in arrays mainly N- and S-dipping, and W- and E-dipping, respectively, roughly **defining an asymmetric horst-and-graben-type morphology in both directions.**
- In particular, **the NW–SE set appears to show the most evident topographic expression**, also coinciding with the front of the alluvial fan.

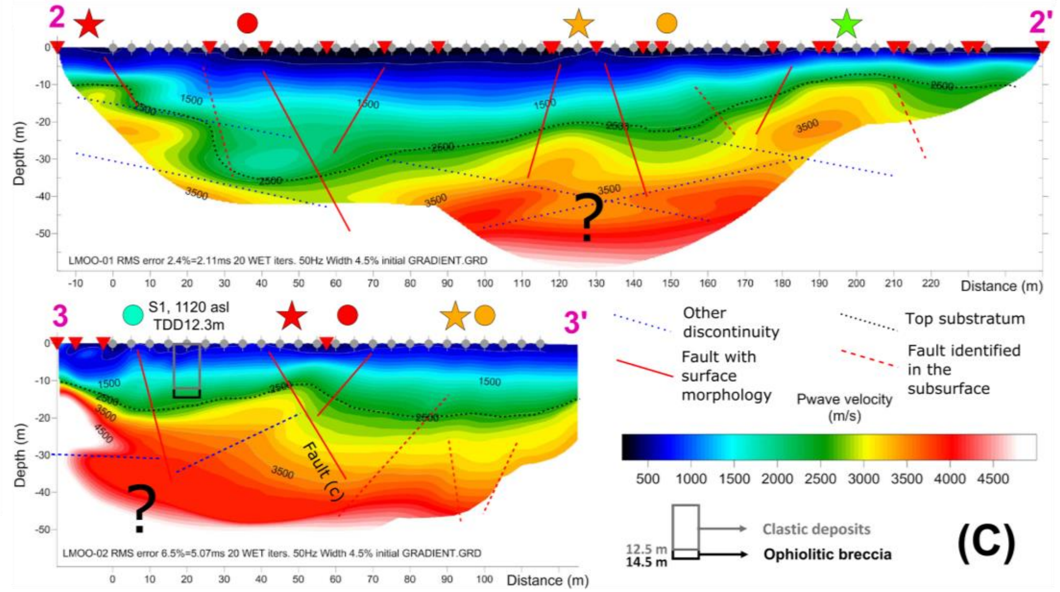
Undisturbed sediment cores S1, T1 and T2 (depths 12 m, 3 m and 4 m respectively) and geoelectrical, seismic survey.

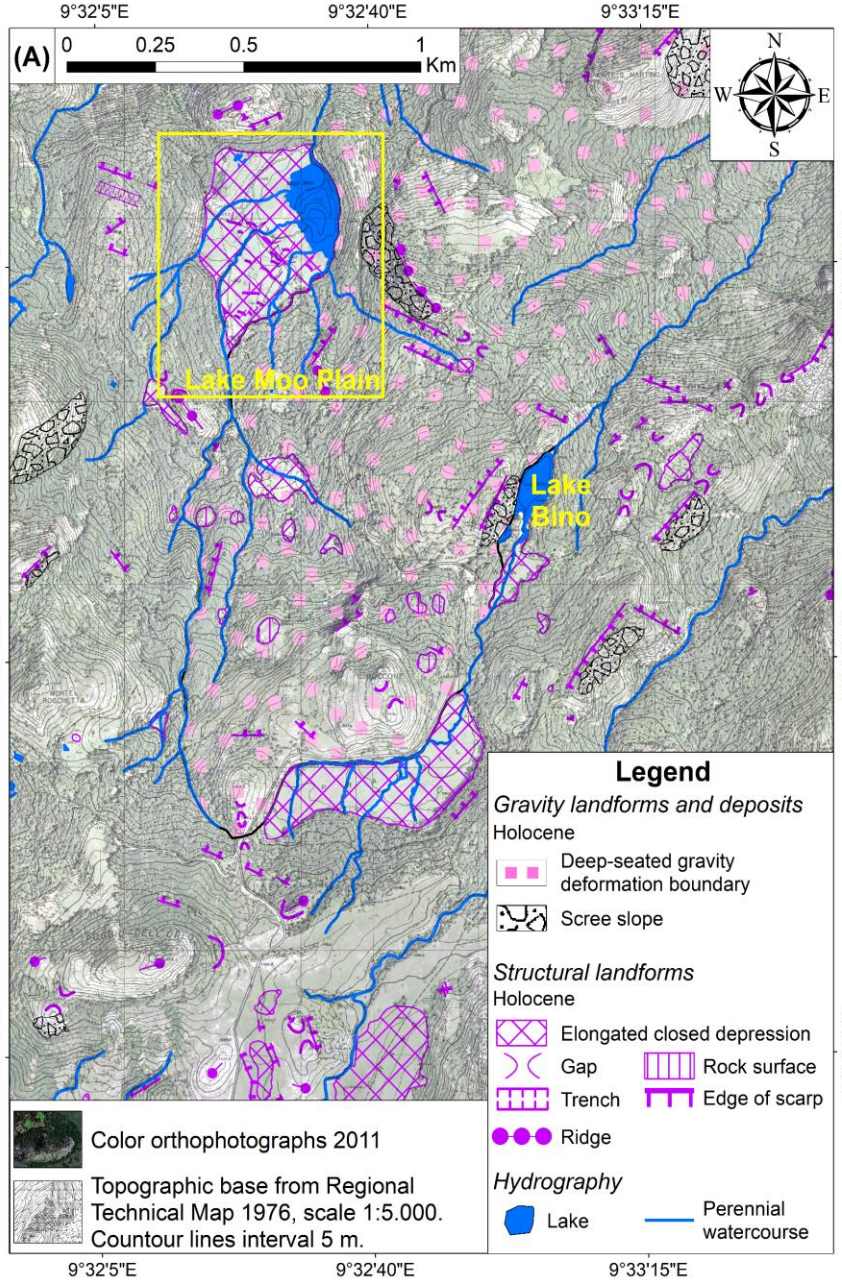



**Geoelectrical resistivity profile**



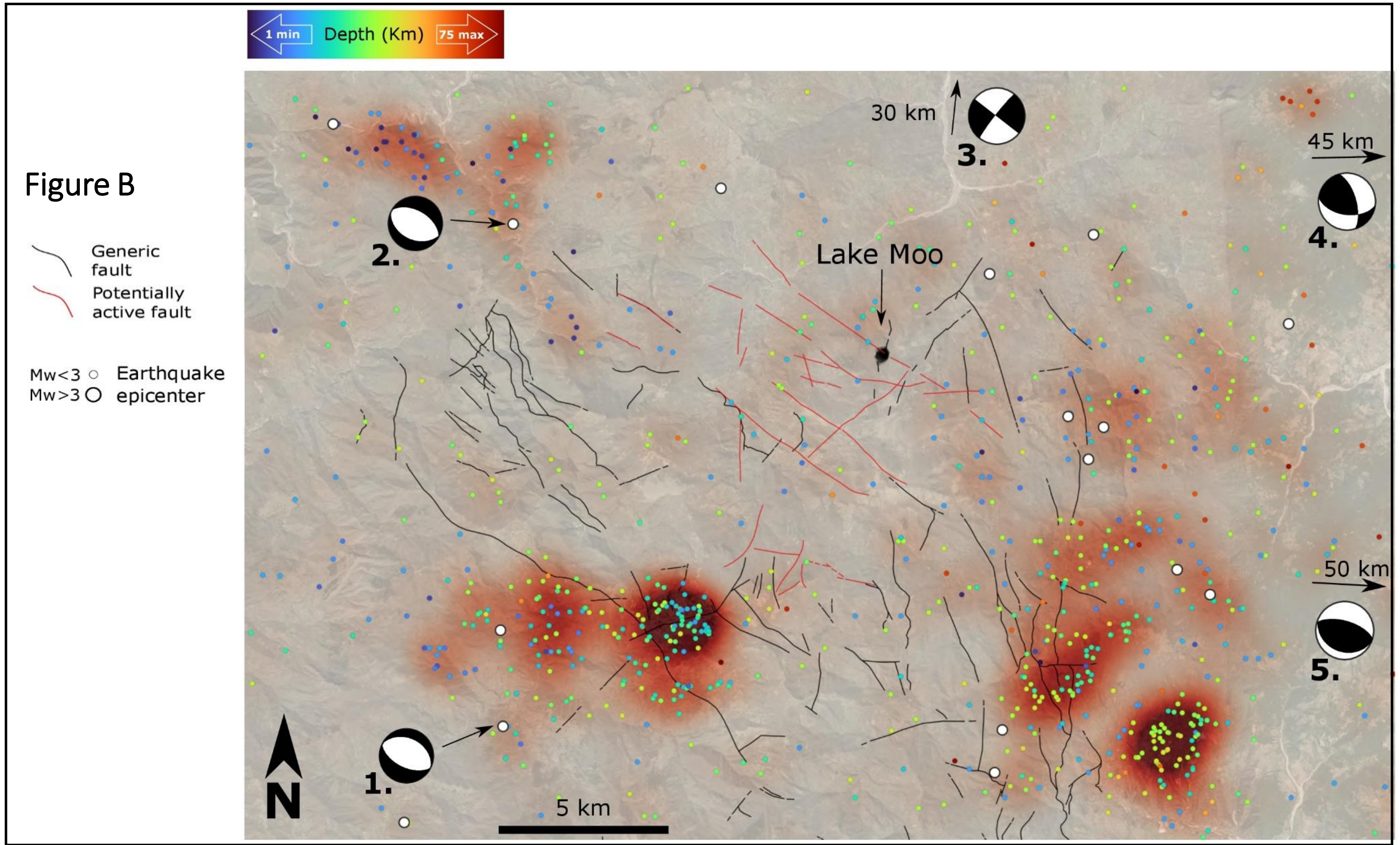

Seismic profiles (2-2' and 3-3') made by Unipr-SCVSA (modified from Segadelli et al., 2020).





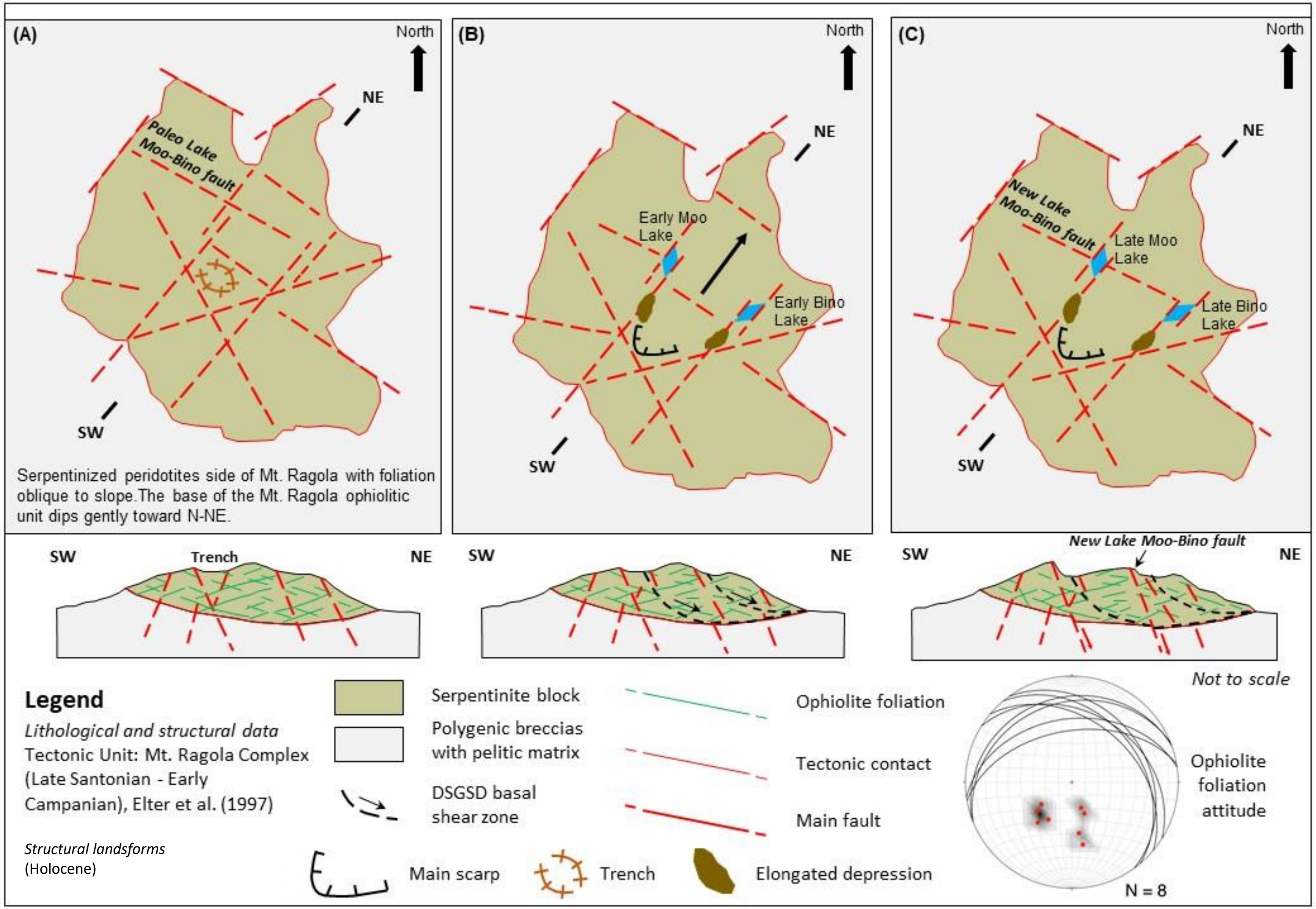

The surface of the deep-seated gravity movement complex and its structures are crosscut by geomorphologic elements such as aligned trenches, saddles, scarps, vegetational lineaments, and interruptions of elongated Structural highs and lows, characterized by lateral continuity outside the lacustrine basin. **In particular, the NW–SE set appears to share the most evident topographic expression** (Figure A).

**This scenario is supported by the literature, as studies carried out in the late 1980s documented several faults in the area sharing a recent activity** (Barbano et al., 1984; Carton et al., 1988; Perotti et al., 1988). **Structural investigations suggested the occurrence of three deformational phases**, two of which were characterized by the transcurrent regime trending NE–SW and NNW–SSE, respectively, **and a third, younger distensive one (Quaternary). The latter developed two normal fault systems, trending NE–SW and NW–SE, with local transtensive movements Perotti et al., (1988).**



# Conclusion and potential developments

Synthetic conceptual model showing the origin and subsequent evolution of the Moo and Bino lakes.




**(A)** Pre-failure stage: Serpentinized peridotites side of Mt. Ragola with foliation parallel to slope;

**(B)** Initiation phase of the DSGSD destabilization, starting in 9.600 B.P. and continuing through the Holocene Climatic Optimum;

**(C)** Recent structural control phase characterized by an abandonment of the southern part and shifting toward the N of the lake Moo lacustrine basin depocenter to its current position.

# Conclusion and potential developments

This study allowed us to **disregard the glacial origin** classically proposed for this lacustrine basin, instead revealing that a possible combination of relatively recent **sedimentary, gravitational, and (neo)tectonic processes played a major role** in the morphological reshaping of the study area. In particular, **three main processes** were responsible:

**1)** Enhanced efficiency of regular flood fluvial in humid and cold climatic conditions at the demise of the last stage of Little Ice Age;

**2)** Deep-seated slope gravity deformation due to tectonic uplift and lateral valley unloading. The deep-seated gravity movement is strongly controlled by tectonic structures responsible of its development and of its lateral compartmentalization;

**3)** The recent reactivation (Holocene) of older tectonic structures are interpreted as capable for the segmentation of the lacustrine basin of the Lake Moo and more in generally the structural architecture of the Mt. Ragola massif.

The resultant physiographic scenario, which is **preconditioned by the subsurface geological architecture**, is mainly driven by **lithological/mechanical contrast and reworking/reactivation of inherited structures**. In this framework, the (geo)diversity of the high Northern Apennines landscape can provide the constraints for a detailed assessment of the present and future geomorphic hazards for the local communities, as well as potential guidelines for the local governance of land management, planning, and safety.

**The proposed multidisciplinary analytical workflow highlights the importance of minor mountain lake environments and peat bogs as high-resolution geological archives through which to study active faults.** Such an approach might be implemented in other similar settings, characterized by limited outcrop conditions, complex argillaceous lithologies, and/or unfavorable vegetation cover.

# Thank you for your attention

Representative photograph of the fluvial incision showing the uppermost 50 cm thick sedimentary succession of Lake Moo plain. Though the exposure is quite small, the different gravel levels can be interpreted as a sheet-flood deposit.

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