A GIS method for obtaining geologic bedding attitude

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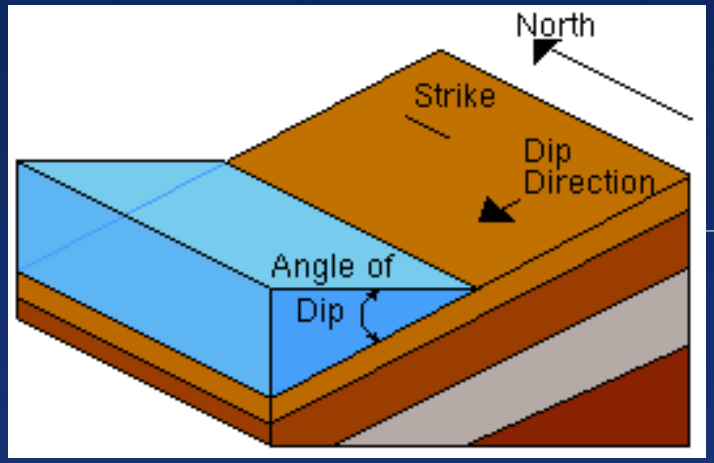
Synopsys

- Introduction
- Bedding trace mapping through the interpretation of aerial photographs
- Bedding attitude estimation through a GIS script
- Case study
- Discussion and conclusion

Definitions

- Bedding attitude is commonly expressed by dip direction and dip angle (inclination) values



http://www.geologyrocks.co.uk/tutorials/introduction_to_structural_geology

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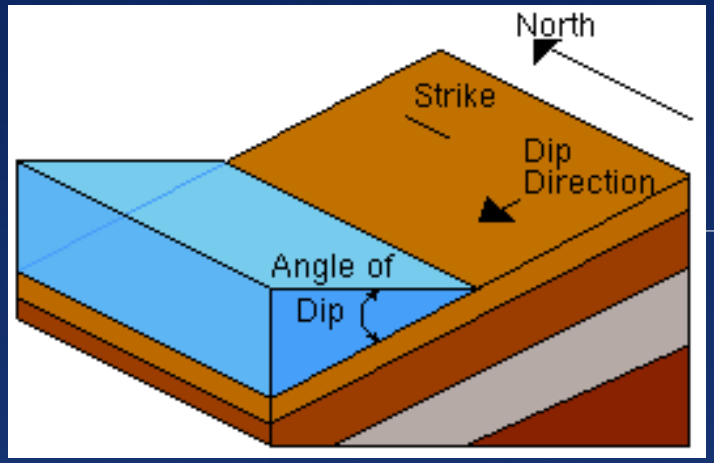

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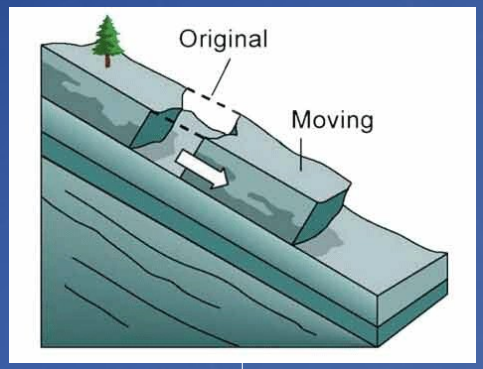
- In the geomorphological applications the bedding attitude (BA) information is important for the determination of landslide susceptibility (Guzzetti et al. 2006)

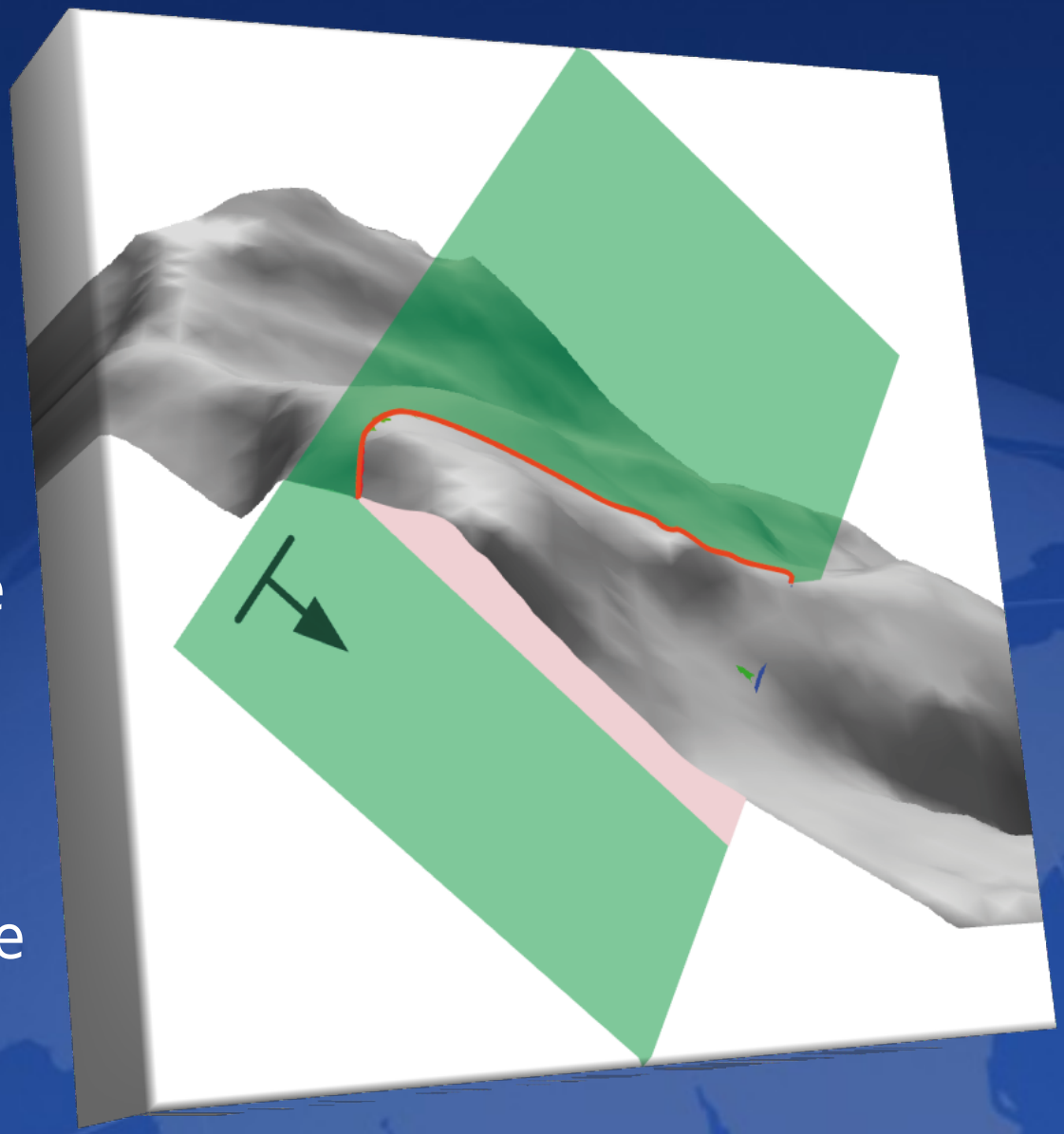
http://blogs.agu.org/landslideblog/files/2010/10/08_07-vancouver-slide-2.jpg



http://www.aegweb.org/images/Geologic%20Hazards/rockslide_schematic.gif

Definitions

- **Bedding Attitude (BA):**
  - defined by dip and dip direction
- **Bedding Surface (BS):**
  - the flat surface that locally approximates the bedding plane
- **Bedding Trace (BT):**
  - the intersection line between a bedding plane and topography



Bedding attitude acquisition

- Through the interpretation of aerial photographs (API) only BA qualitative (!!) data are commonly collected

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- We are interested in obtaining, using API, quantitative (!!) BA data, like those obtained during geological survey

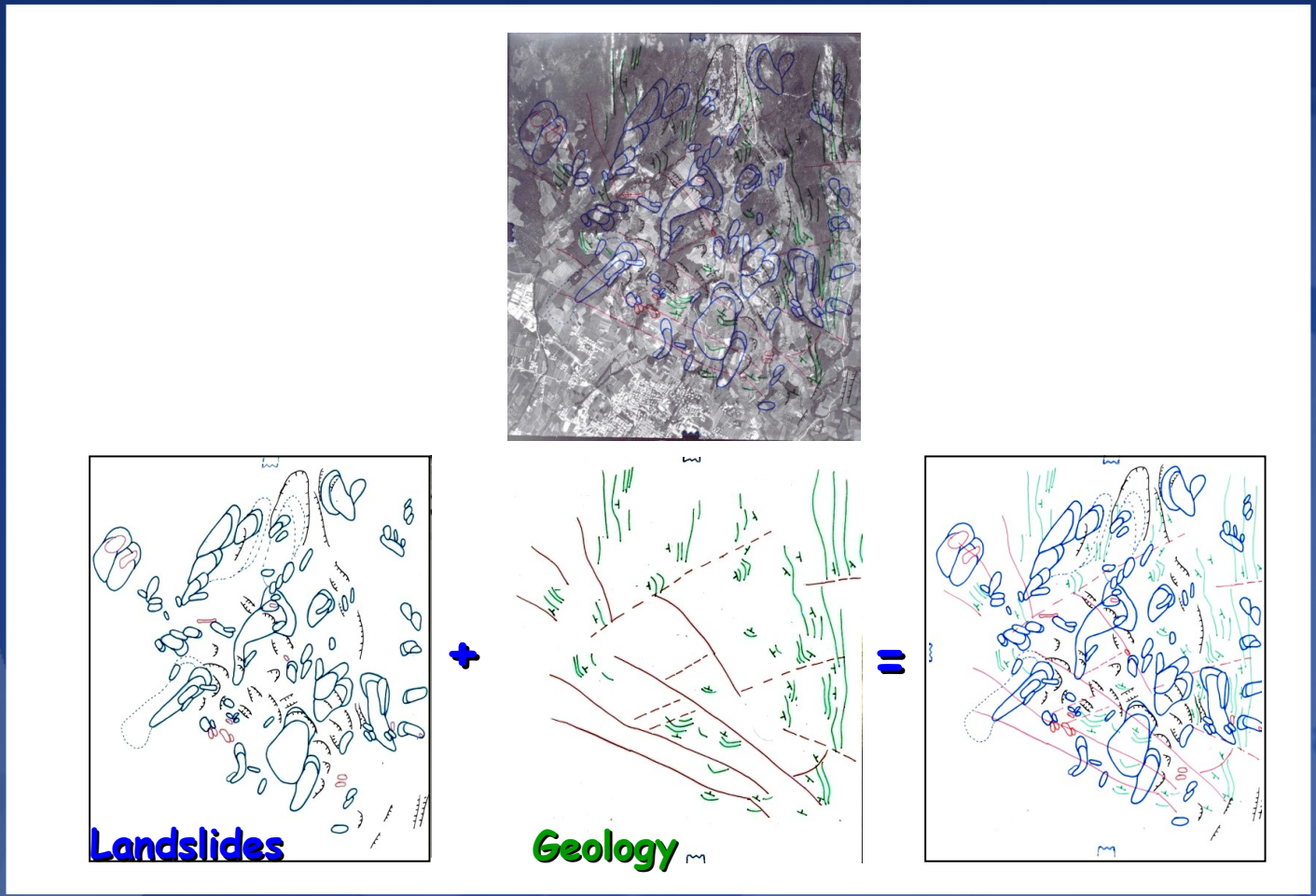
http://commons.wikimedia.org/wiki/File:Liquid_filled_compass.jpg

Aerial Photographs Interpretation

- The interpretation of aerial photographs is an empirical and subjective process

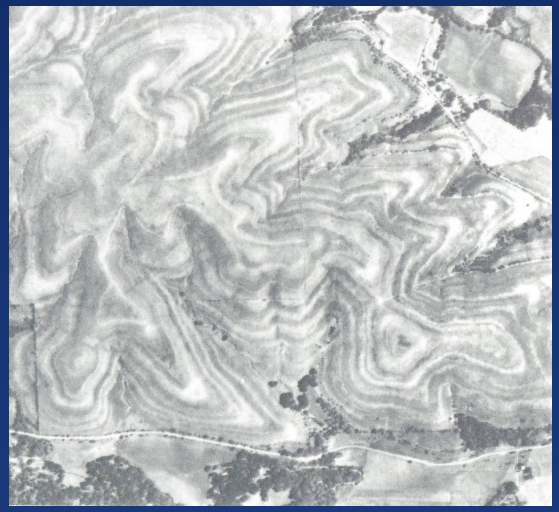
Aerial Photographs Interpretation

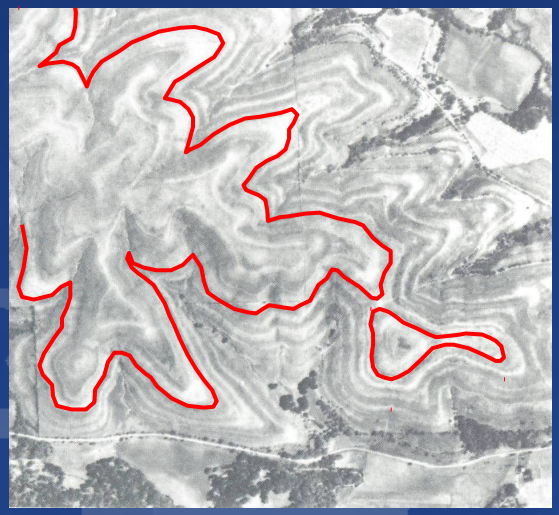
- To look for geomorphological and geological feature



API of bedding traces

Colors and tones





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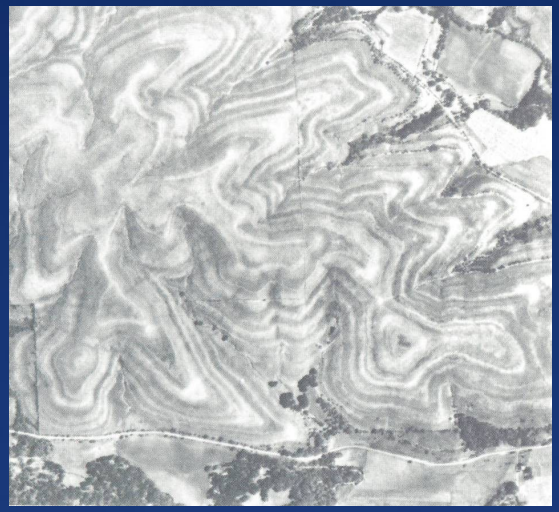
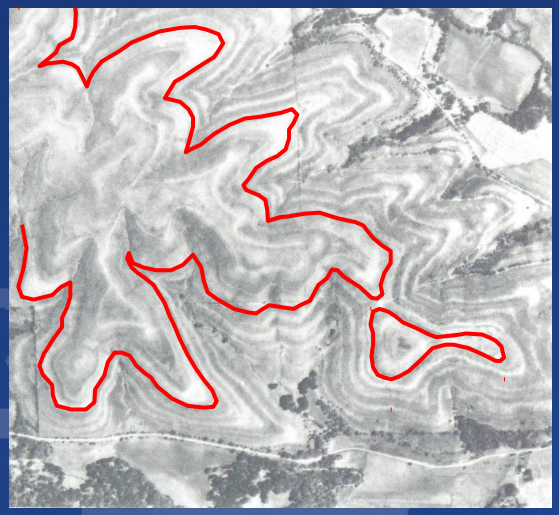
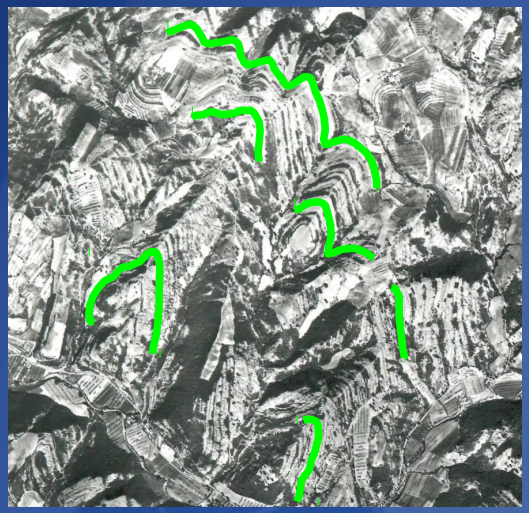




Vegetation



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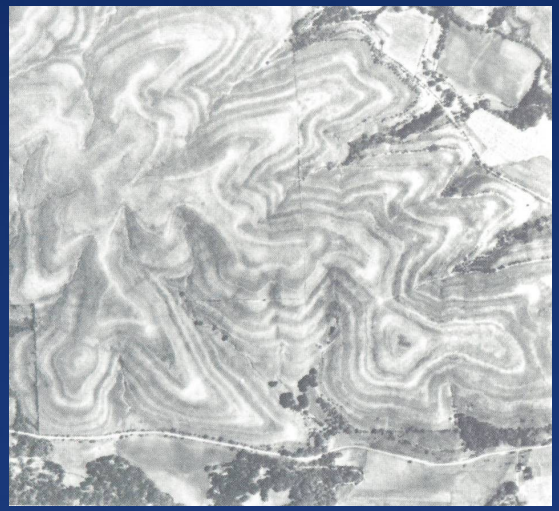

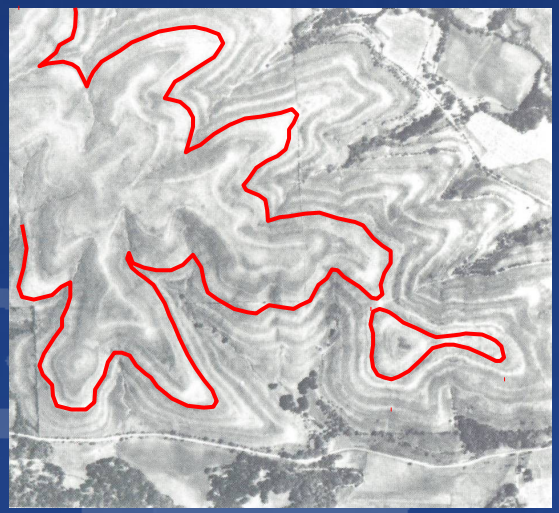

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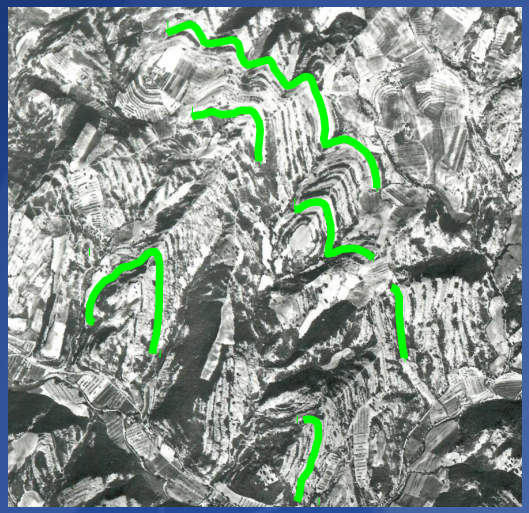
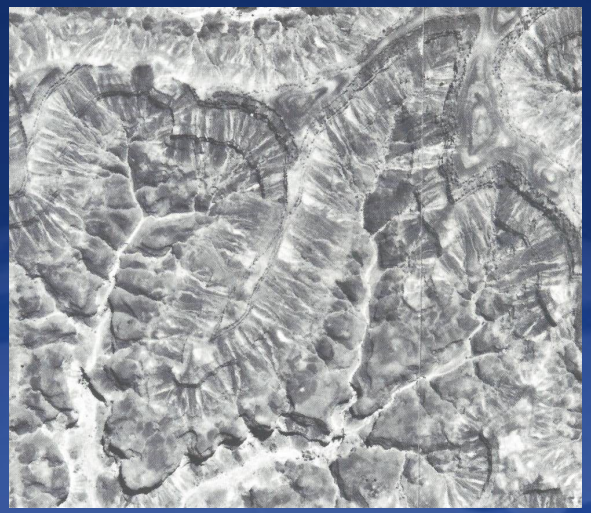


Relief



Field evidence of bedding traces

- A closer look, using field evidences, in case of uncemented sand, silt and clay

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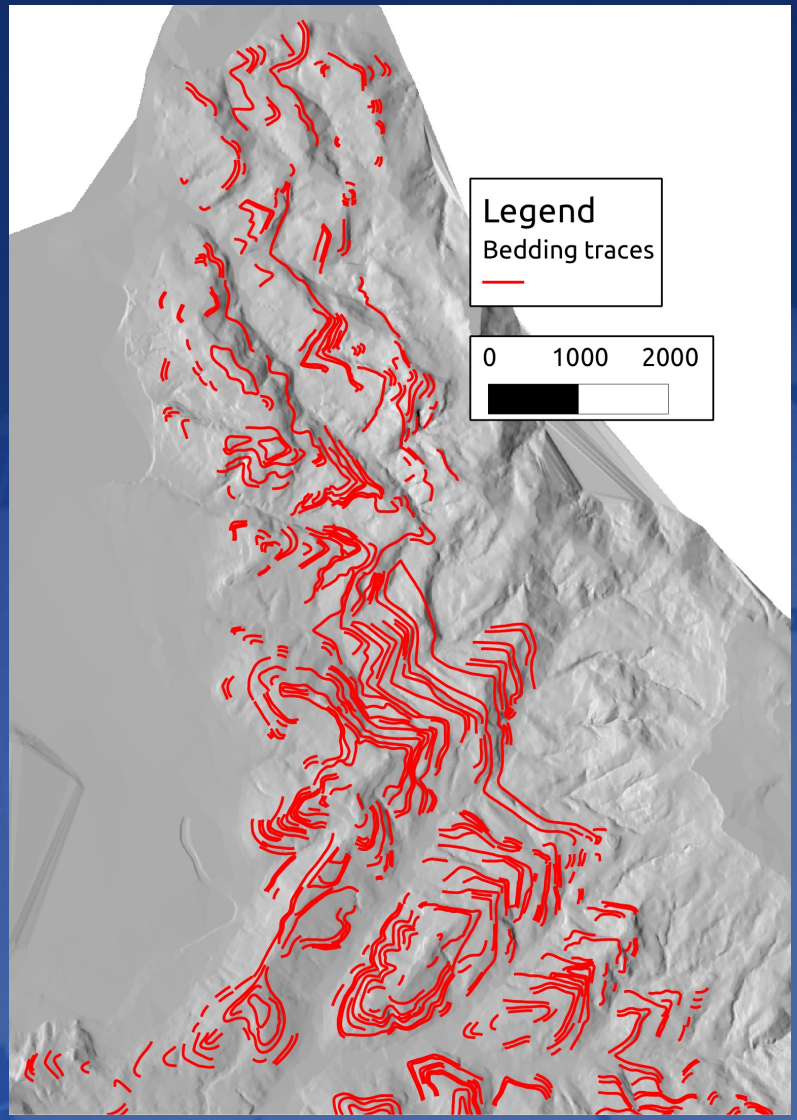
BT for the Collazzone test area

- As an example we show the BT (in red) of the Collazzone test area (Central Italy)
- Created using stereoscopic b/w aerial photographs taken at 1:33.000 scale in 1954
- These bedding traces were already been used for a landslide hazard assessment study (Guzzetti et al. 2006)
- The same data was used for the case study we are going to describe later



BA estimation through a GIS script

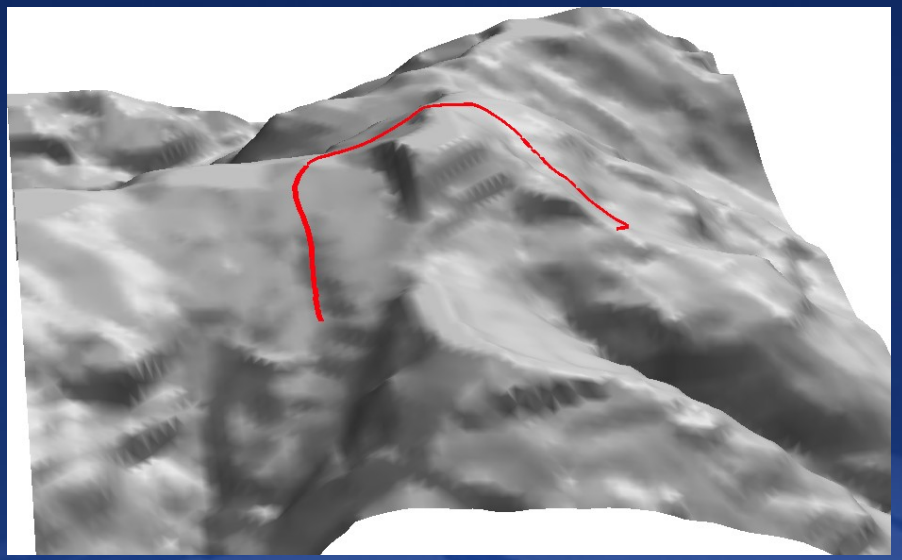
- As already mentioned we were interested in rapidly obtain BA **quantitative** estimations starting from aerial photo-interpretation
- In order to solve this problem we have created a GIS tool:
  - it is a simple GRASS GIS script
    - The requested Inputs are:
      - A bedding traces layer
      - A DEM
    - The Output is:
      - A vector layer of points whose attributes contain information on dip angle, dip direction, and associated uncertainty

GIS script (1)

- Five steps (loop for each BT)

1) The bedding trace (BT) is draped on the DEM, becoming a 3D line

1)



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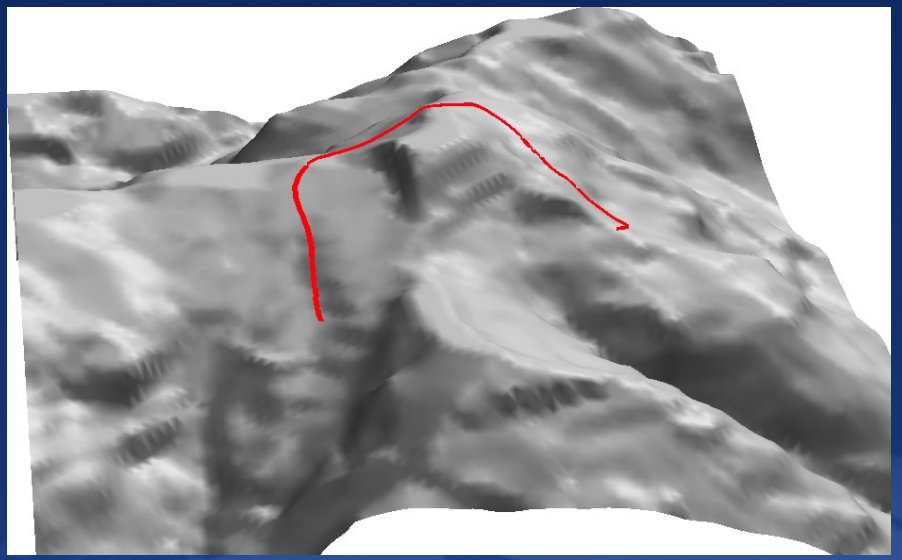
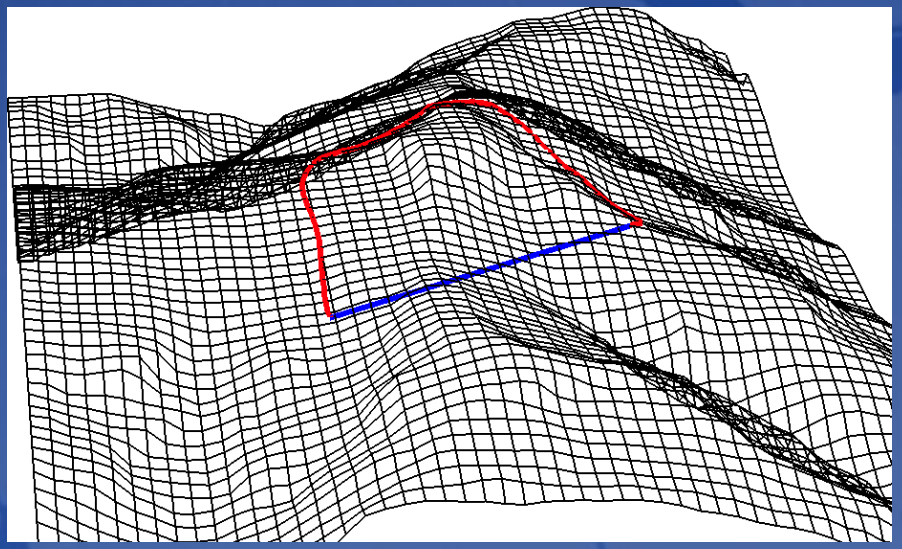


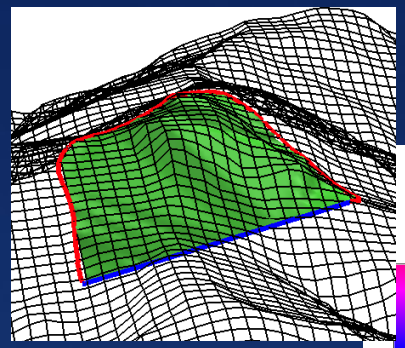
2) three-dimensional segment, joining the two end nodes of the BT, is created

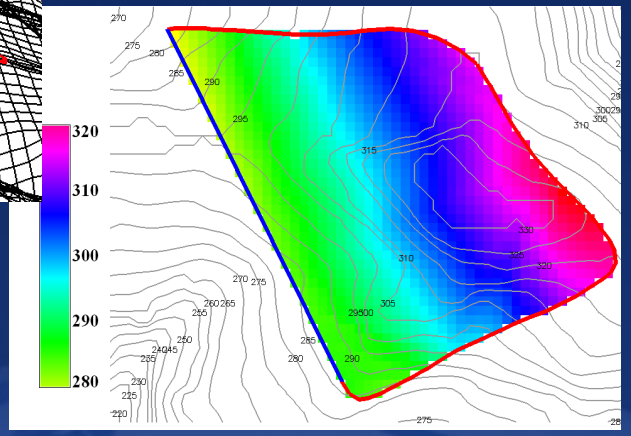
2)



GIS script (2)

3) A 3D Delaunay triangulation is performed. The result is a nearly flat surface corresponding to the bedding surface (BS).





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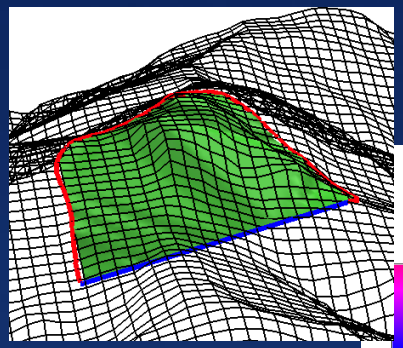

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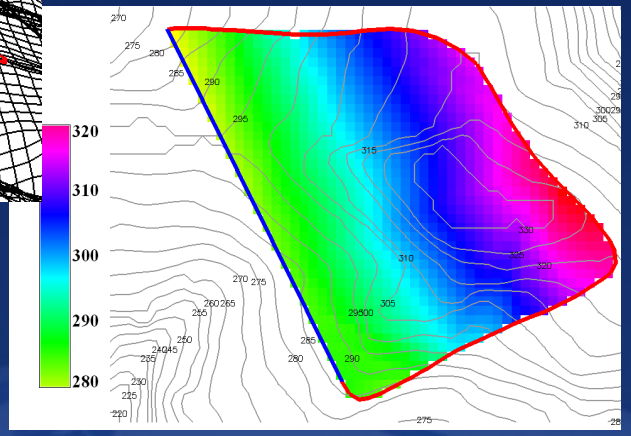
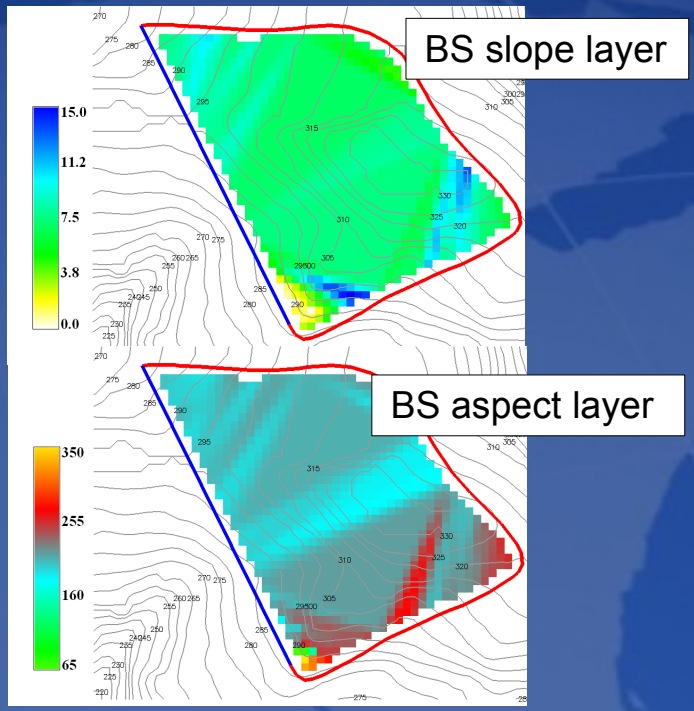


4) Slope and aspect layer are created. Mean slope and mean direction are taken as dip and dip direction to define BA

4)



GIS script (3)

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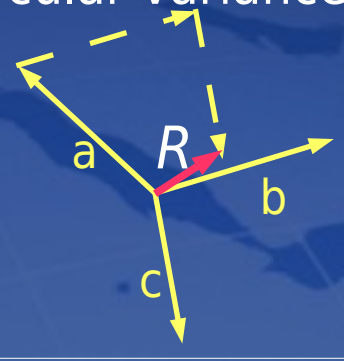
Circular variance

$$V = 1 - \frac{R}{n}$$

Low circular variance

n=3
|a| = |b| = |c| = 1

High circular variance



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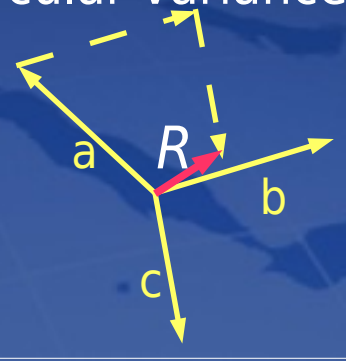
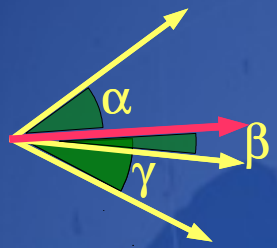


Angular standard deviation

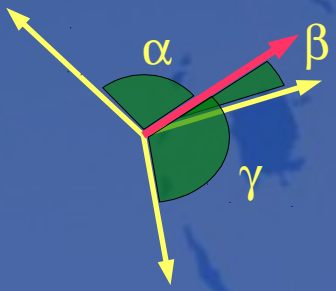
$$S = \frac{1}{(n-1)} \sum_{i=1}^{n} \Delta_i^2$$

Low angular std. deviation



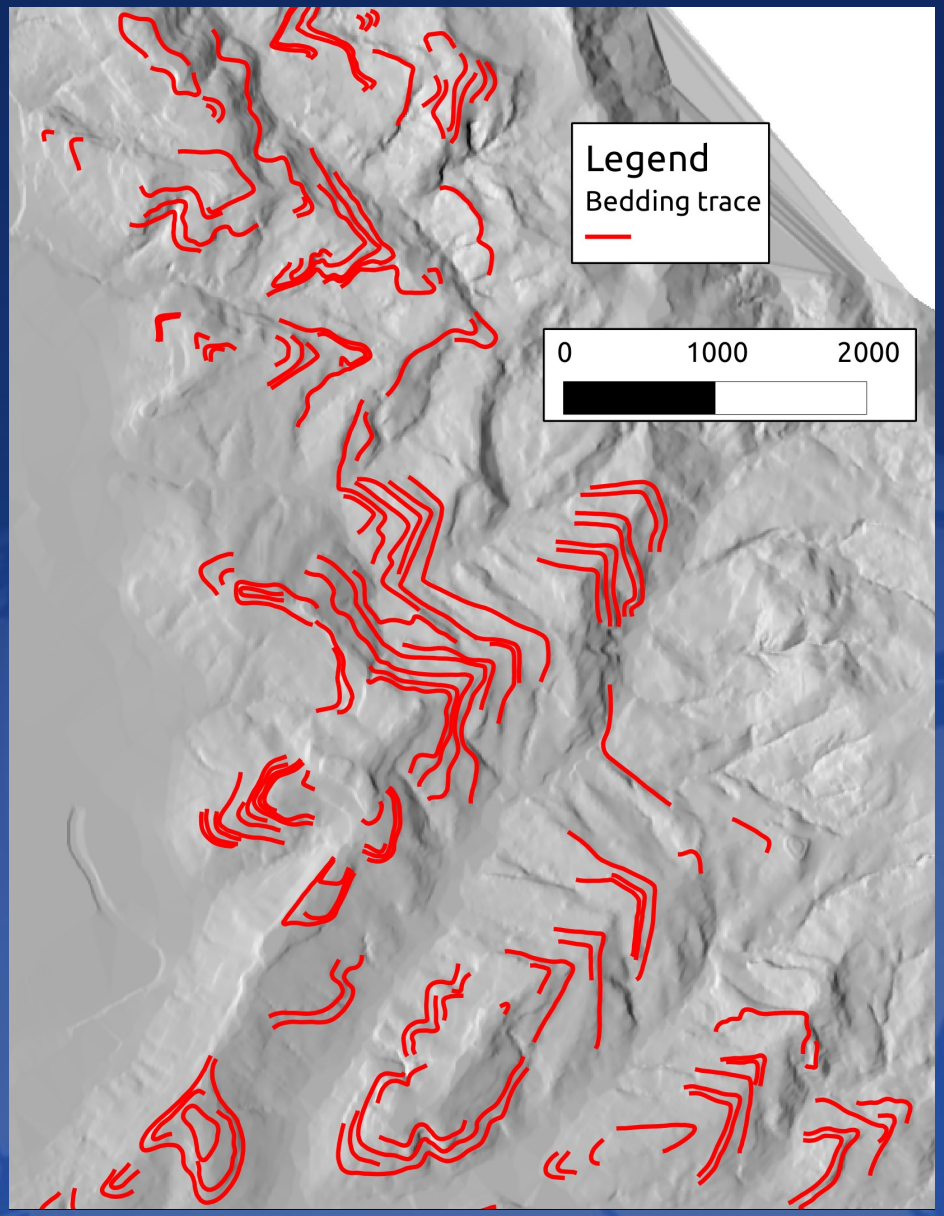
n=3
$\Delta_1=\alpha$, $\Delta_2=\beta$, $\Delta_3=\gamma$

High angular std. deviation



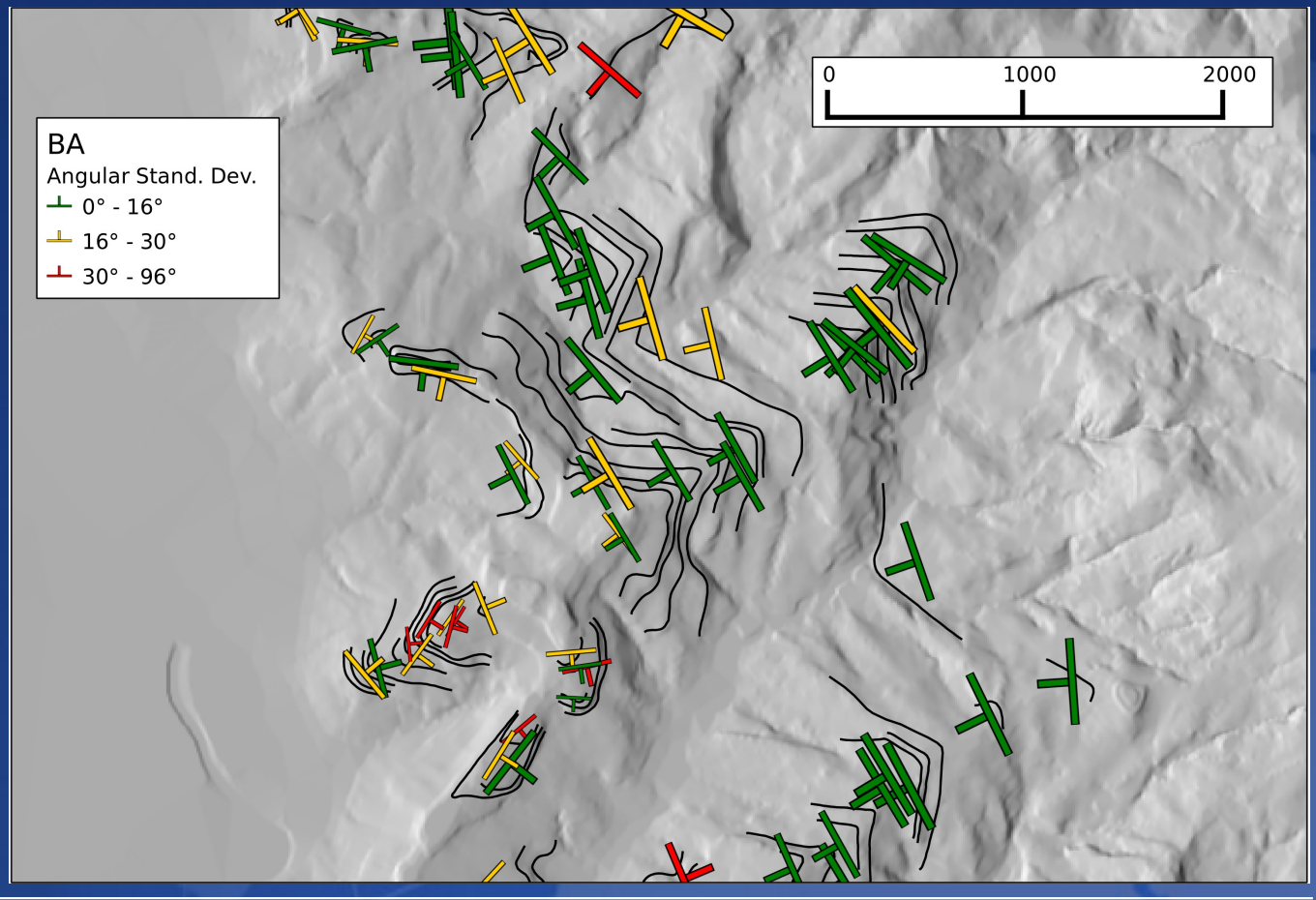
Case study

- The Collazzone (Central Italy) test area
- Input data:
  - DEM (10 m resolution)
  - 230 bedding traces (BTs)



Results: bedding attitude map

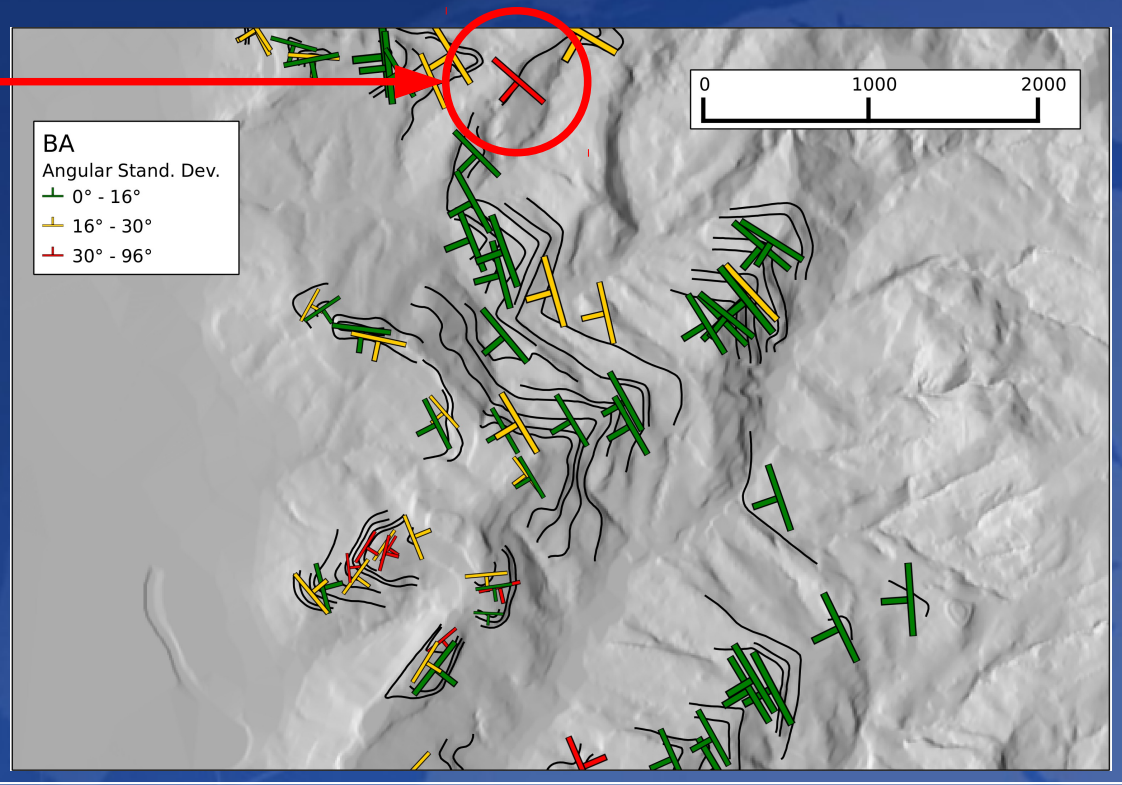
- Orientation of symbols is accorded to the dip direction
- Dimensions of symbols are scaled to the inclination angle
- Green/yellow/red color means low/medium/high dip direction uncertainty



Results: Errors (1)

- High values of angular standard deviation can be related to:
  - Sub-horizontal strata,
  - **Positioning errors**, transferring BTs from the aerial photographs to the GIS dataset,
  - **Identification errors** (it wasn't a bedding trace),
  - **Presence of folds errors**.

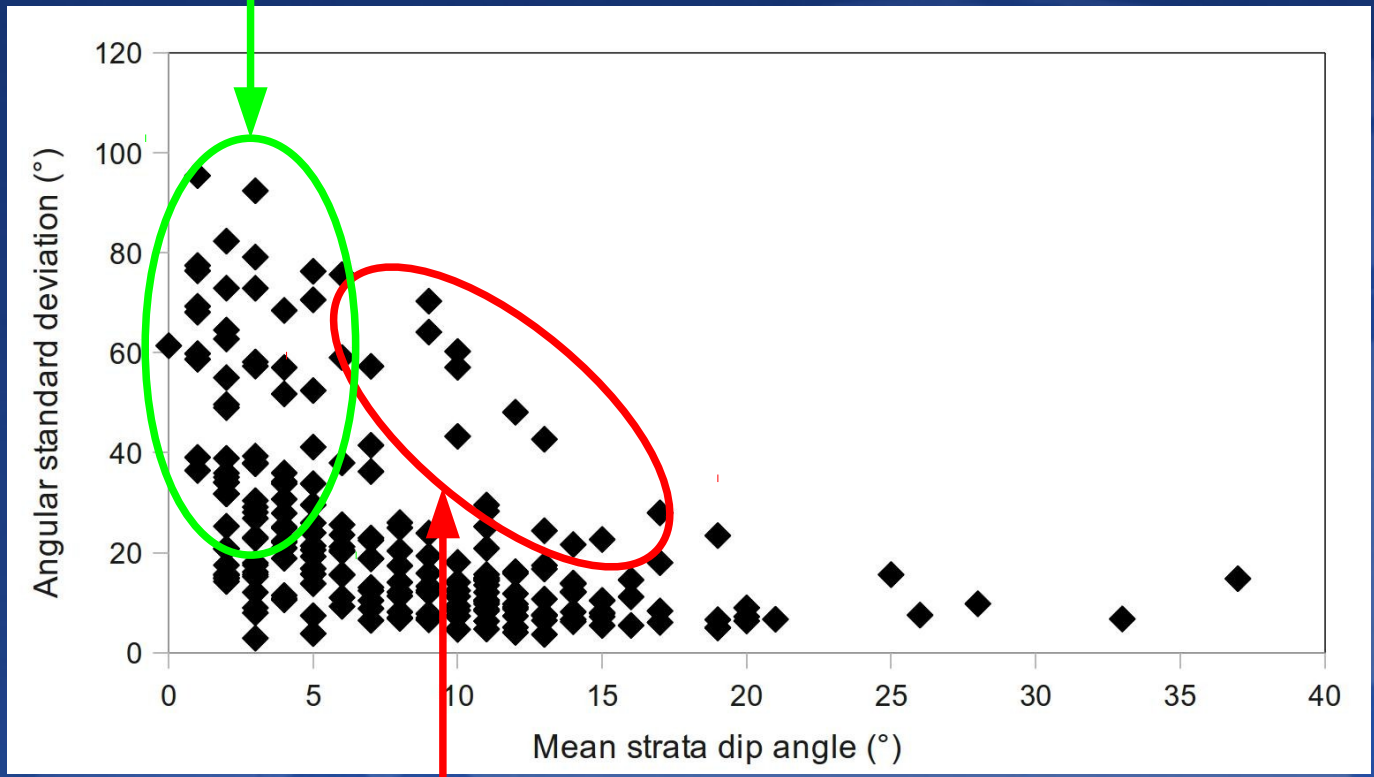
Probable error



Results: Errors (2)

- High values of uncertainty (angular standard deviation) are frequently related to sub-horizontal strata (low inclination angle)
- Obviously dip direction is particularly uncertain for sub-horizontal strata

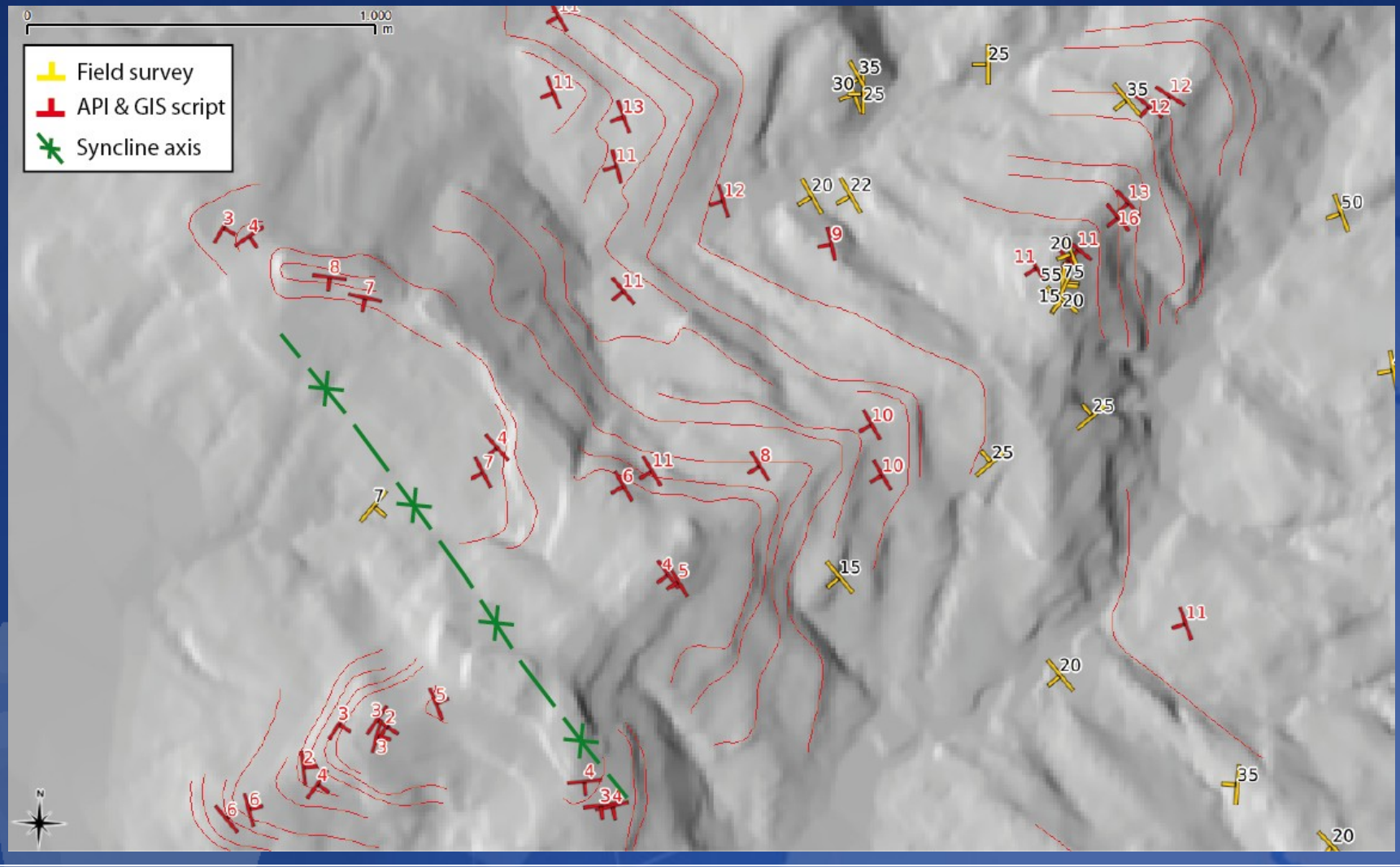
Sub-horizontal bedding attitude



Positioning, identification, or fold presence errors?

Results: comparison with field data

- Comparison of the obtained API& GIS bedding attitudes with data relating to a detailed geological survey (yellow symbols).



Discussion and conclusion

- Requirements:
  - Since the Aerial Photographs Interpretation (API) is an art as much of a science, it requires well trained and experienced investigators
  - GIS module needs GRASS GIS 6.4

Discussion and conclusion

- Advantages of the procedure include
  - a quantitative estimation of the inclination and dip direction of multiple BTs mapped trough API,
  - a significant increase in the number of bedding attitude features compared to those obtained during field survey,
  - the rapid execution of the procedure, compared to long and expensive field survey
  - moreover, using the proposed method, it is possible to obtain a dense spatial distribution data, useful for BAs spatial interpolation (Meentemeyer and Moody 2000; Günther 2003; Günther et al. 2004; Ghosh et al. 2010).

Discussion and conclusion

- Open Problems
  - The GRASS shell script has not been still tested in areas characterized by steeply inclined bedding strata
- How to test the script:
  - The script is available under the terms of the GPL license:

    http://geomorphology.irpi.cnr.it/tools

..... thank you

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