DRAINAGE REVERSAL REVEALED BY GEOMORPHOMETRIC ANALYSIS OF FLUVIAL TERRACES IN CENTRAL UMBRIA (ITALY)

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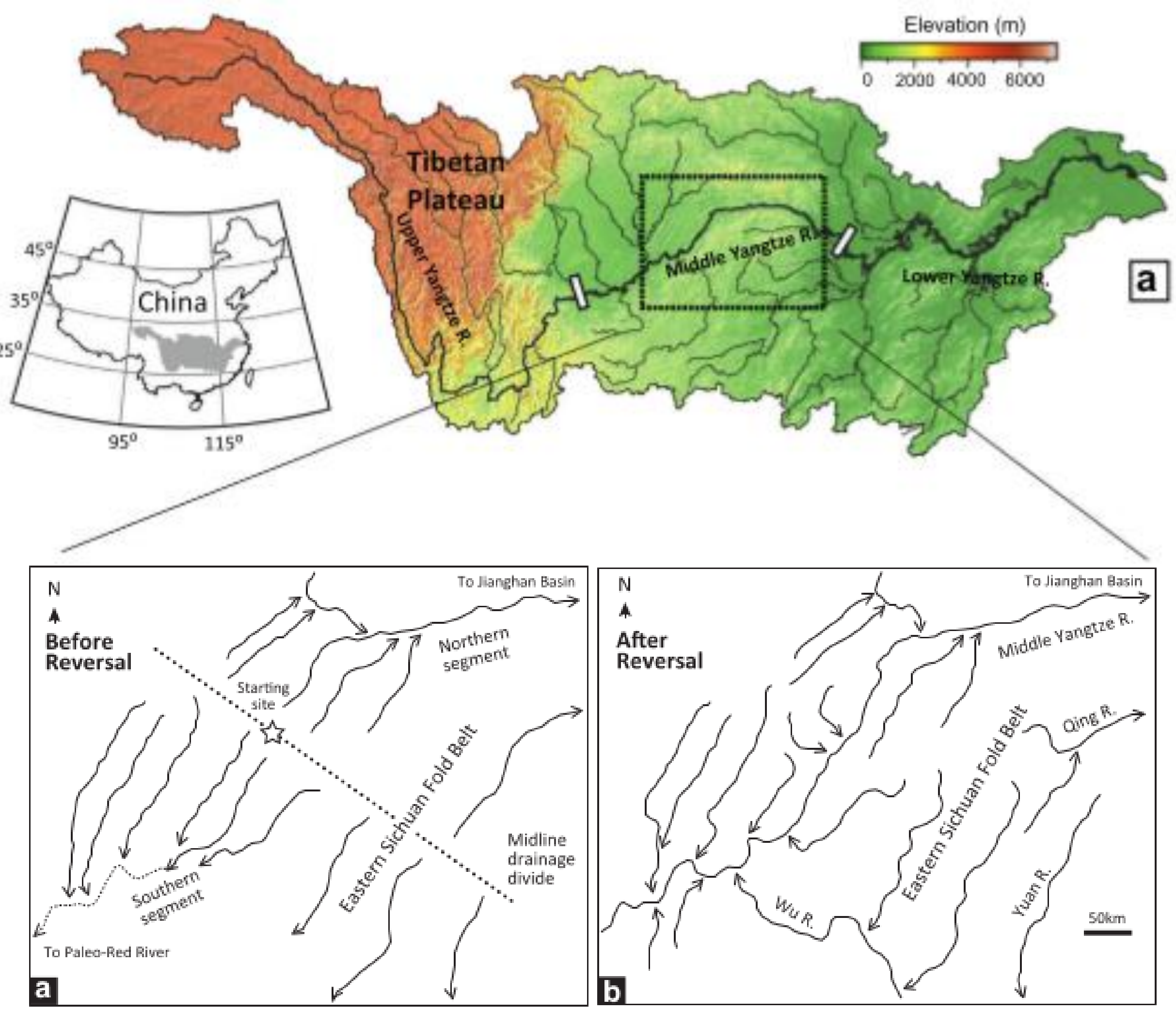
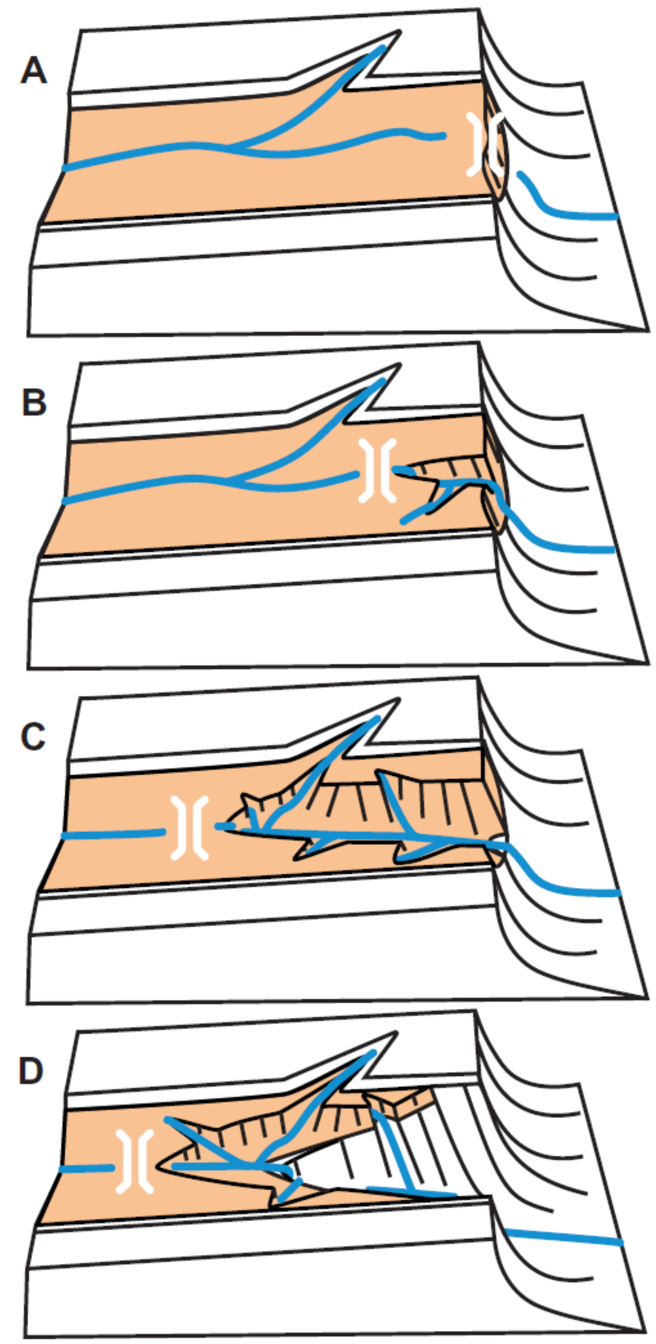
Uplifted (m 400 a.s.l.) relict landscape in the Puglia river Basin (PG)

FLUVIAL REVERSALS: DISTRIBUTION, SCALE AND CAUSES

REVERSAL OF RIVER FLUX CAN OCCURRED WORLWIDE AT EVERY SCALE. COMMON CAUSES ARE:

- TECTONIC (UPLIFT/SUBSIDENCE) CHANGES
- CLIMATE (GLACIATION/DEGLACIATION) CHANGES
- GEO-LITHOLOGICAL (DIFFERENTIAL EROSION) CHANGES





***The Yangtze River (China)** - continanta scale*

- *Fluvial reversal caused by tectonic subsidence (uplift) of east (west) China*

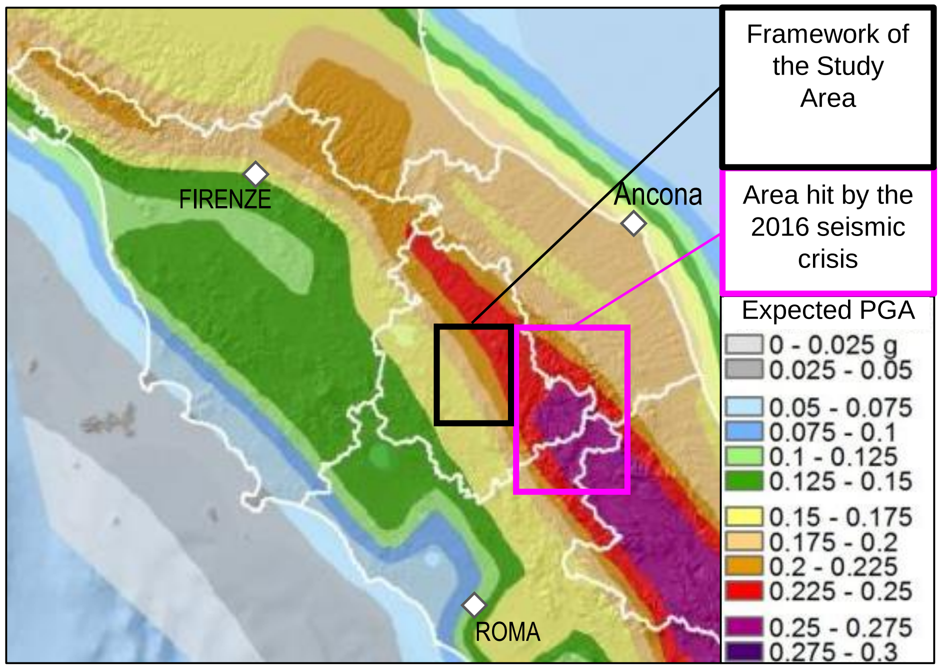
Wang et al., (2013), *Journal of Asian Earth Sciences,* 69, 70-35

***The Arava Valley (Istrael)** - local scale*

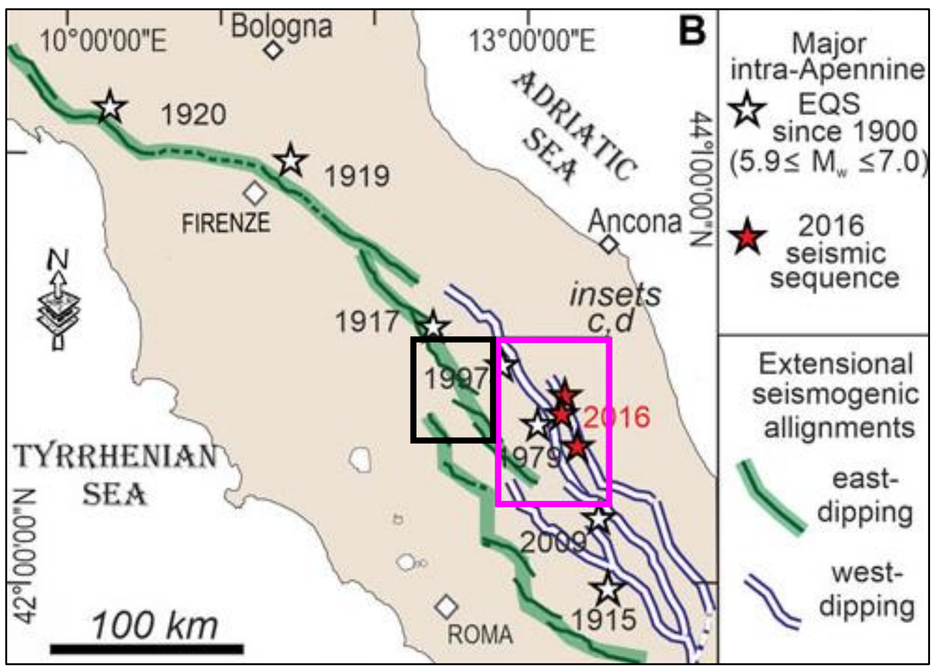
- *Drainage reversal occurs when erodible valley fill exists toward cliffs*

Harel et al., (2019), *Geology*, https://doi.org/10.1130/G46353.1

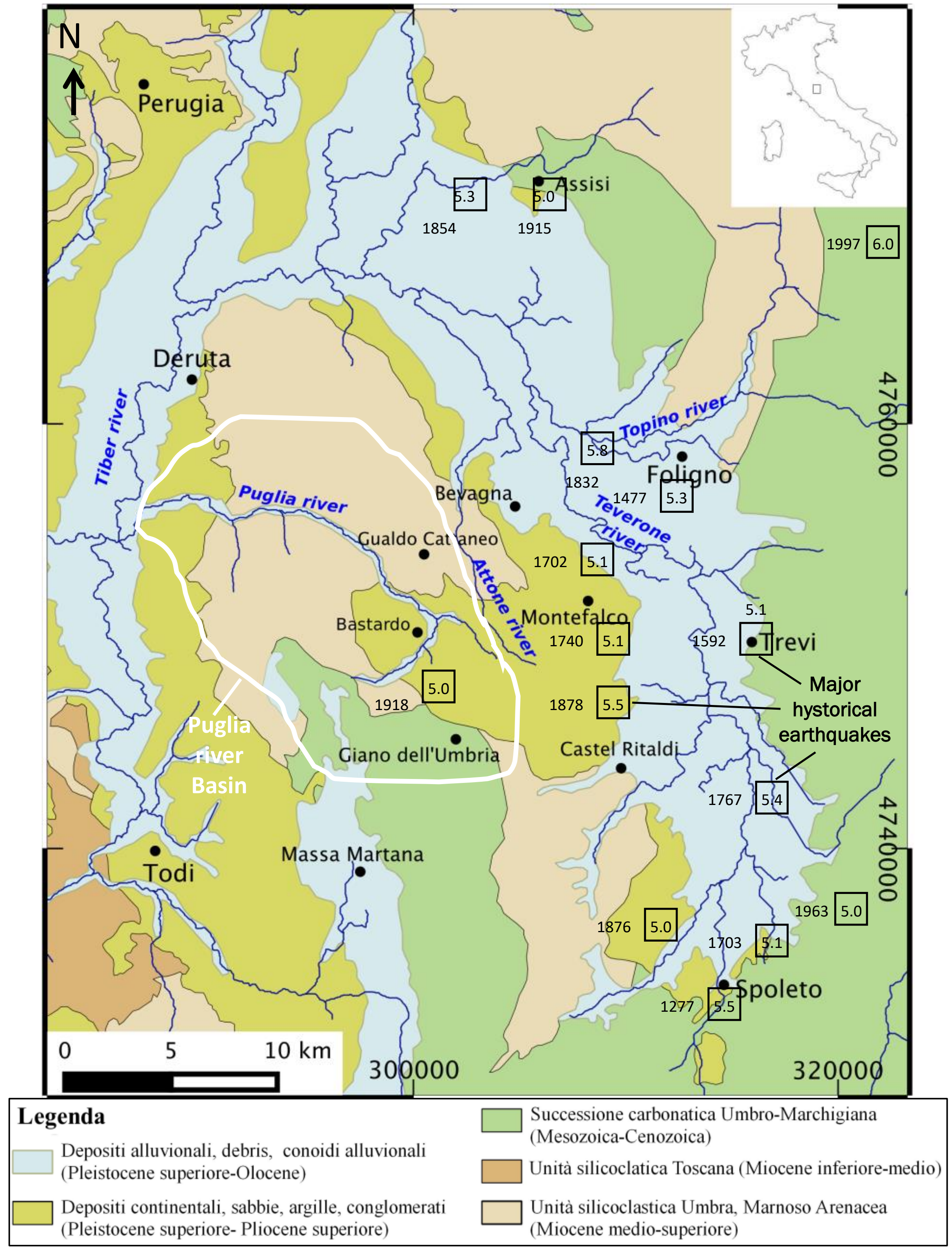
STUDY AREA: SEISMOTECTONIC FRAMEWORK



Seismic hazard map of Italy,
https://ingvterremoti.com/la-pericolosita-sismica/



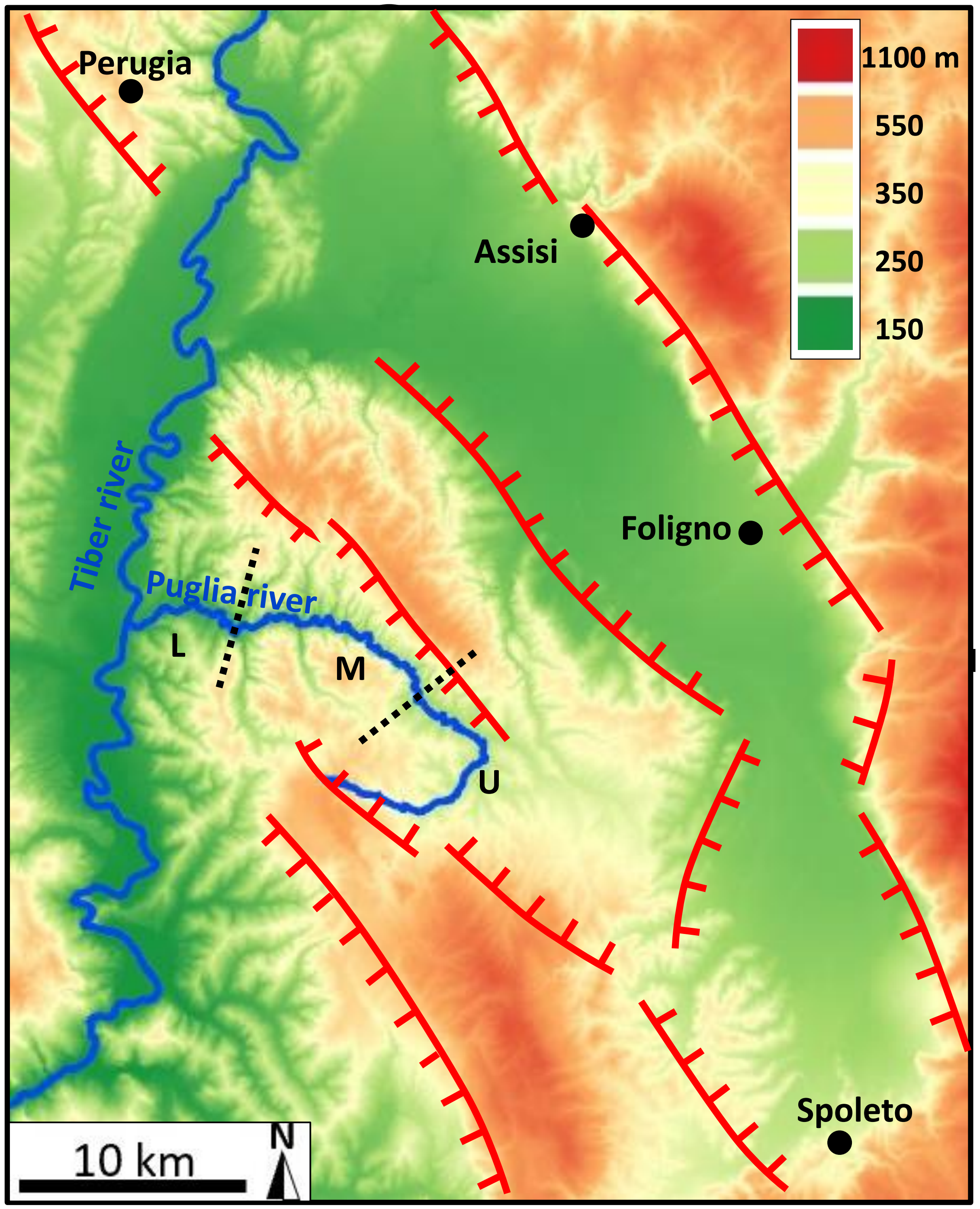
Ferrarini et al., (2021), *Frontiers in Earth Science*,
doi: 10.3389/feart.2021.642243

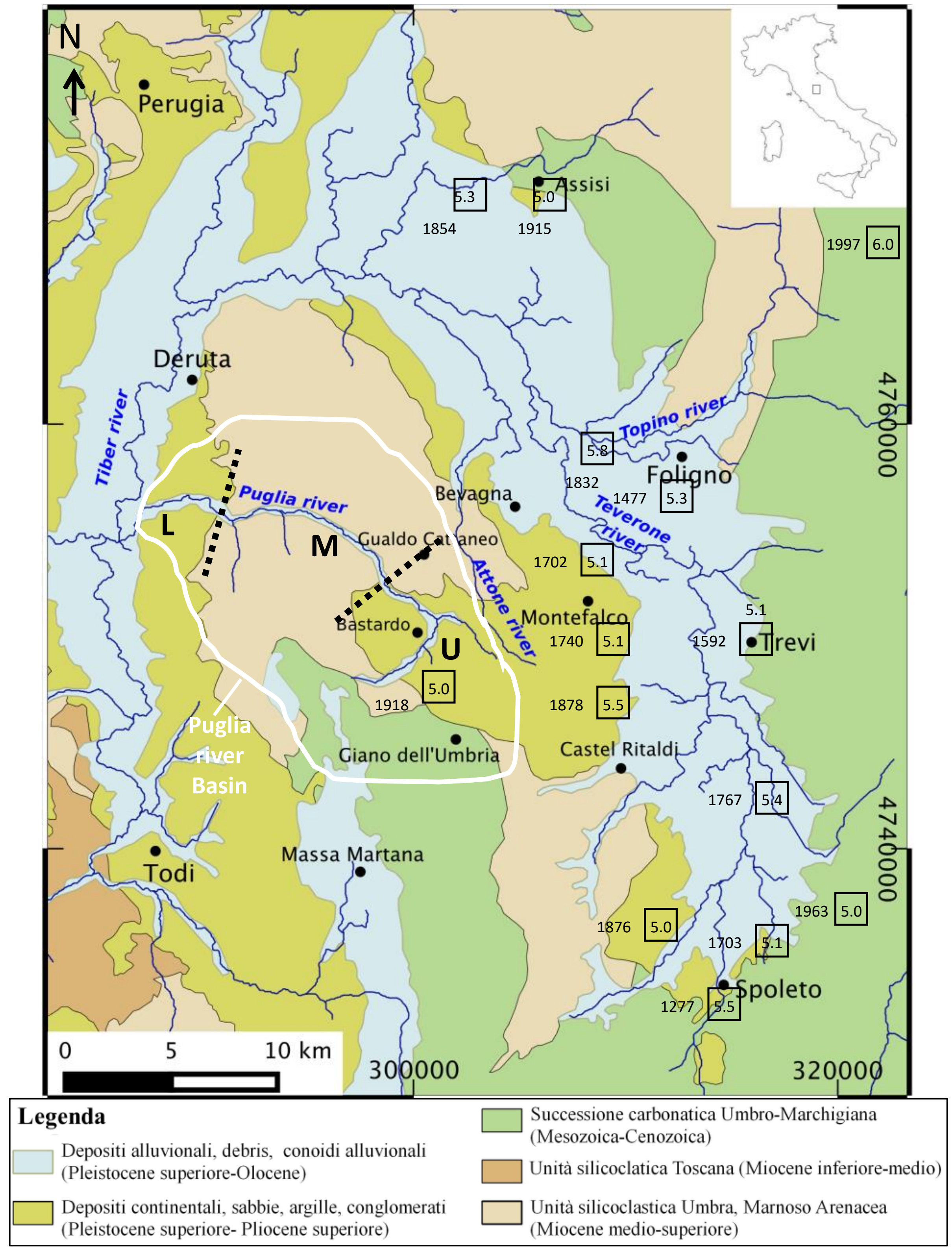


• We investigate fluvial reversal in central Italy in an active tectonic setting characterized by medium to hight seismic hazard grading from W to E.

• Our target is the Basin of Puglia river, a tributary of the Tiber river, which bounds westard the seismic zone of the Foligno valley

STUDY AREA: MORPHOTECTONIC/GEOLOGIC FRAMEWORK

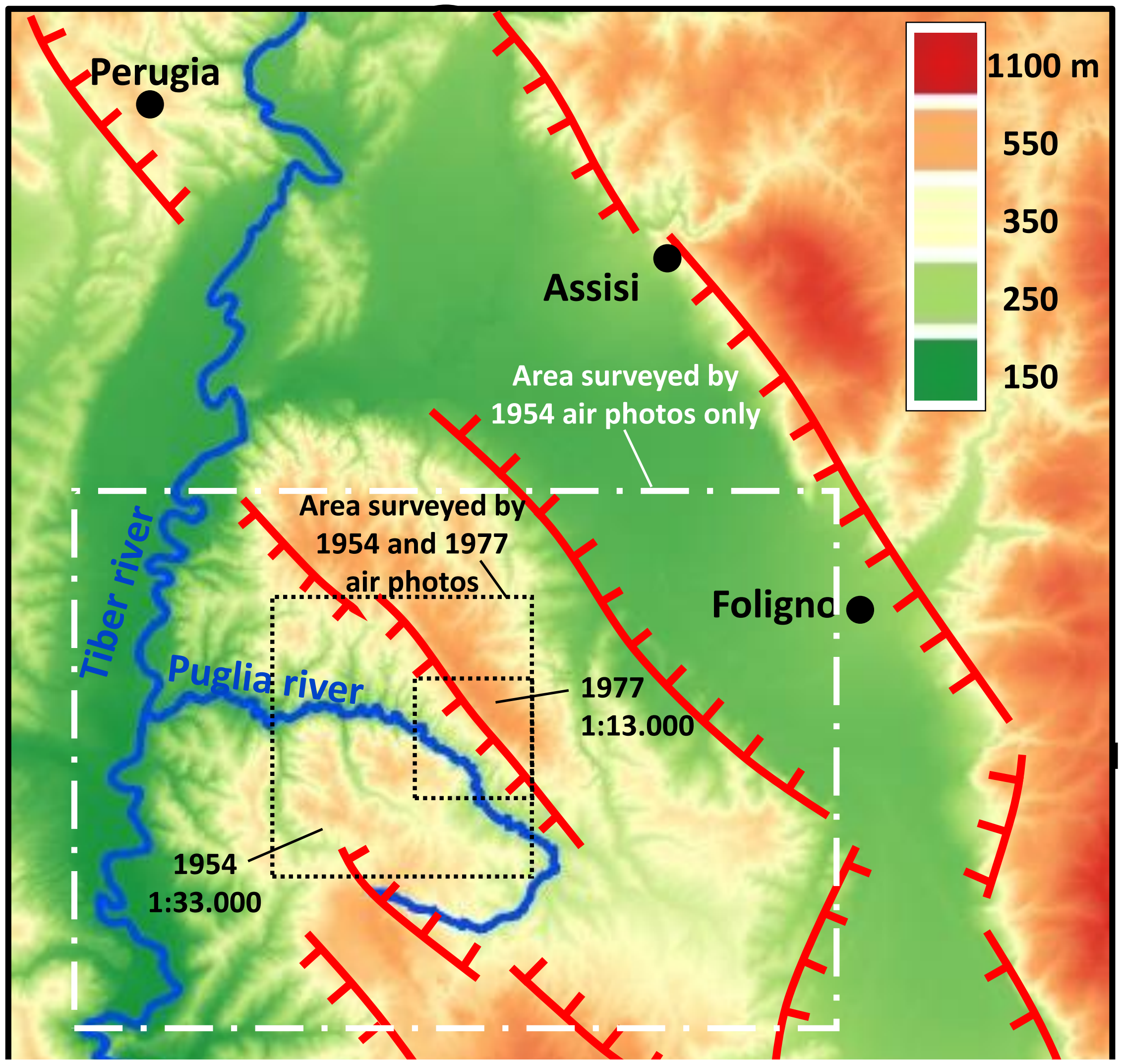




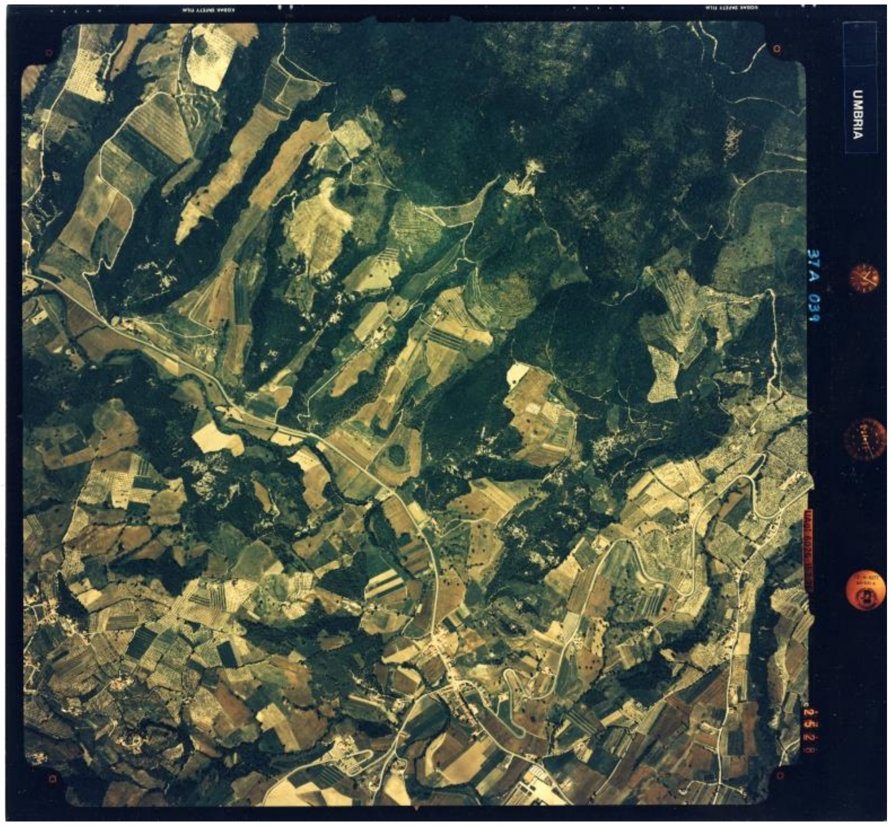
- The Puglia river flows through a ridge crossed by an array of NW-SE trending Quaternary faults.
- The upper (U) and lower (L) course drain gentle landscape. The medium (M) course flows in a narrow valley.

- Medium course of the Puglia river incides flysch sediments of the bedrock.
- The upper and lower courses flow in alluvial plains, over lacustrine deposits.

SURVEY BY MULTISCALE AIR PHOTO INTERPRETATION

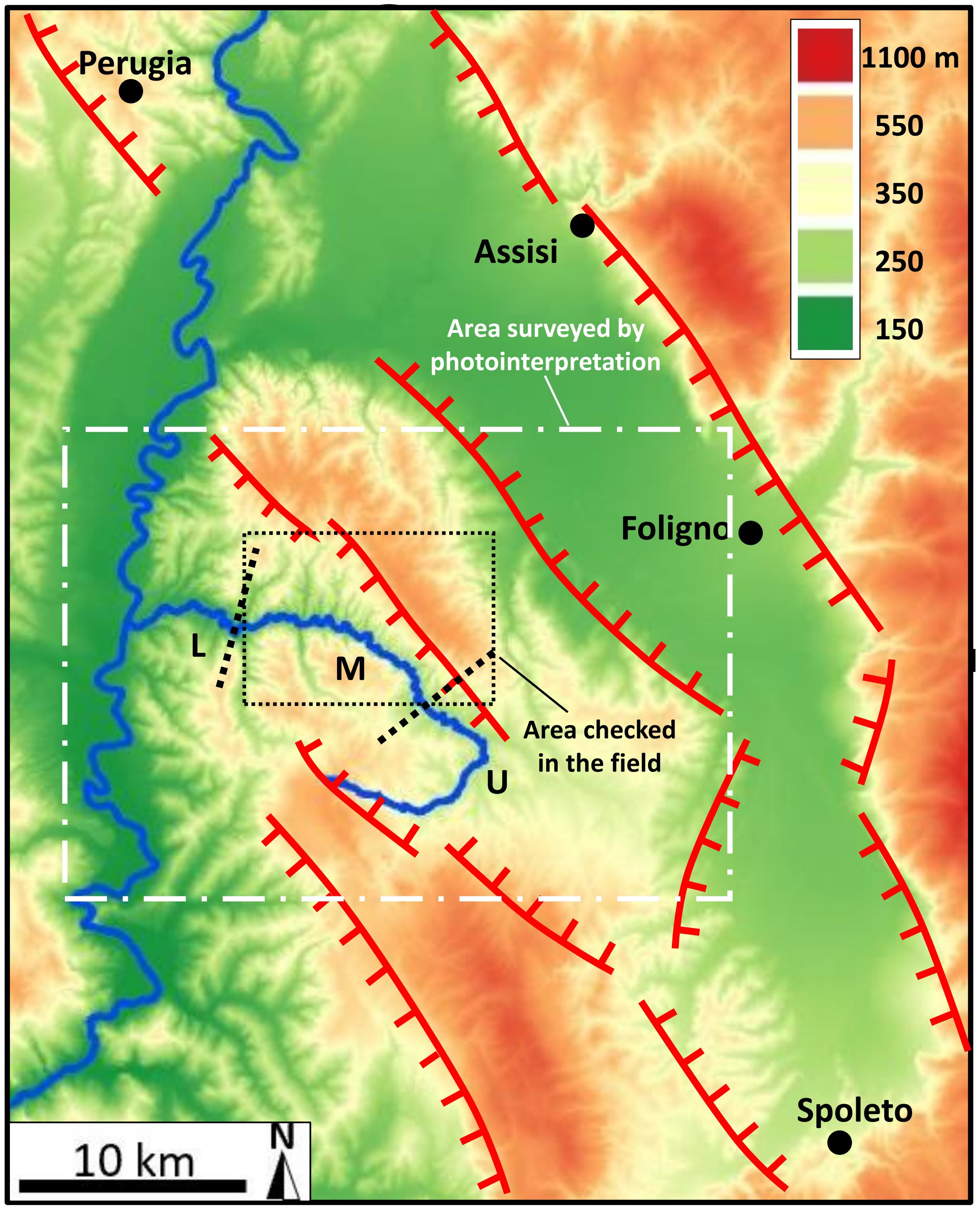


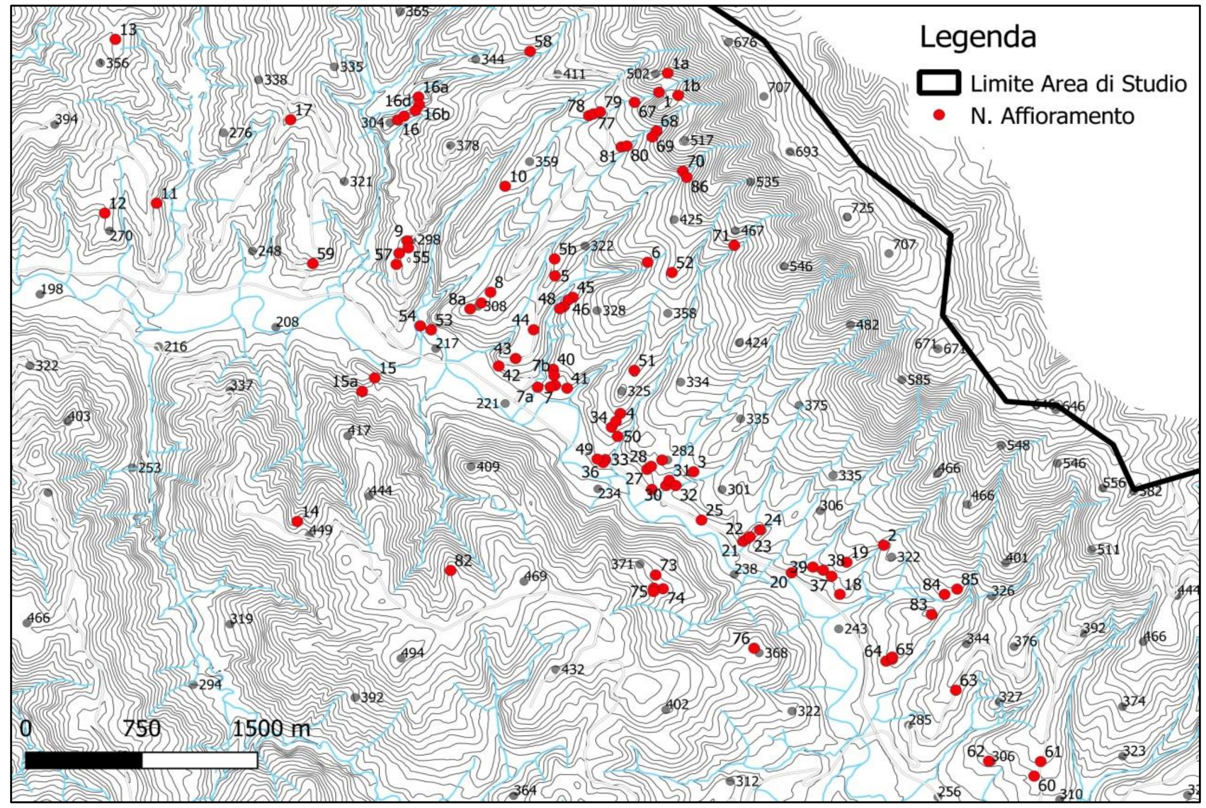
• N-S, Year 1954, B/W, 1:33.000, 60 km^2



• E-W, Year 1977, C, 1:13.000, 10 km^2

FIELD CHECK OF PHOTO INTERPRETED INFORMATION



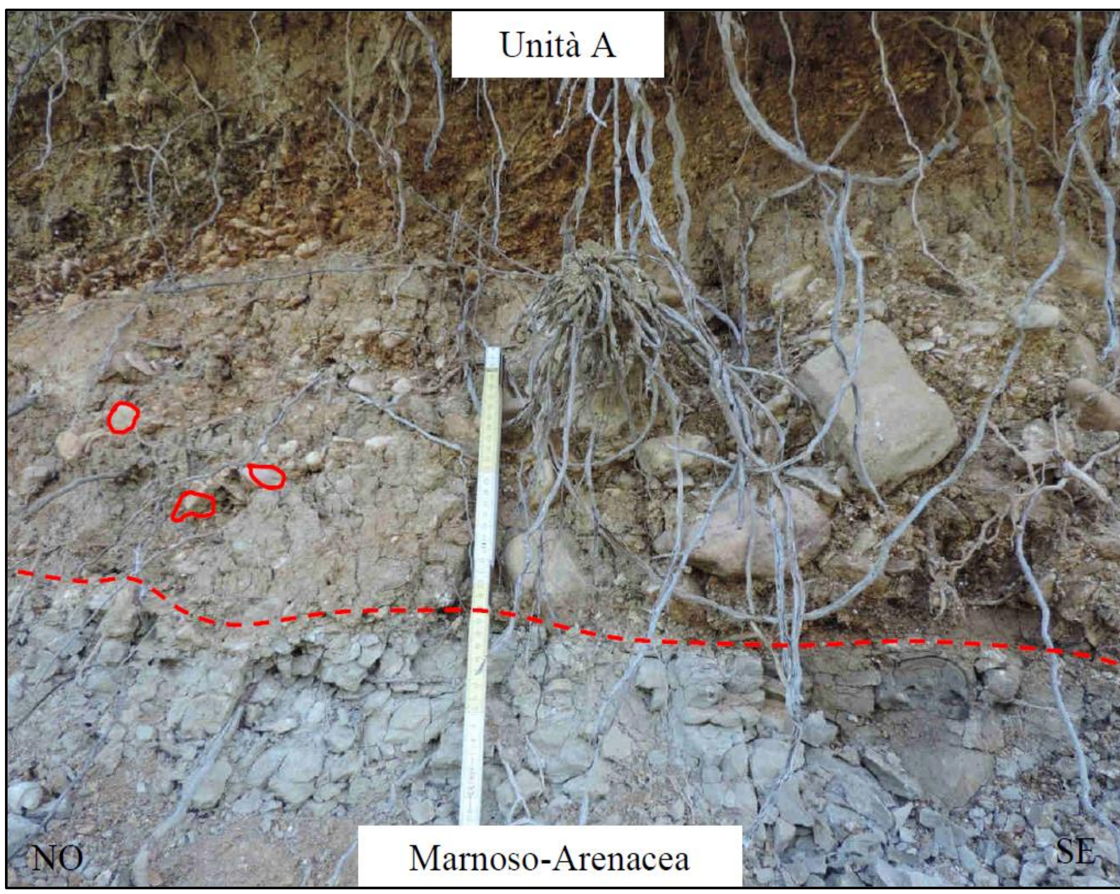


- Field check also was performed along the medium course of the Puglia river
- A total of 84 survey points were collected in order to integrate and check the photo interpreted information.

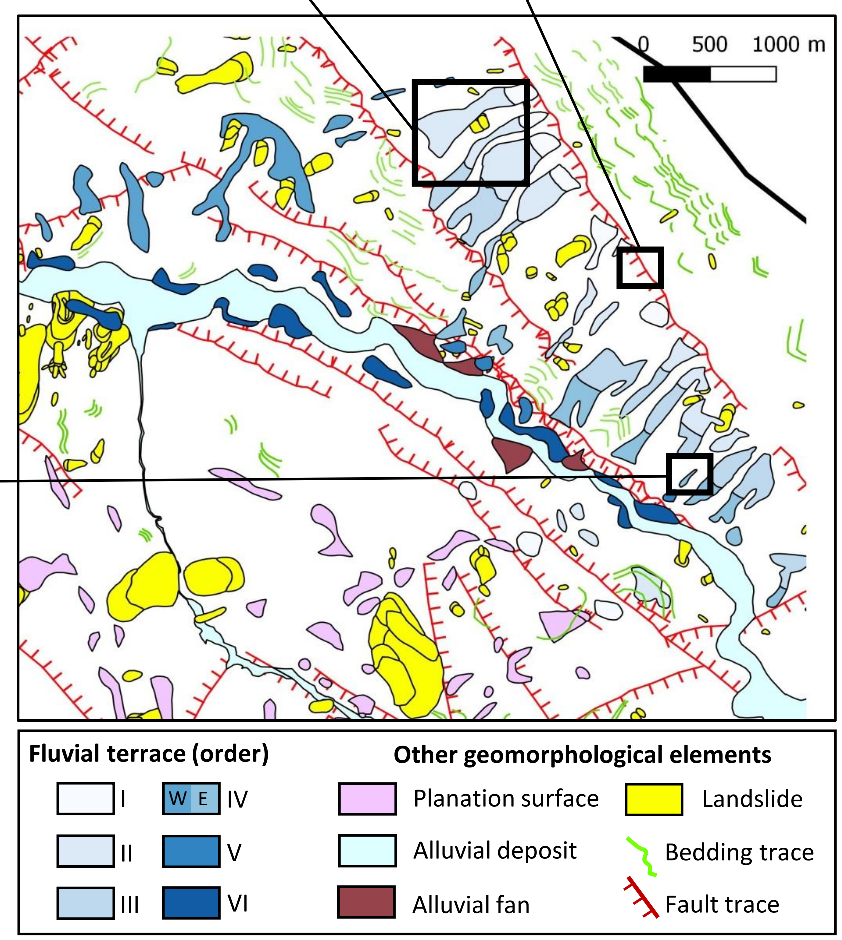
FIELD CHECK OF PHOTO INTERPRETED INFORMATION

• Check of the mapped terraces edges

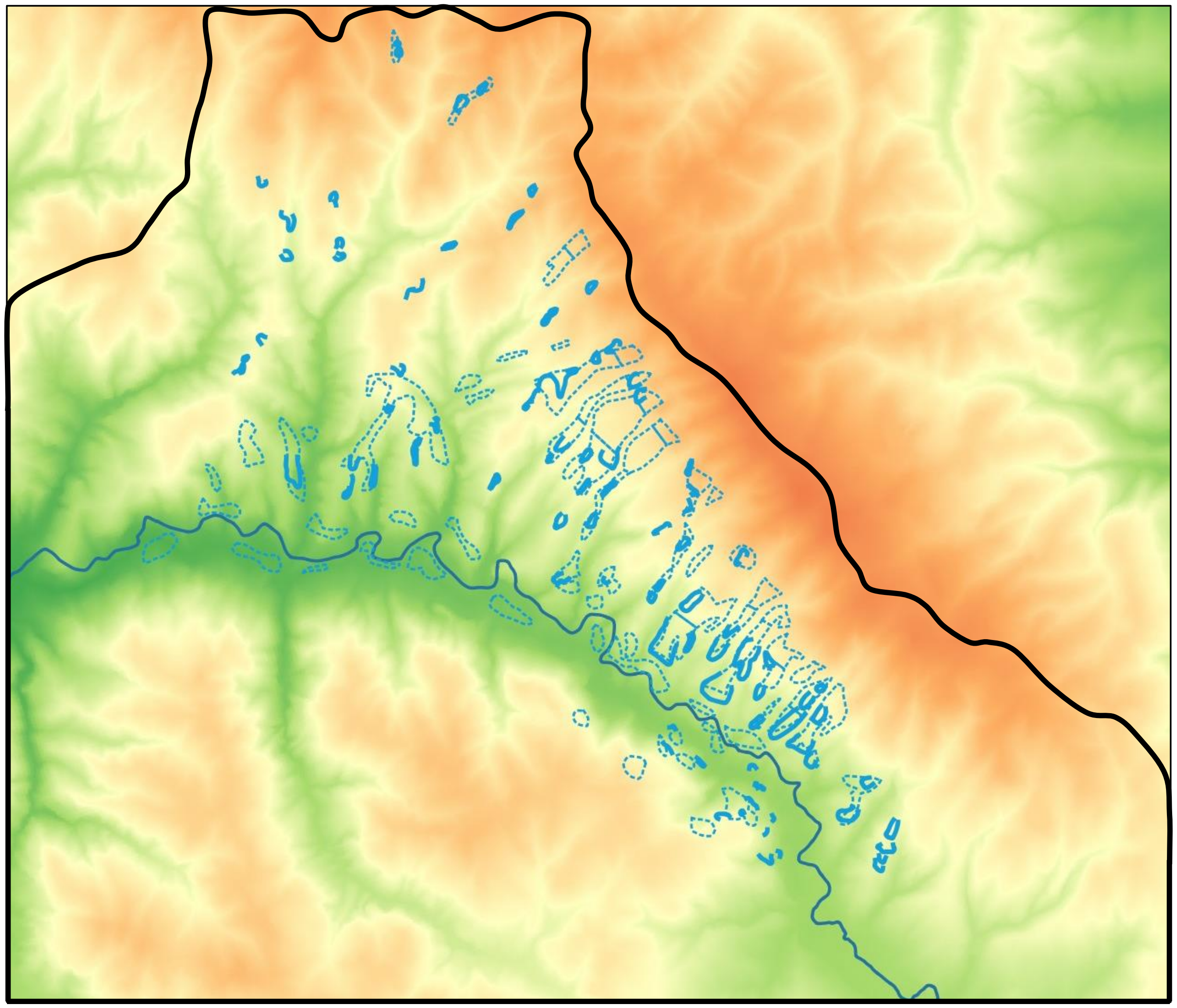
• Check and measure of the mapped faults



• Terrace deposit detection and characterization



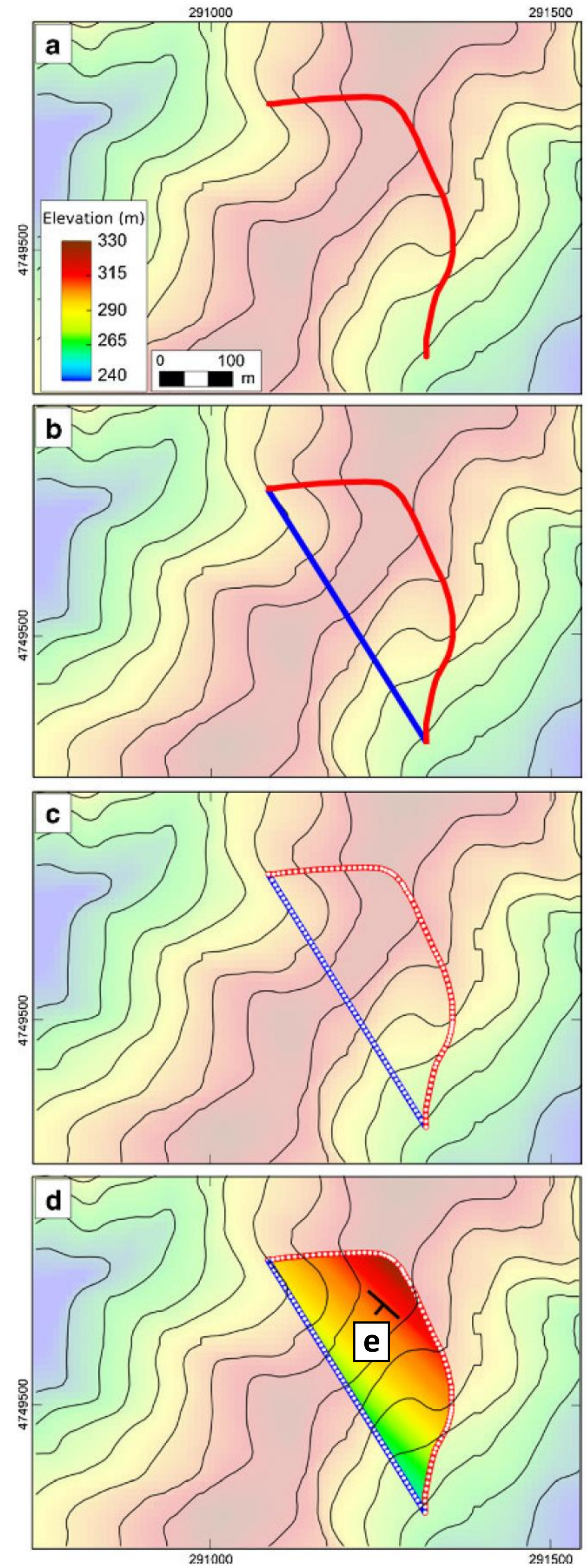
COMPUTATION OF TERRACE SURFACES ATTITUDE



• We select the traces of the fluvial terraces and computed their surface attitude following a procedure based on a GRASS GIS tool, geobed.py

• The geobed.py tool in origin was developed to reconstruct the attitude of bedding planes, and requires a bedding traces map and a DEM.

• In this contribution, a map of outer and inner edges of fluvial terraces were used in the place of the bedding trace map.



The script iterates five steps:

a) Trace of terrace edge (red line) is drawn on a base map.

b) End nodes of the red line are joined with a single segments (blue line) to form a polygon

c) Equally spaced points are selected along the boundary of the polygon, and their elevation is obtained from the DEM.

d) Elevation values along the trace of terrace edge are interpolated to obtain a 3D model of the terrace surface plane.

e) The mean values of slope (dip angle) and aspect (dip direction) of the terrace surface are then estimated

More about geobed.py tool here: Santangelo et al., (2015), *Landslides*, https://doi.org/10.1007/s10346-014-0485-x

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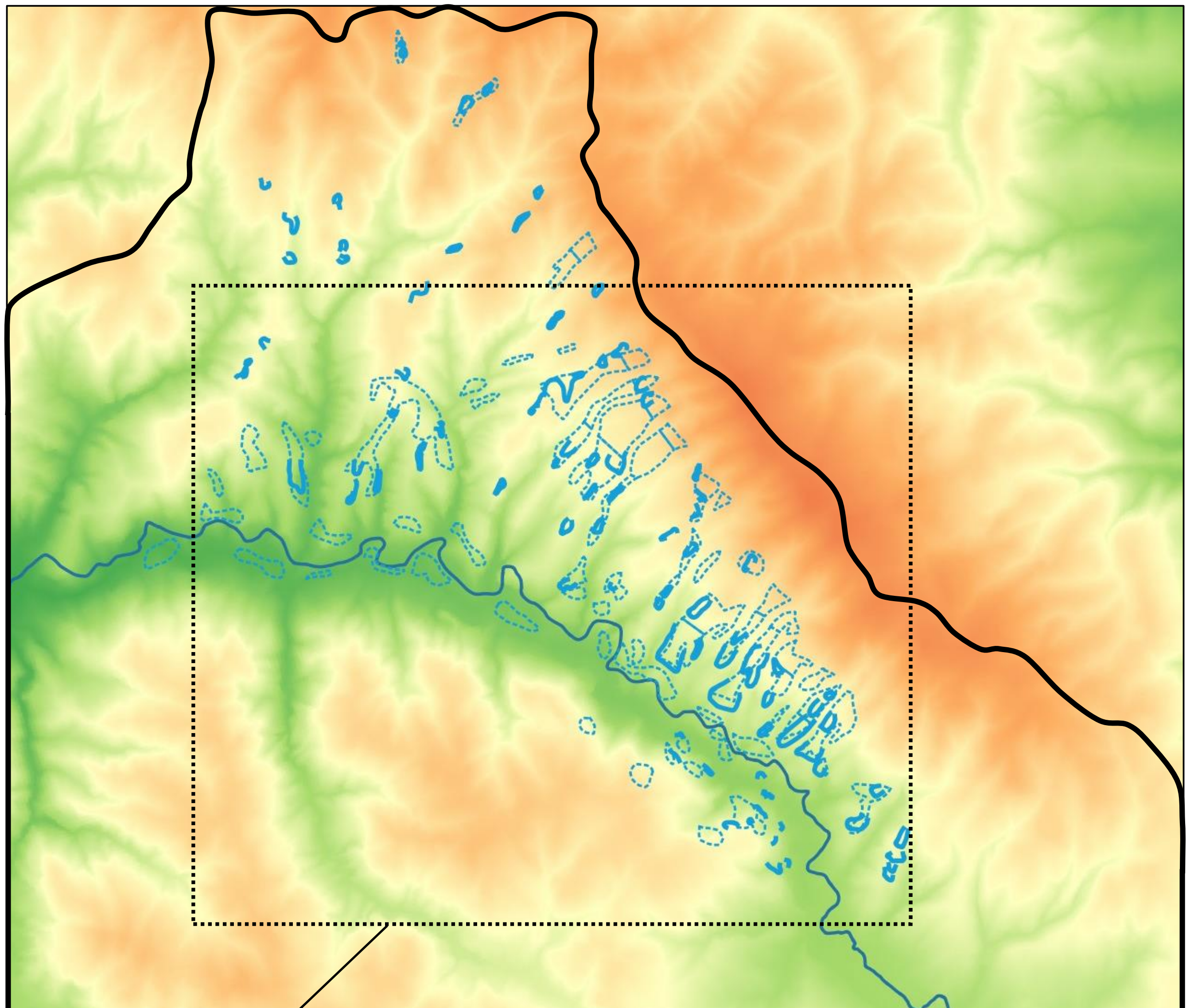
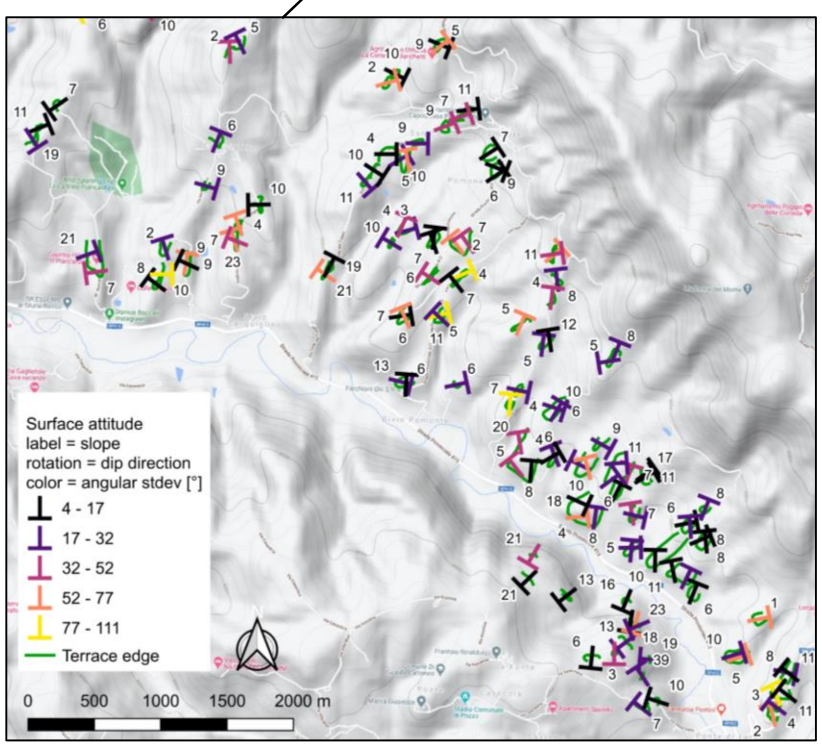
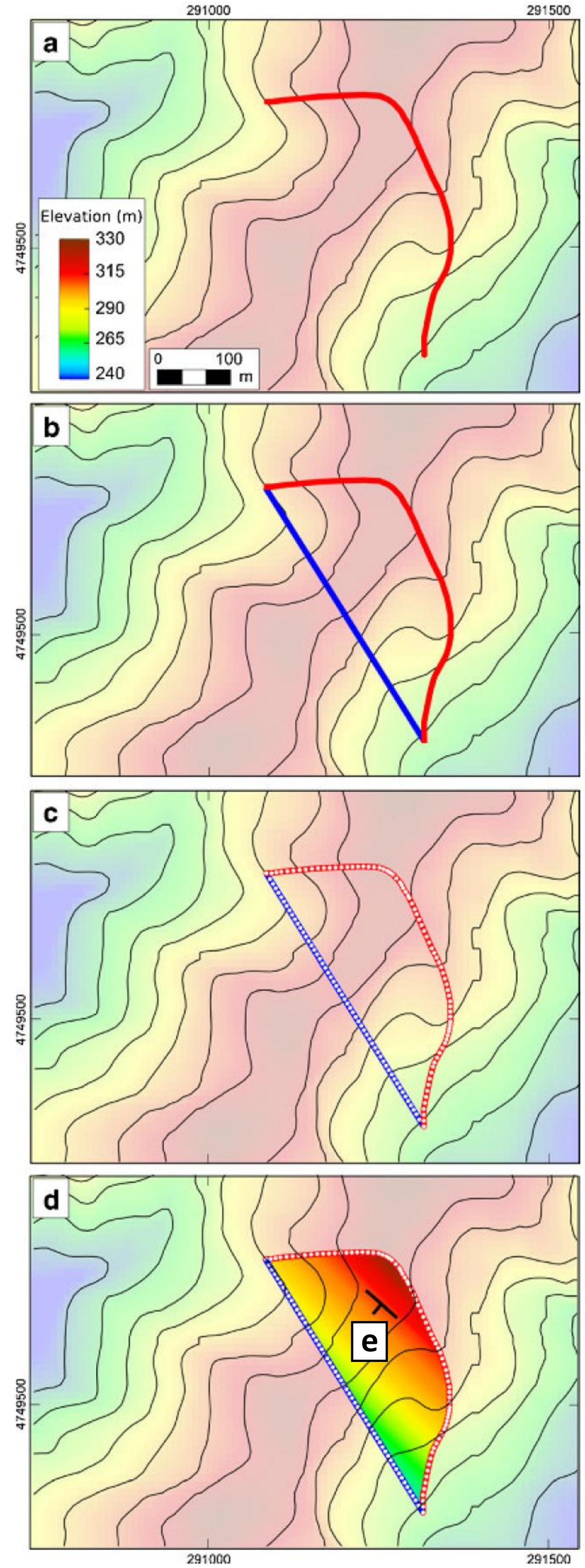




• The script returns a point vector map containing information on dip angle and dip direction of every terraced surfaces



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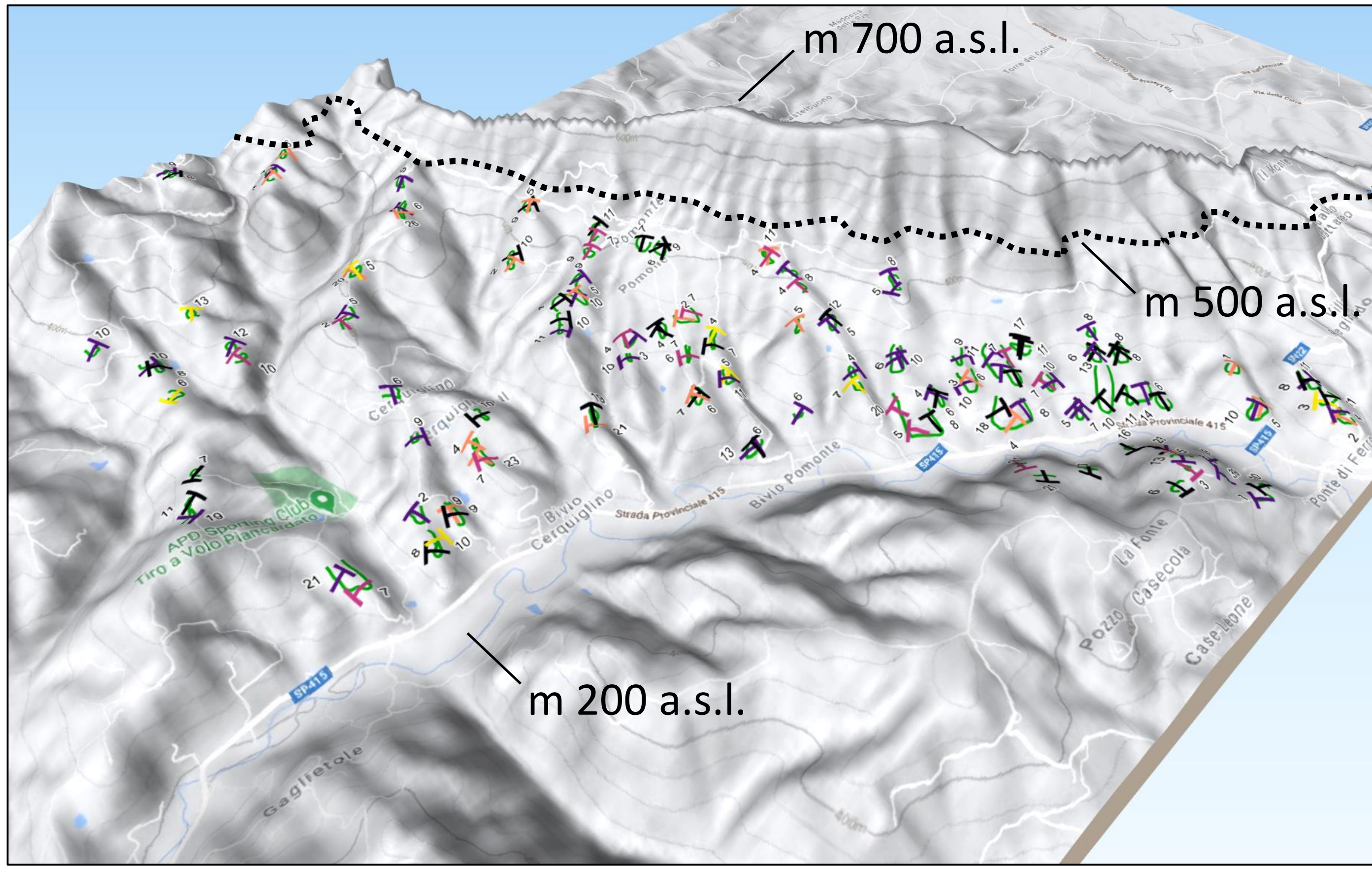
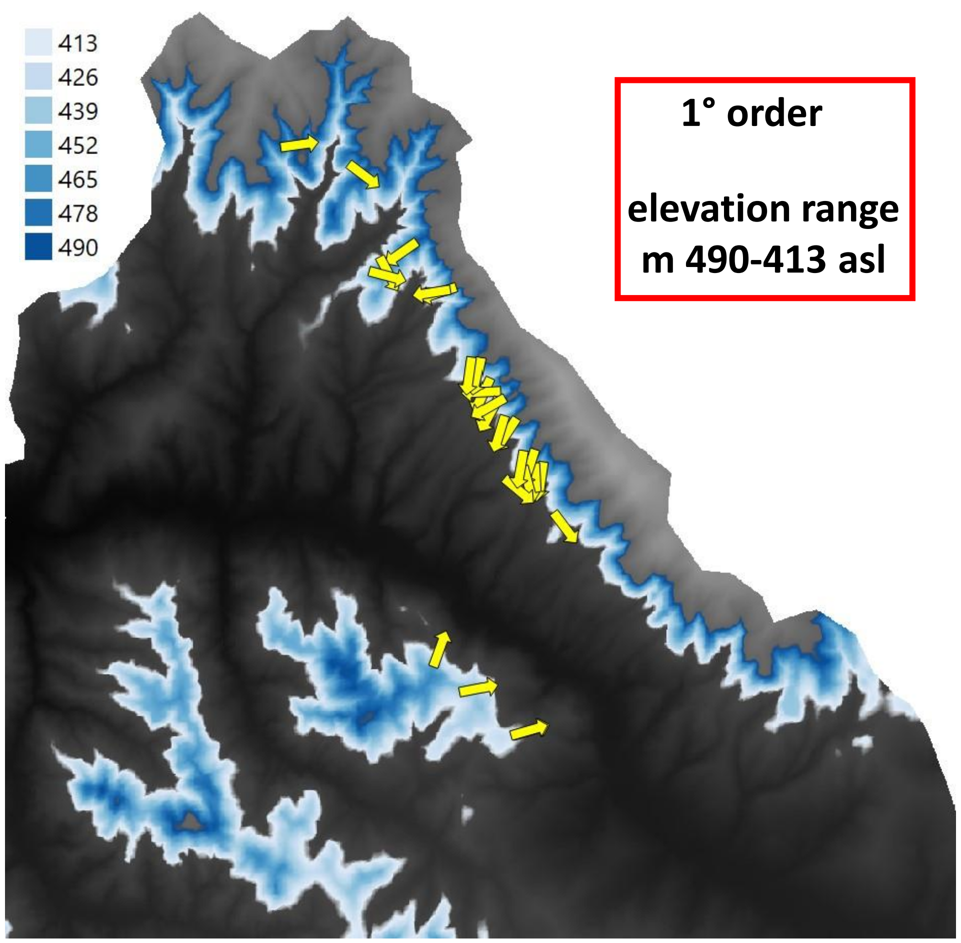
ATTITUDE AND ELEVATION OF FLUVIAL TERRACES

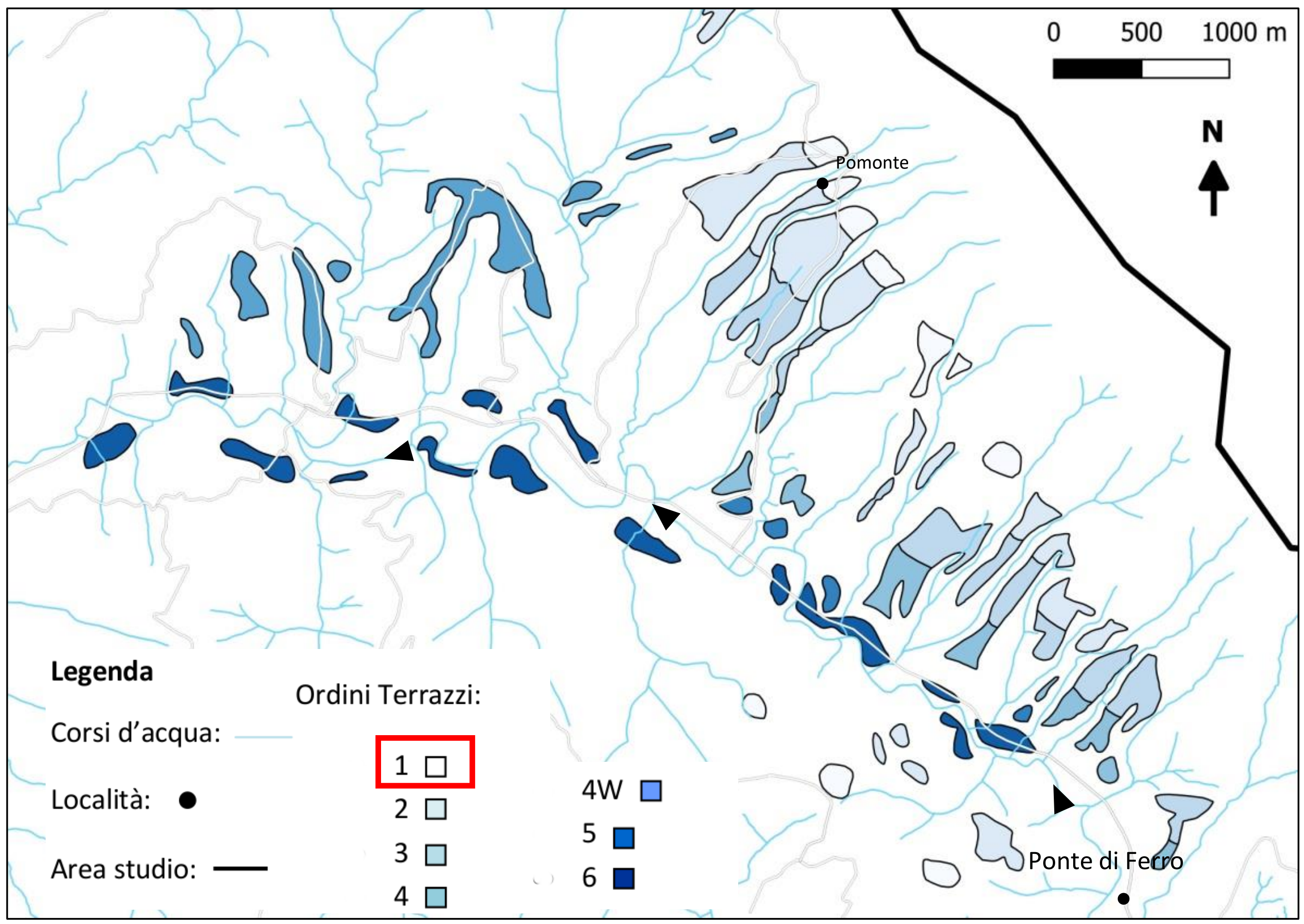
- At this point, terraces attitude data were separated and grouped by terrace order,
- displayed as arrows pointing toward the dip direction,
- and plotted on an elevation map with outlined, for each order, the range of elevation.





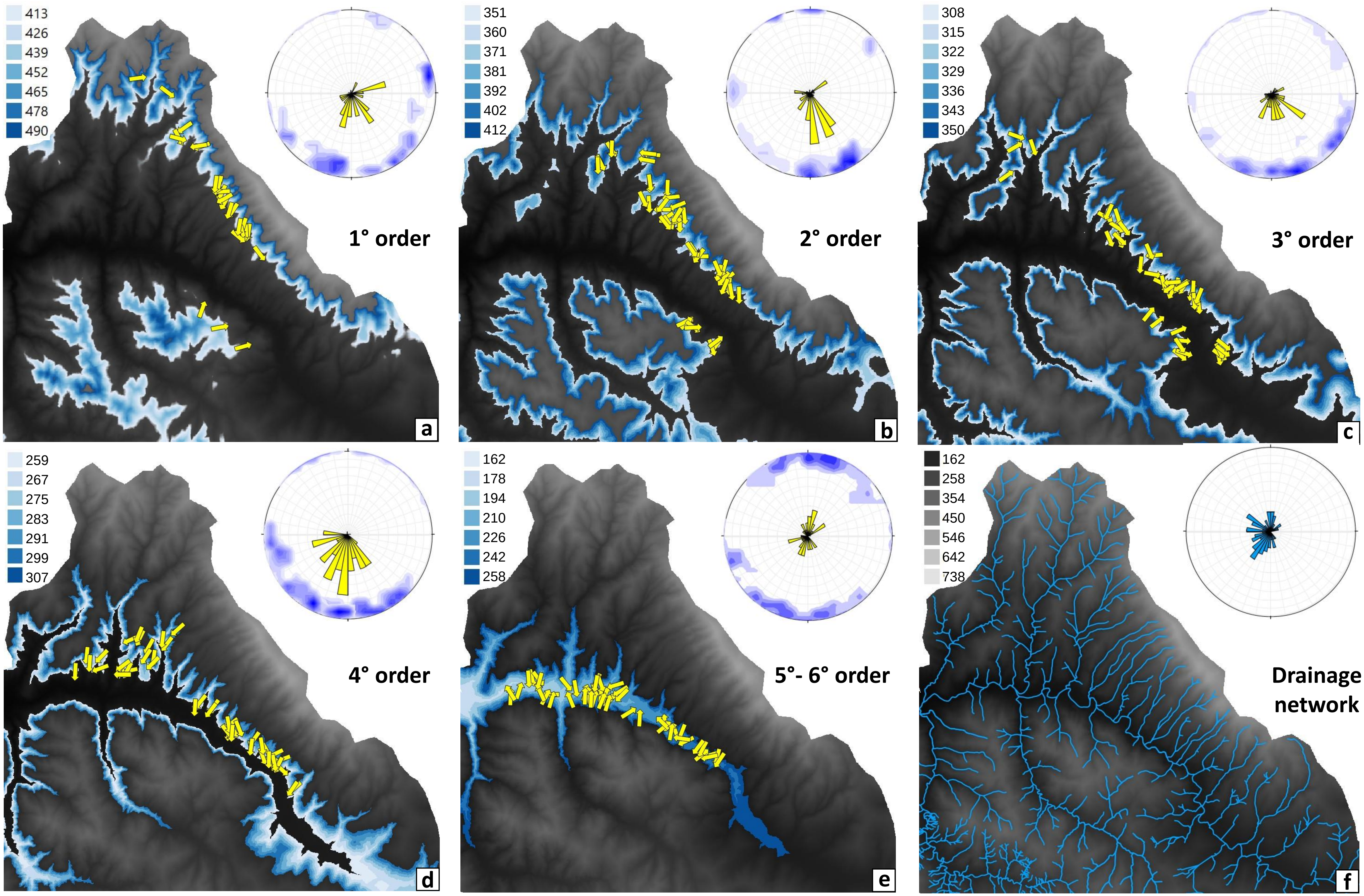
1° order

elevation range m 490-413 asl



CIRCULAR DISTRIBUTION OF DIRECTIONAL DATA

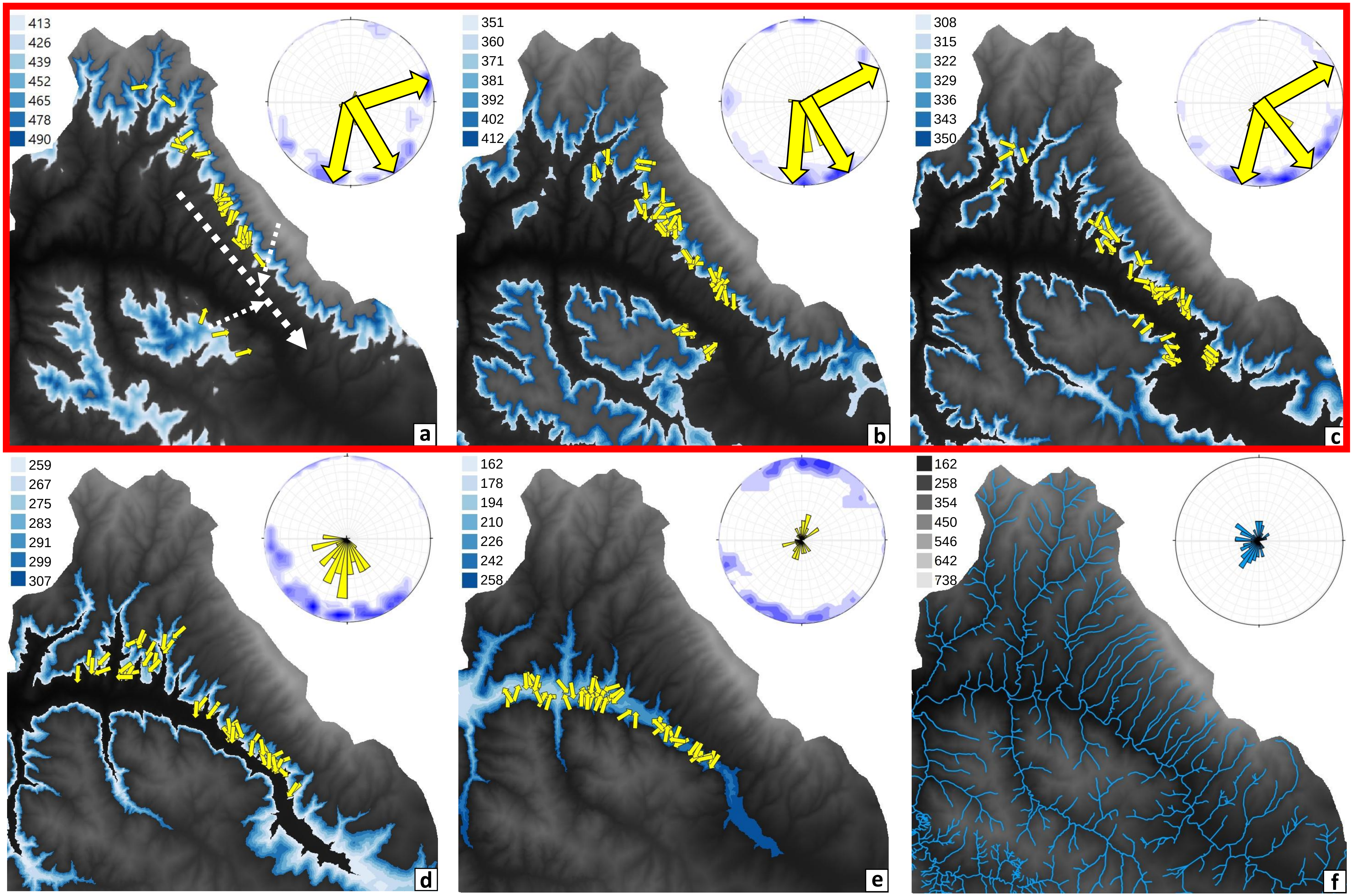
- For each orders, dip direction of terraces surfaces has been plotted in a rose diagram



- Flow direction of present day drainage network also was plotted for comparison

CIRCULAR DISTRIBUTION OF DIRECTIONAL DATA

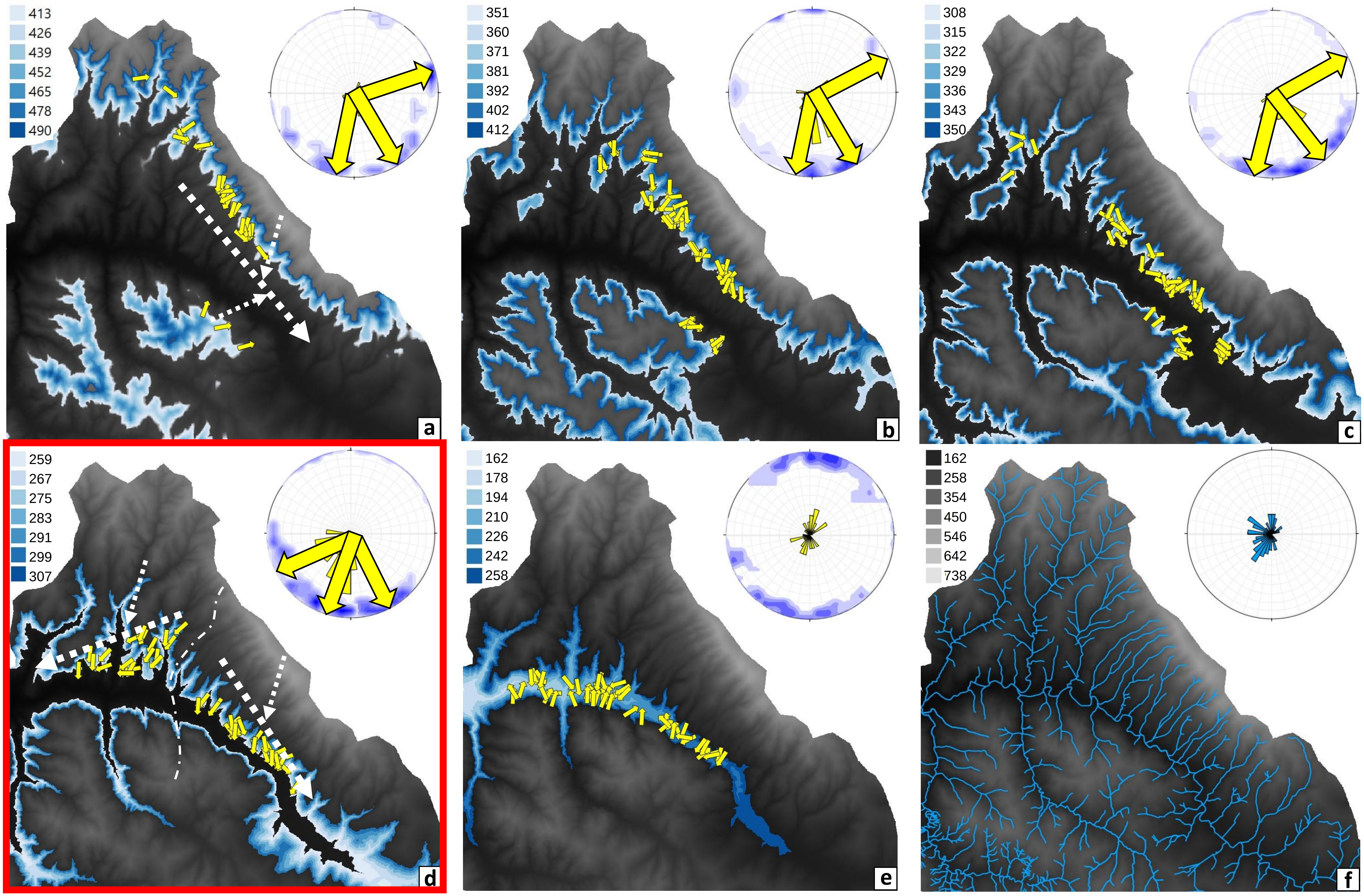
- Dip direction of the terraces orders 1, 2 and 3, displays three quite constant maxima



- SE direct arrows stay at lower elevation and are interpreted as flow direction of a river.
- SSW and NE direct arrows are interpreted as flow direction of left and right tributary.

CIRCULAR DISTRIBUTION OF DIRECTIONAL DATA

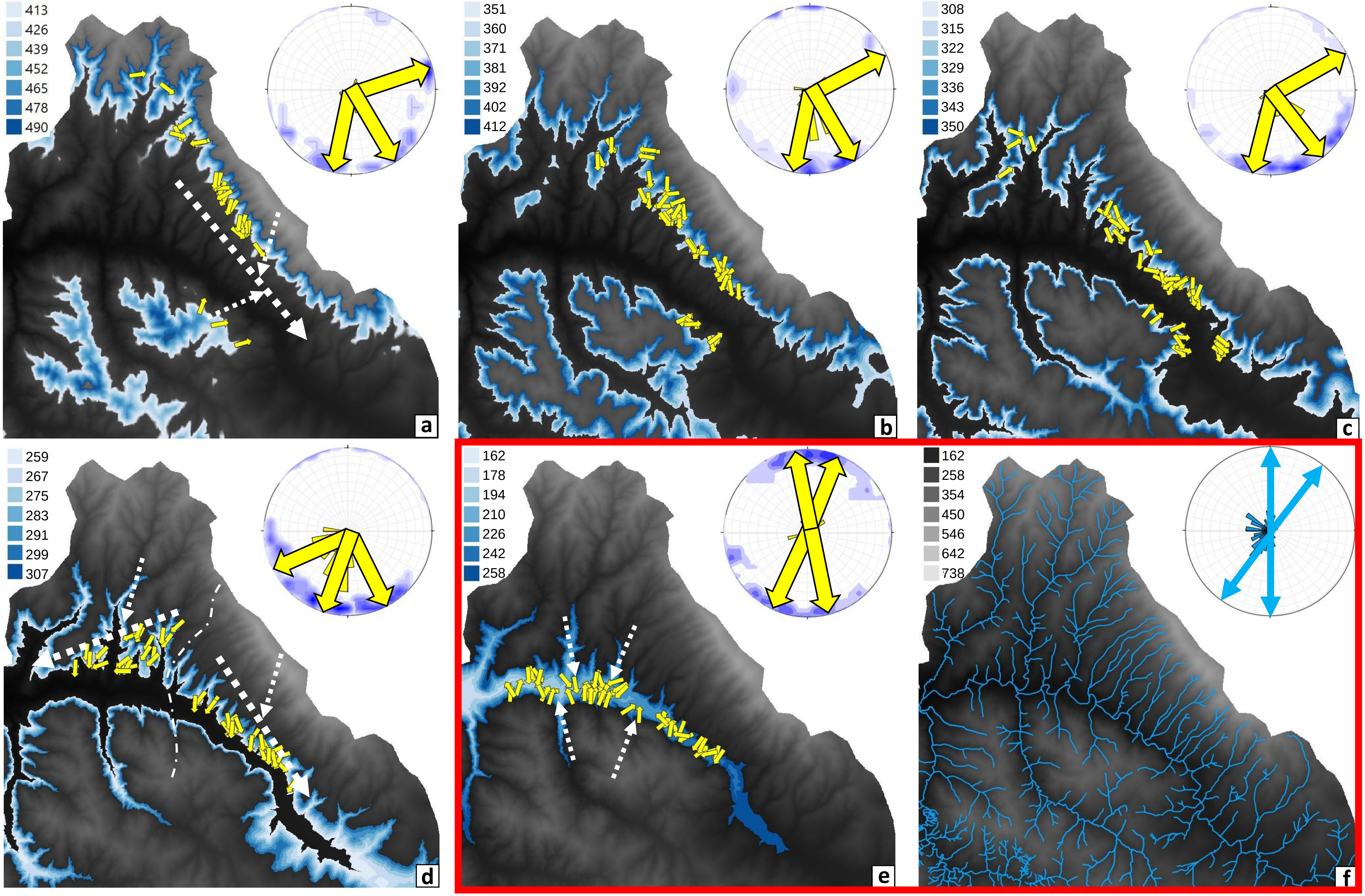
• Dip direction of the terraces order 4 displays a bimodal distribution, simmetric with respect to the SSW direct maximum which records the river tributaries coming from NNE



• A zone without terraces remnants separates all the SE and the WSW direct arrows
• The zone is interpreted as a transient divide (wihite dotted line) separating distinct rivers

CIRCULAR DISTRIBUTION OF DIRECTIONAL DATA

- The simmetric distribution of the dip direction of the 5 & 6 orders with respect to the NS direction is interpreted as evidence of the lateral streams contribution to the terraces building



- The same distribution is observed for the flux direction of the modern Puglia river tributaries

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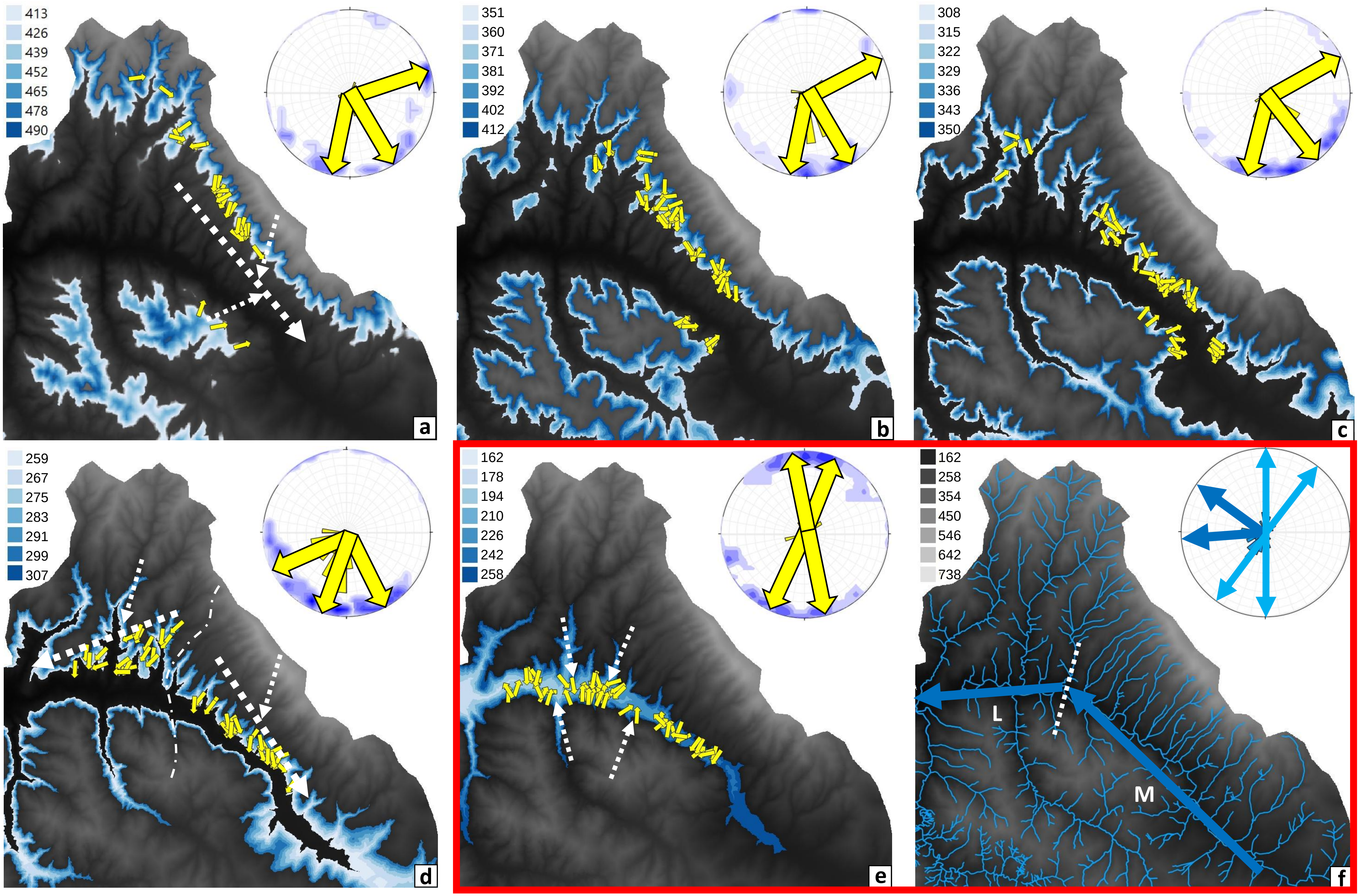
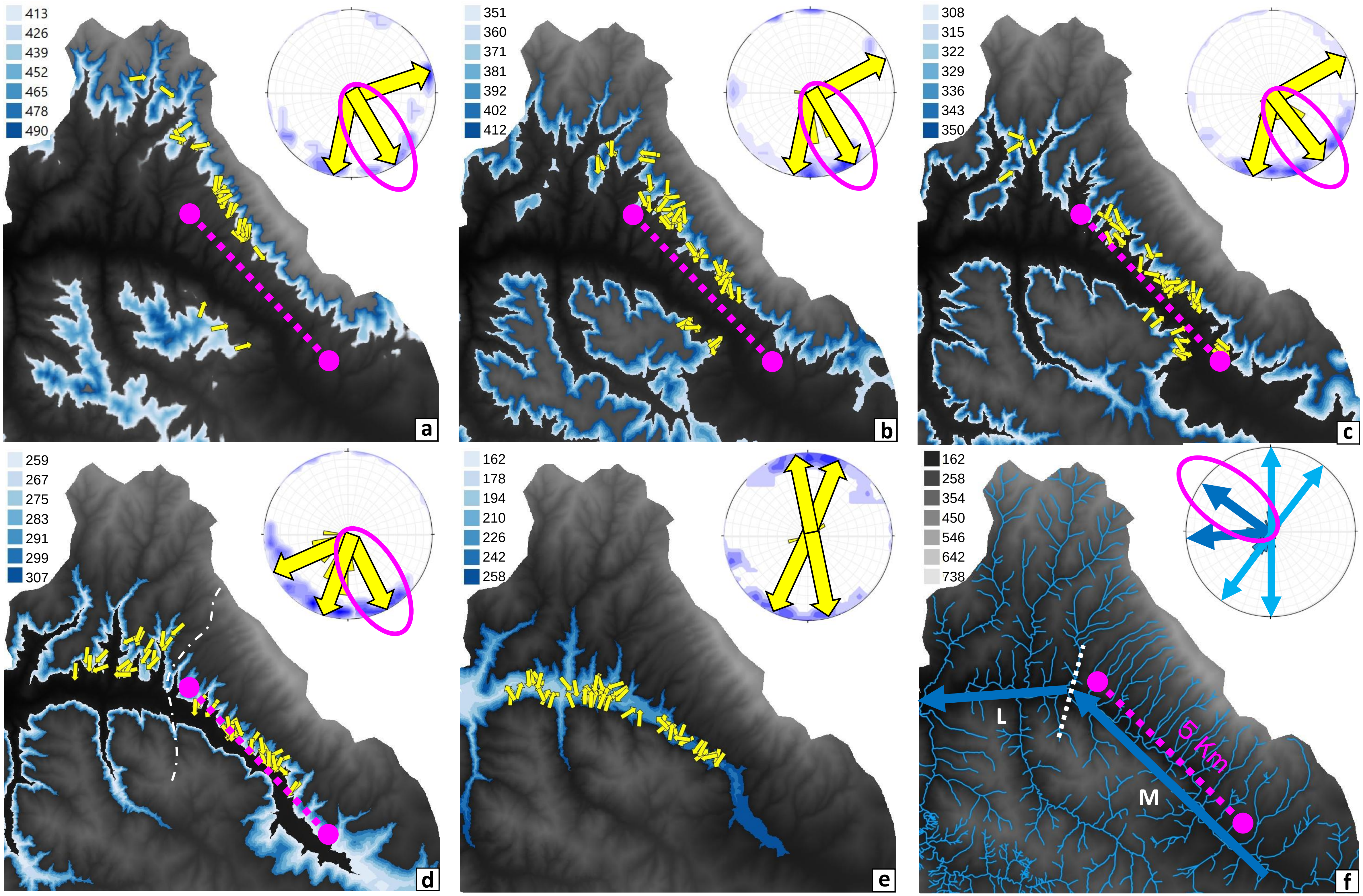


- The same distribution is observed for the flux direction of the modern Puglia river tributaries
- NW and W direct maxima record the present day flow direction of the Puglia river.

CIRCULAR DISTRIBUTION OF DIRECTIONAL DATA

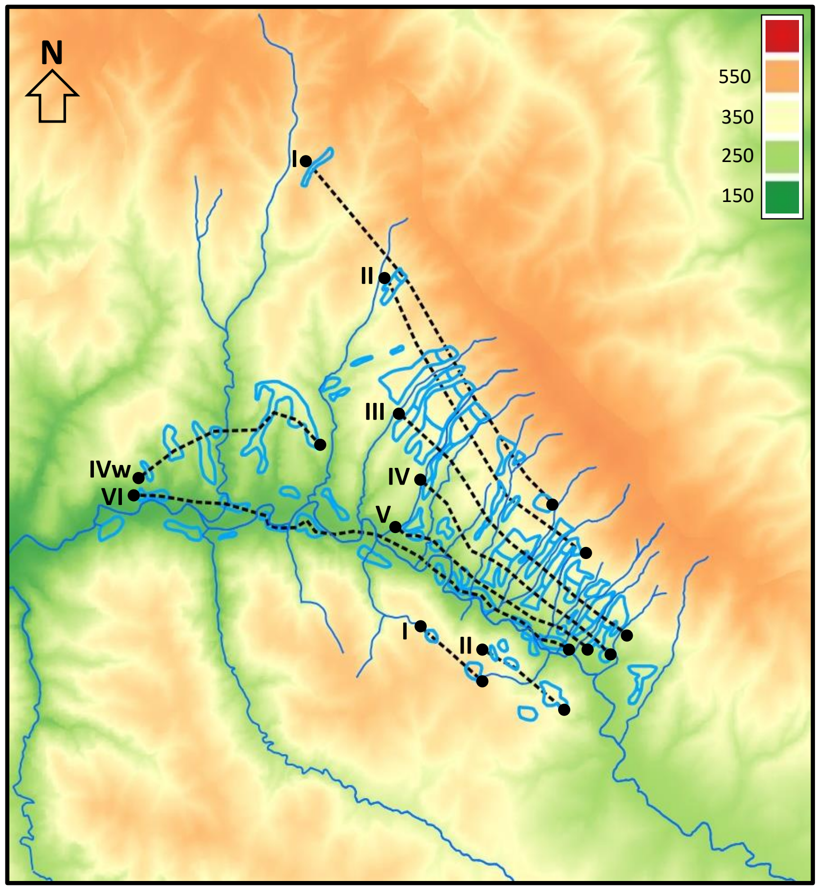
• The NW flux direction of the Puglia river is opposed to the SE maximum computed in the same area for the dip direction of the terraces surfaces of the order 1, 2, 3, and 4.

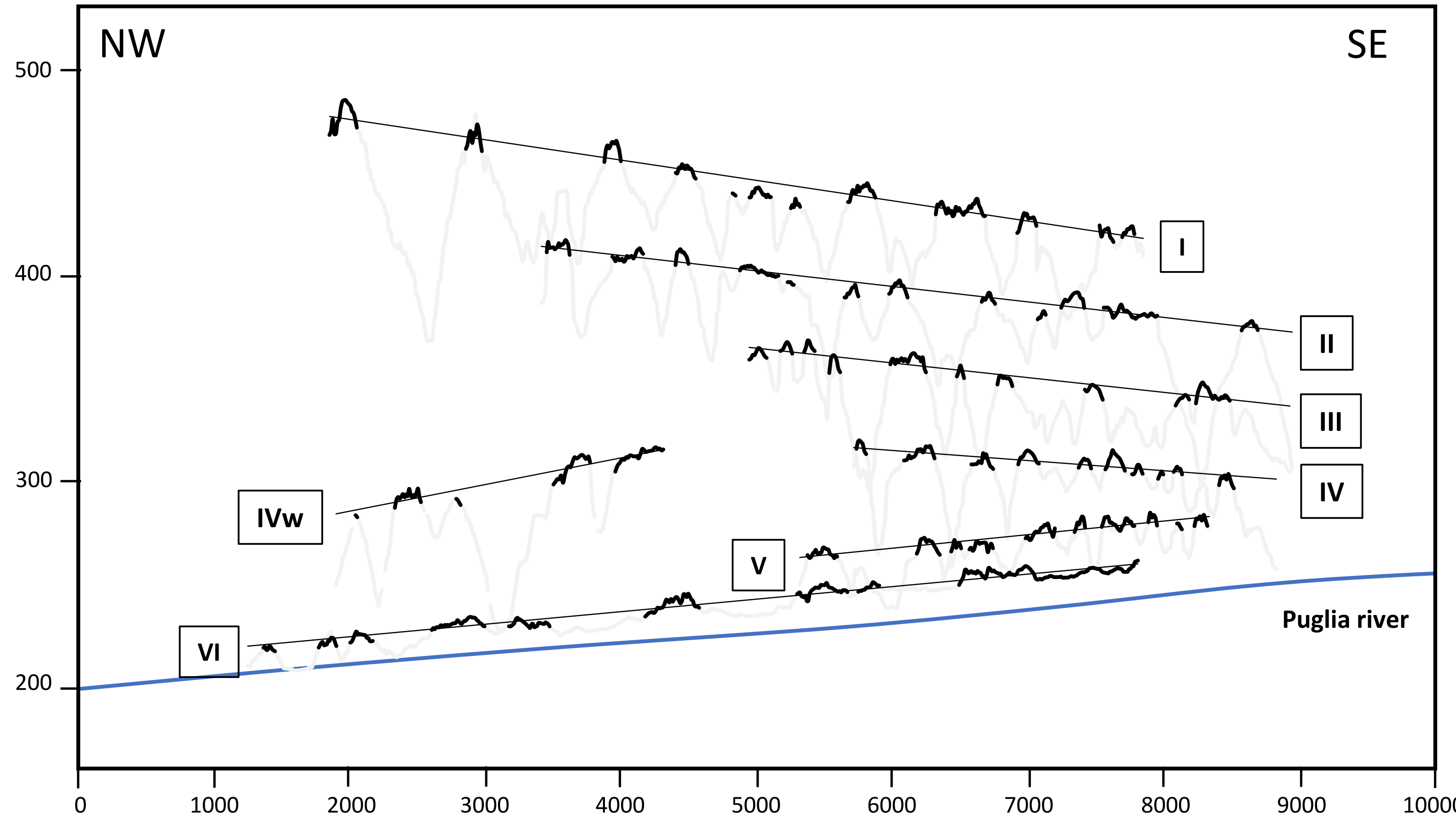


• We interprete the evidence as the result of a 5 km long inversion of the Puglia river course.

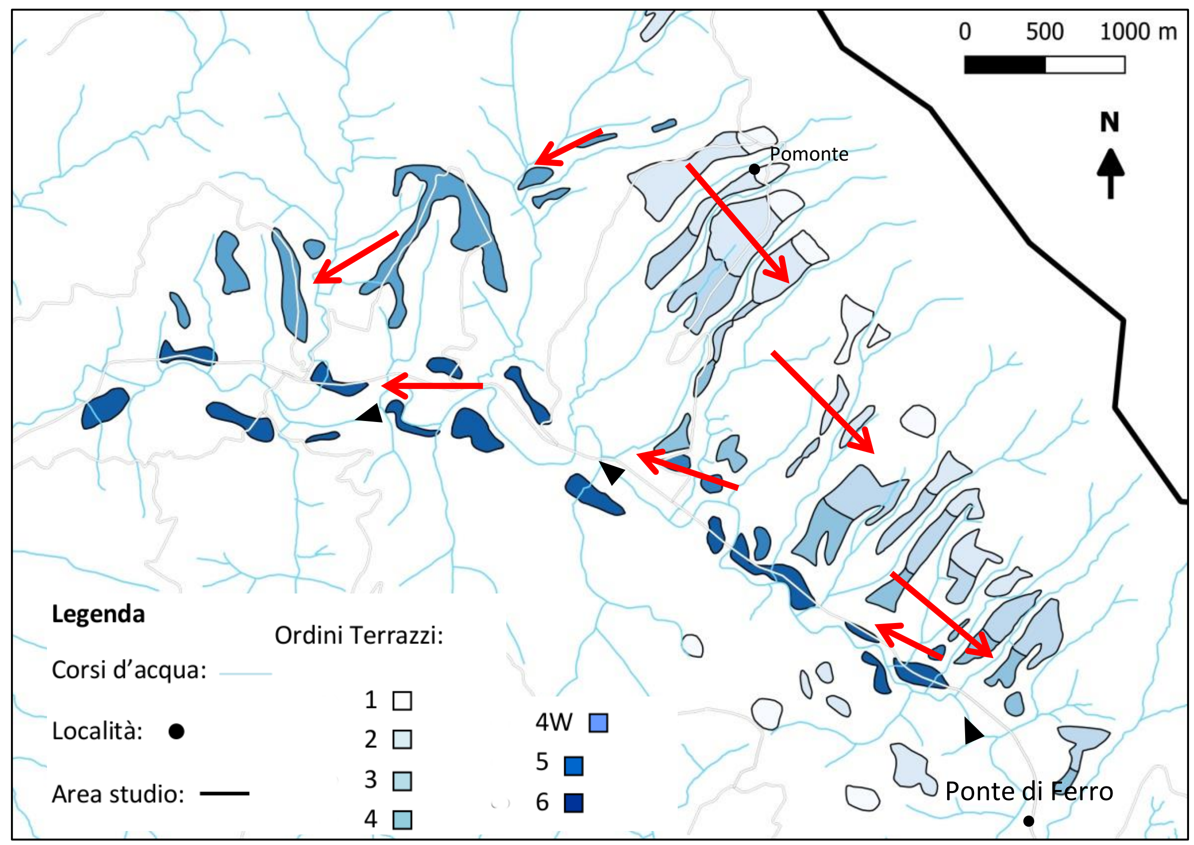
• Ancient Puglia river flowed toward the SE. Modern Puglia river flows toward the NW.

TERRAIN PROFILES OF FLUVIAL TERRACES





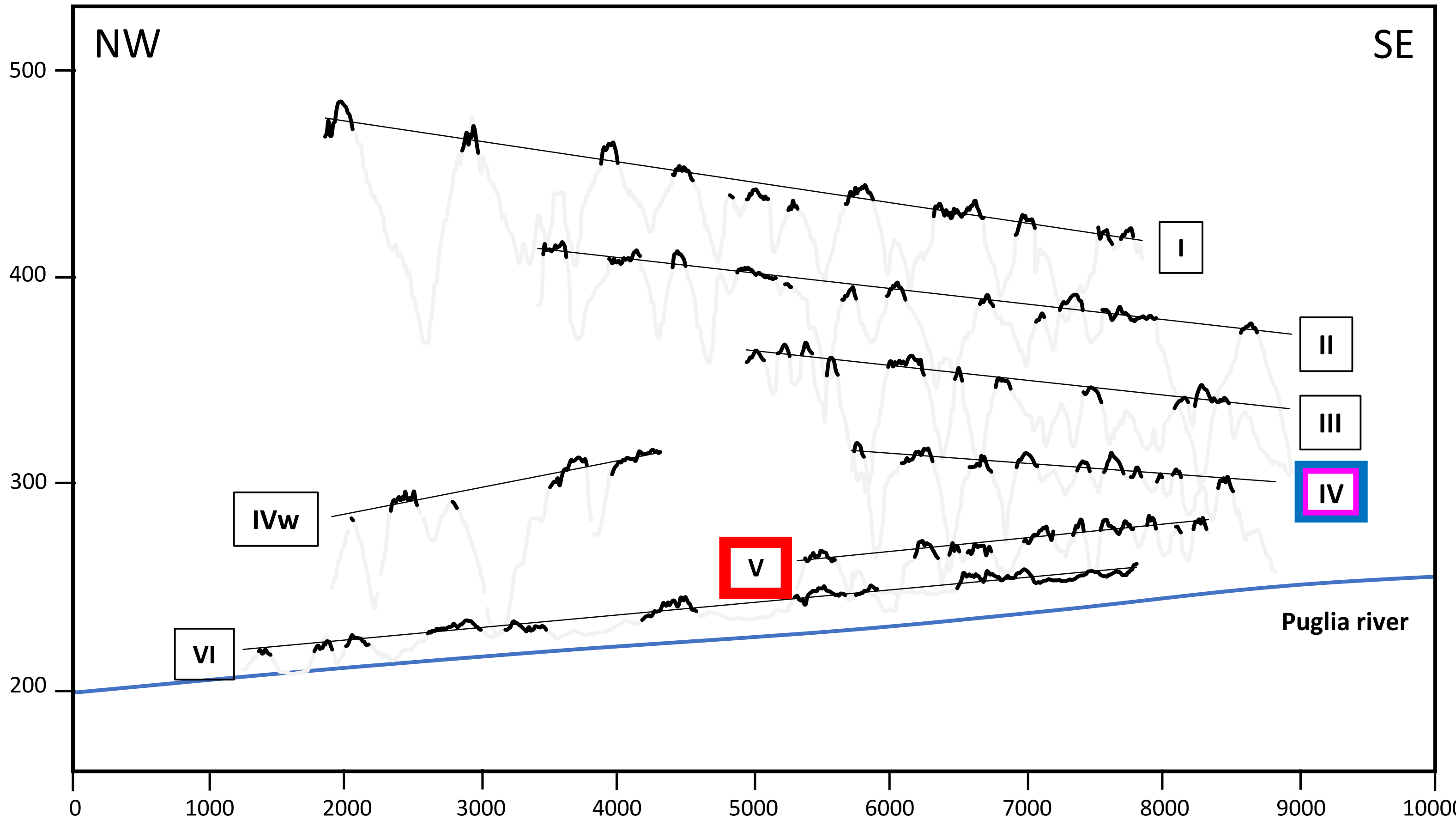
- Terrain profiles crossing terraces of the same order confirm the results of rose diagram analysis.
- Profiles I, II, III show well the SE dipping paleo-profile of the ancient Puglia river
- The Profile IV supports the interpretation of a divide between two opposed rivers.
- Profiles V and VI are consistent with the modern Puglia river profile
- Overall, terrain profiles show a progressive cannibalization of the ancient Puglia river course

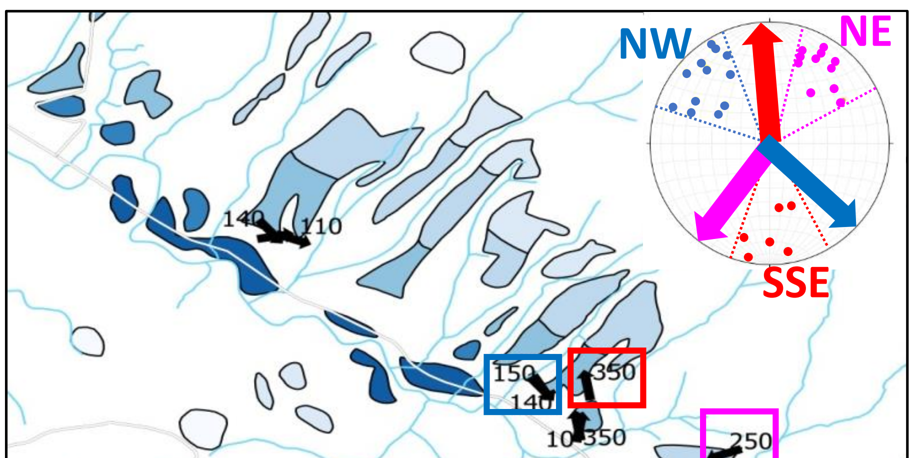


FIELD SURVEY: PEBBLE IMBRICATION

- Directional data of pebble imbrication from terraces orders IV and V confirm the interpretation of river inversion

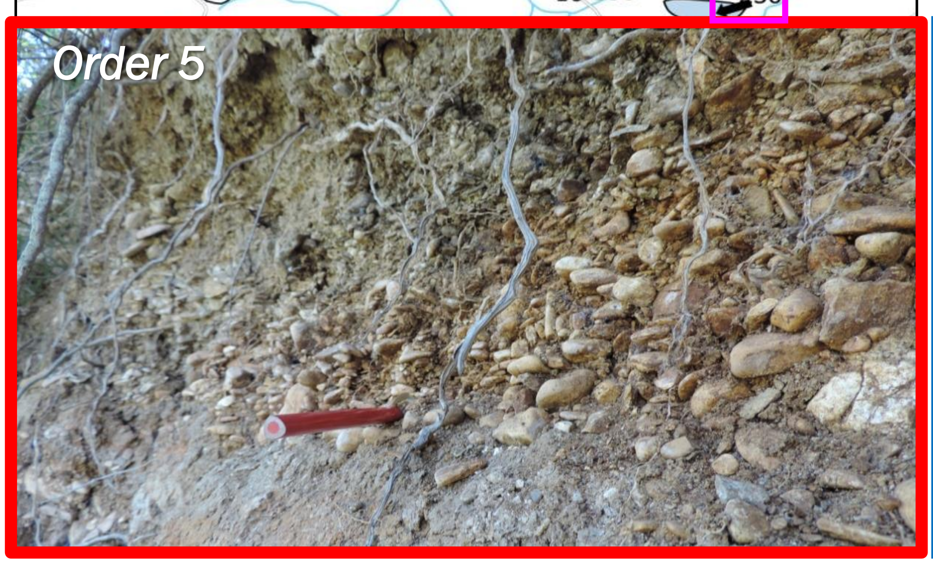
- Red arrow is related to pebble imbrication in deposits of the order 5, and indicate a NNW flow direction, which is consistent with the reversed Puglia river course.





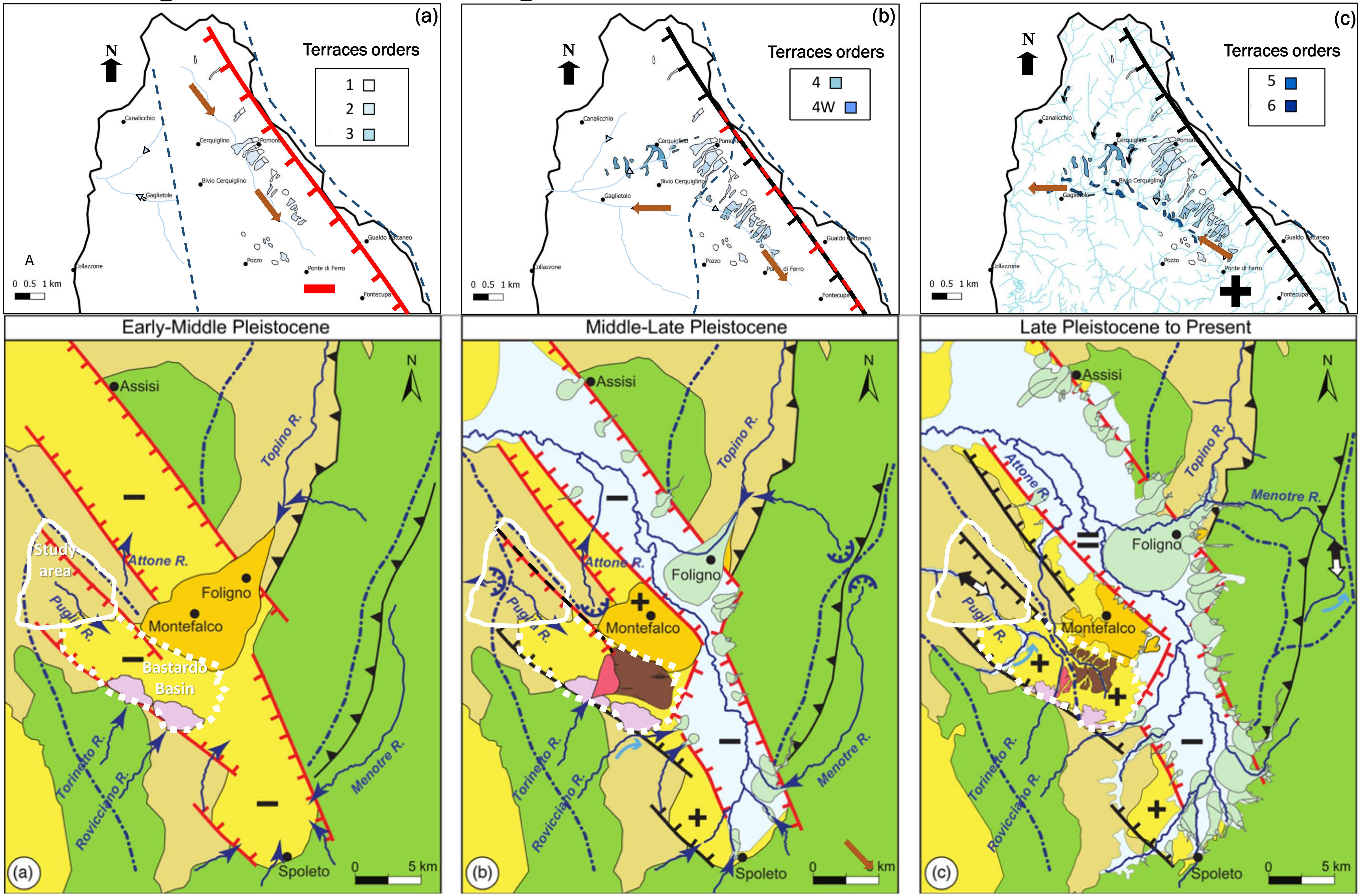
- Blue arrow is related to the order 4, and indicates a SE flow direction, which is consistent with the paleo-river course.

- Pink arrow is related to the order 4, and indicates a SW flow direction which is consistent with the lateral streams contribution.



MODEL OF TIME/SPACE REVERSAL OF PUGLIA RIVER

- The Puglia river evolution is integrated in an evolution model of the central Umbria



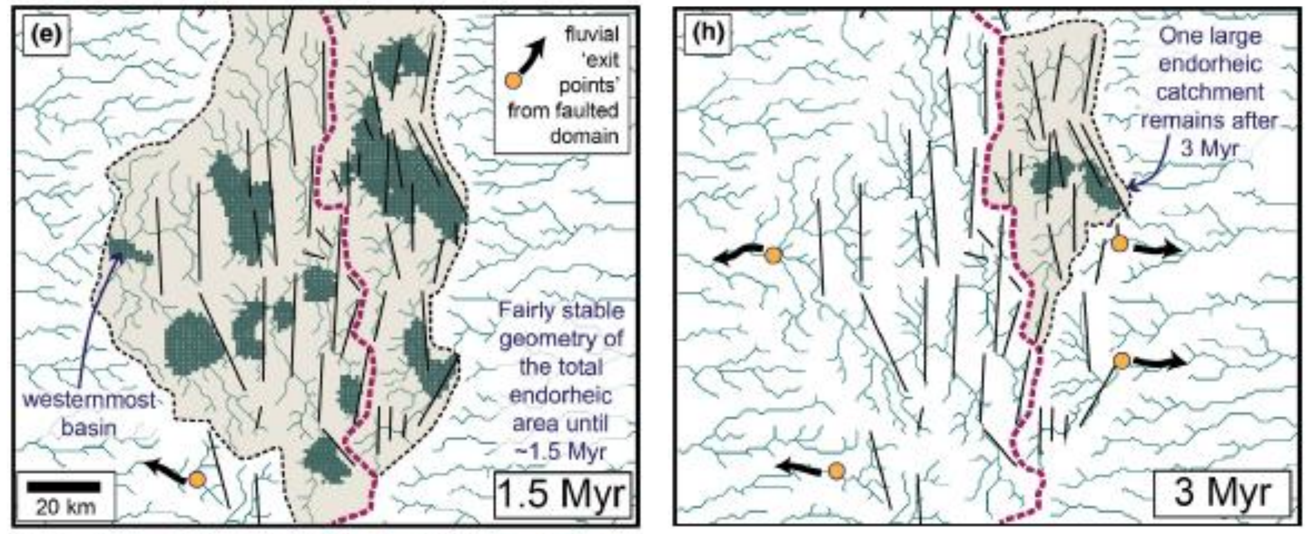
- According to the model, the Puglia River capture and reversal was driven by the progressive end of active faulting in the Puglia Valley, and its shift in the Foligno Valley.

More about the evolution model here: Mirabella et al., (2018), *JGS, London*, https://doi.org/10.1144/jgs2017-138

IMPLICATIONS AND CONCLUDING REMARKS

Tetonic geomorphology

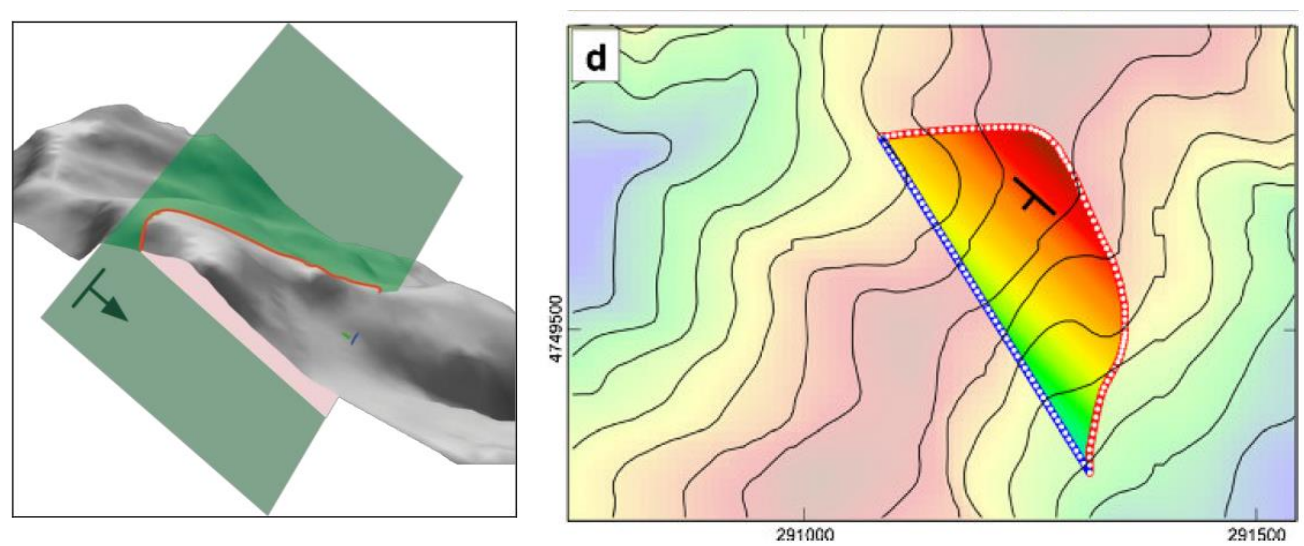
- The main implication of our finding is that fluvial reversal can be use as a geomorphologic indicator of changing in rate and locus of tectonic deformation, benefiting active tectonic studies.
- Well documented fluvial reversal events can be used as costraints within landscape evolution model under variable tectonic forcing



Geurts et al., (2018), *Basin Research*, https://doi.org/10.1111/bre.12315

Methodology

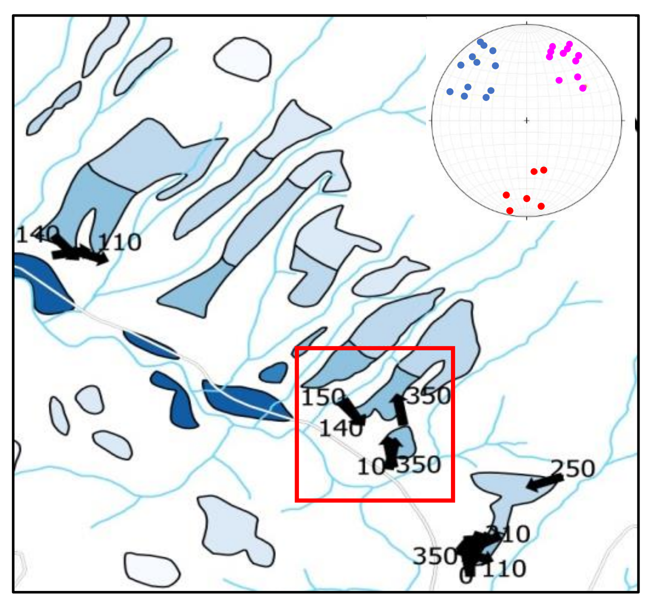
- The method was set up for bedding trace analysis, but it works well for terrace edge analysis too.
- The findings open at the possibility to apply the method to others mapped traces with a geomorphological significance, as planation surfaces, abandoned valley, paleo shoreline ecc.



Santangelo et al., (2015), *Landslides*, https://doi.org/10.1007/s10346-014-0485-x

What next

- To date (OSL?) the river terraces (main target is the IV order), which will allow determine the timing of the inversion of the Puglia river, and will help to constraint the space-time changes of fault activity.
- To Investigate other river inversions to test and/or strengthen the drowned conclusion



THANK YOU!

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