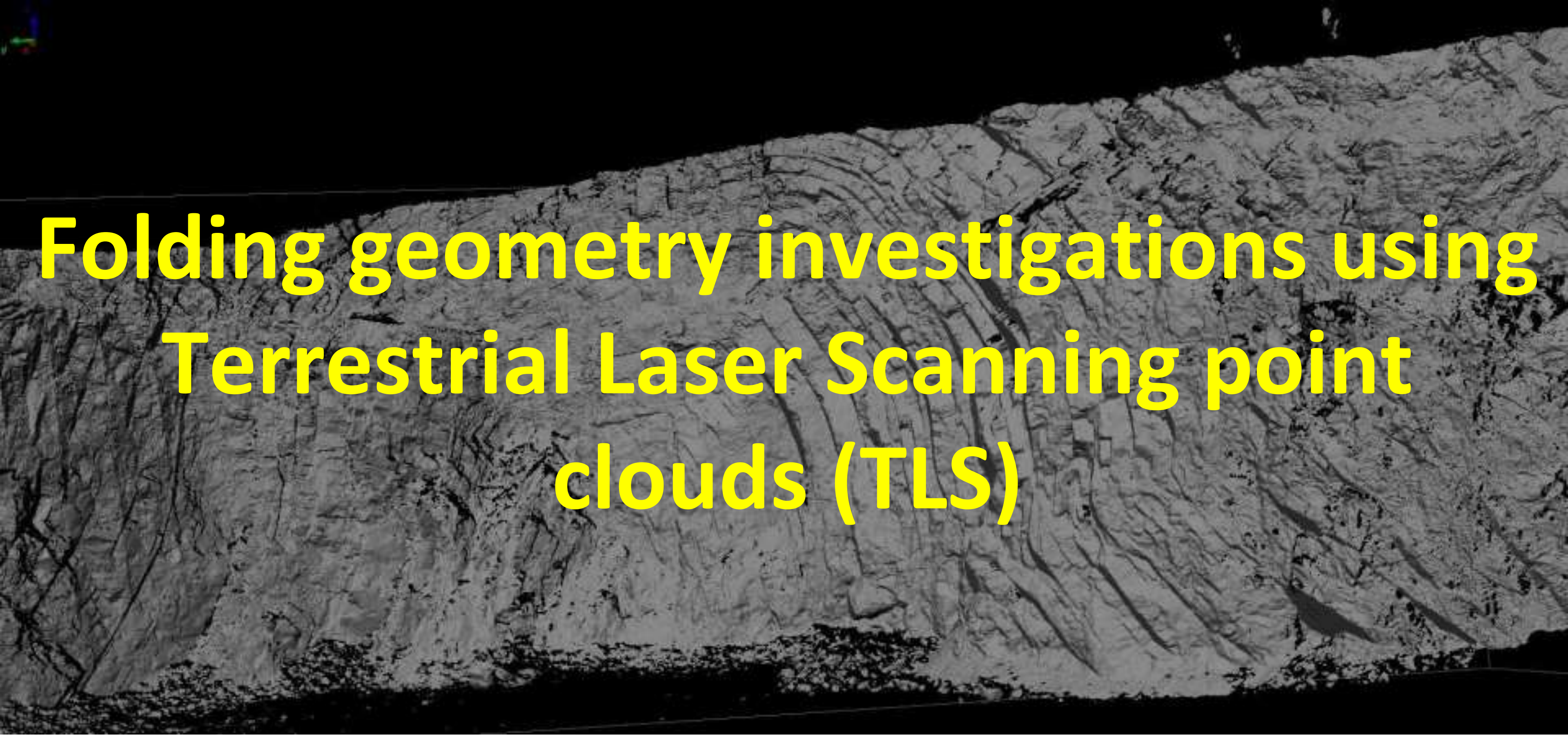
Folding geometry investigations using Terrestrial Laser Scanning point clouds (TLS)



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VERTICAL GEOLOGY CONFERENCE

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University of Lausanne
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General framework

Terrestrial Laser Scanning (TLS) site-specific method of investigation
→ Very high spatial resolution recently achieved

→ Unprecedented quality of virtual outcrops

→ This new kind of such high quality data is not yet fully exploited.

TLS applications mainly oriented towards **rock slope engineering and monitoring.**

Few studies focus on **tectonic and structural geology applications** (short review on VGC paper).

Objectives

Aim

Use *High Resolution TLS methods* to investigate the geometry and related features of folded surfaces:

→ Testing capabilites of TLS methods for structural geology investigations.

→ 3D layers boundaries tracking across the fold.

→ 3D modelling of the fold geometry.

→ Lithology discimination based on signal strength.

Case study

Box-fold anticline in Swiss Jura Mountains. Exceptional outcropping conditions, in an active quarry.

Tools TLS point clouds data / Field mapping.

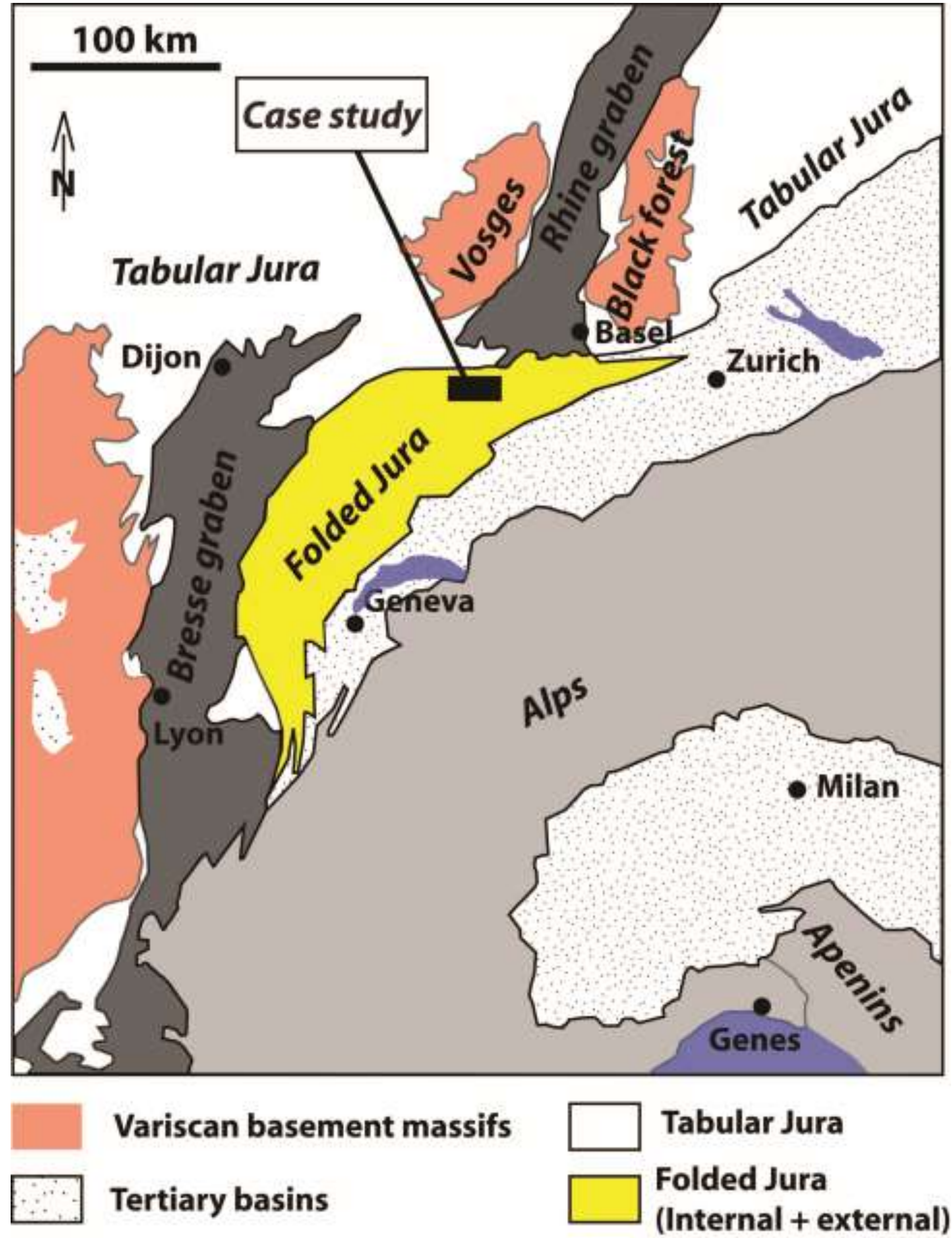
General context
Jura mountains

400 km long arcuate moderate-relief mountain belt.

Thin skin tectonic: cover rocks deformed and displaced over weak basal decollement towards NW.

Fold and thrust belt forms the frontal portion of the western Alpine arc.

Main folding and thrusting: 9 to 3.3 Ma (Becker, 2000).

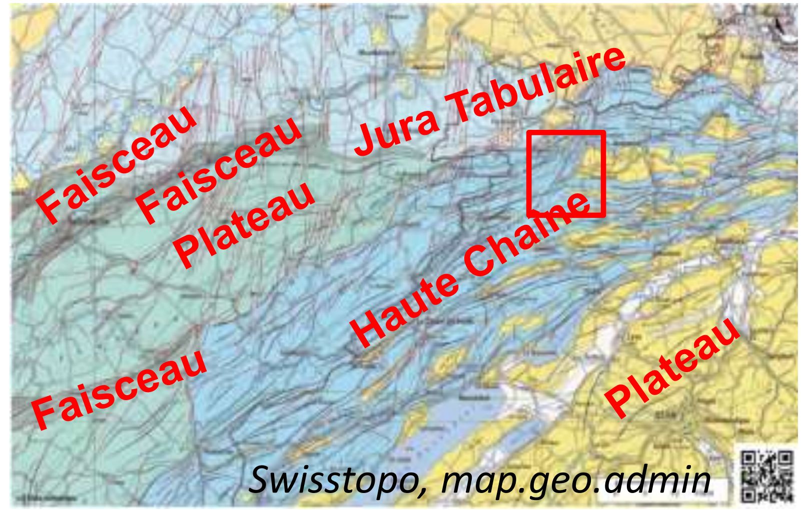


Modified after Braillard, 2006 and Sommaruga, 1995.

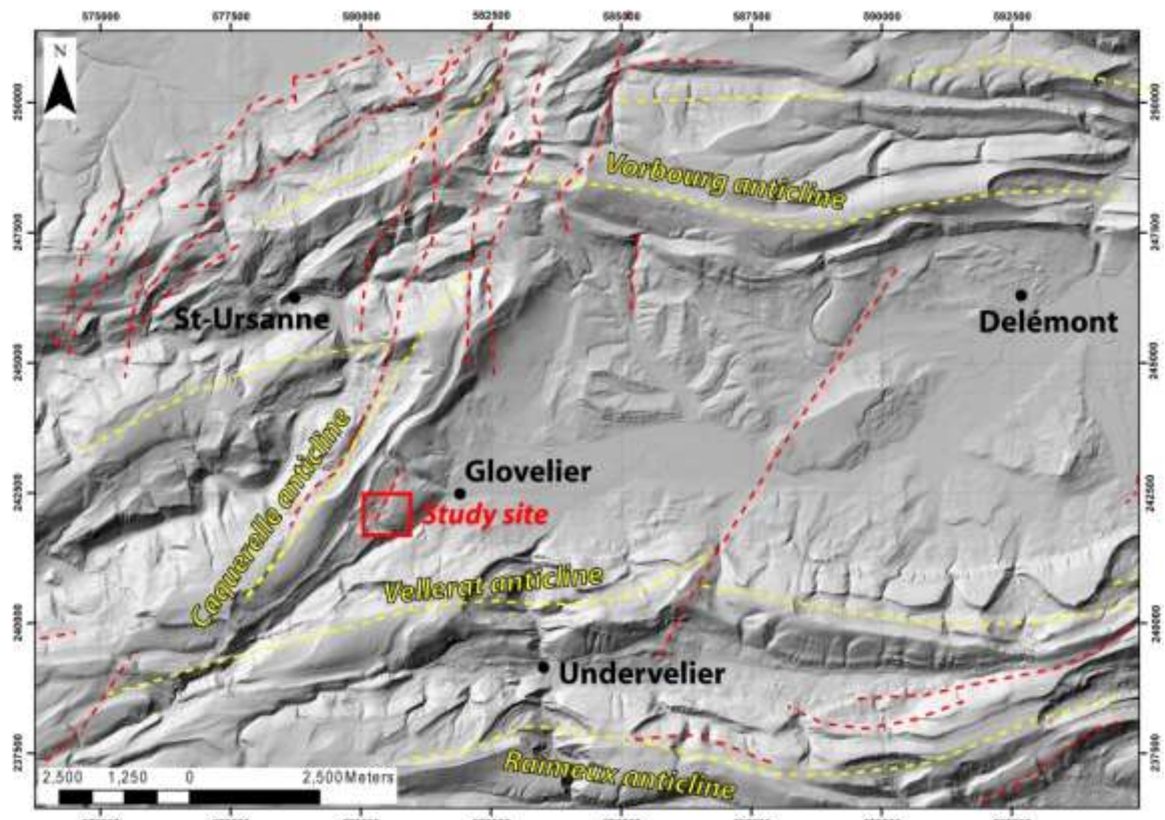
General context
Caquerelle anticline

Part of the *Haute chaine* characterised by high amplitude folds and major brittle accidents.

Caquerelle anticline follows a SSW-NNE trend at the border of the Delémont basin.



Caquerelle anticline

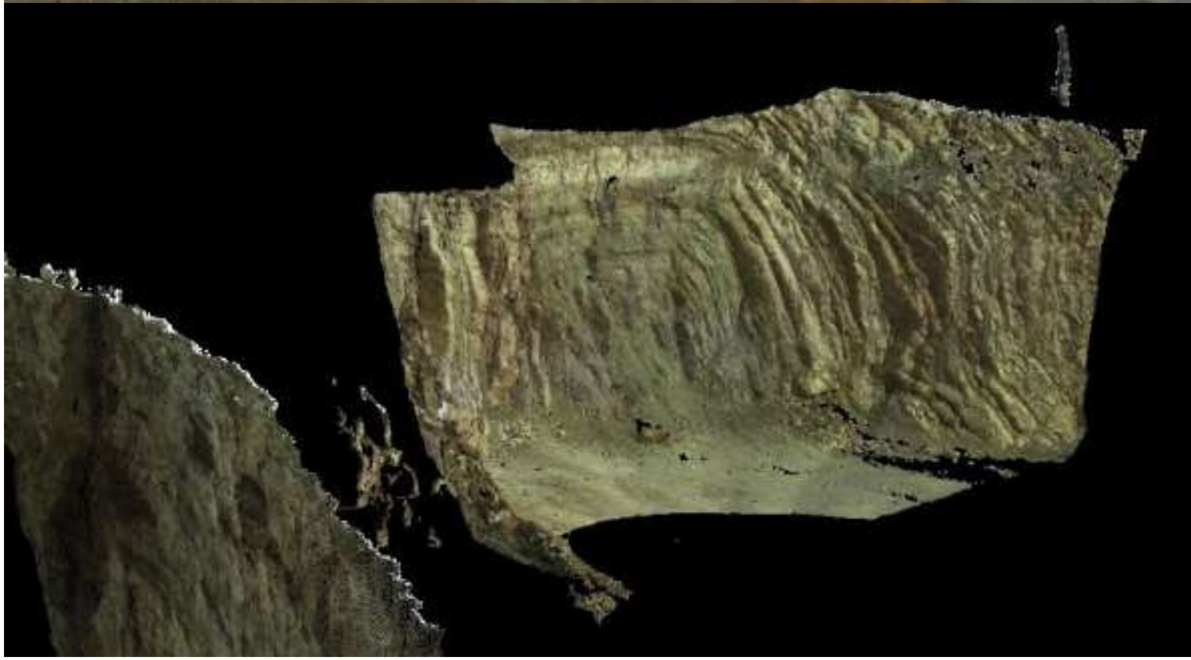


Study site: Box-fold

- ~30 m high box fold → secondary fold of the Caquerelle anticline?
- Subvertical tear fault
- Sequanian and Kimmeridgian series:
  - Marly limestone
  - Marls

Adopted methods
Data collection

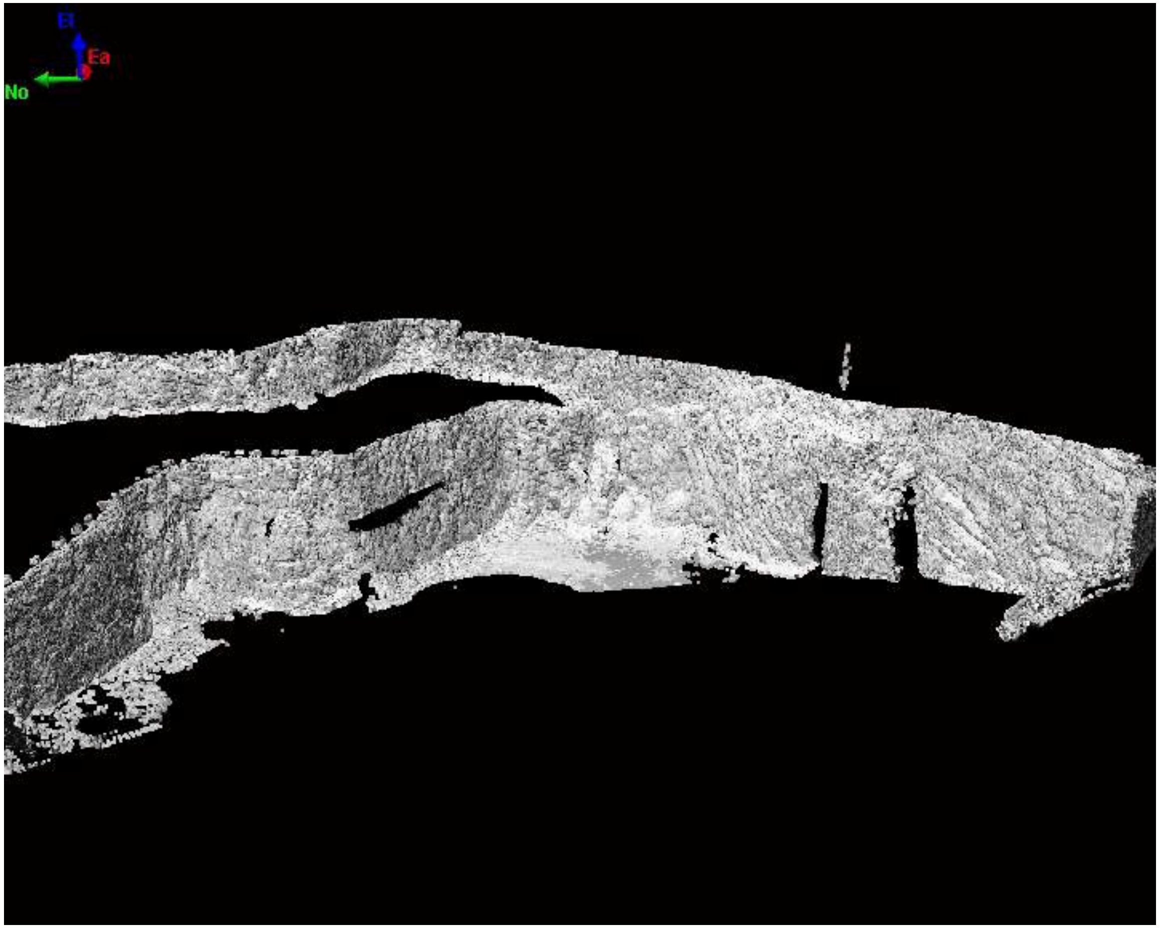
Photograhy



Leica scan station point cloud

LiDAR devices	*Leica scan station II* *Optech ILRIS 3D ER*
Number of points	*12'638'570*
Mean point spacing (mm)	*30*
Acquisition range (m)	*18 – 150*
Scan positions	*5*
Georeferencing	*HRDEM (2m cell size) (Swisstopo)*

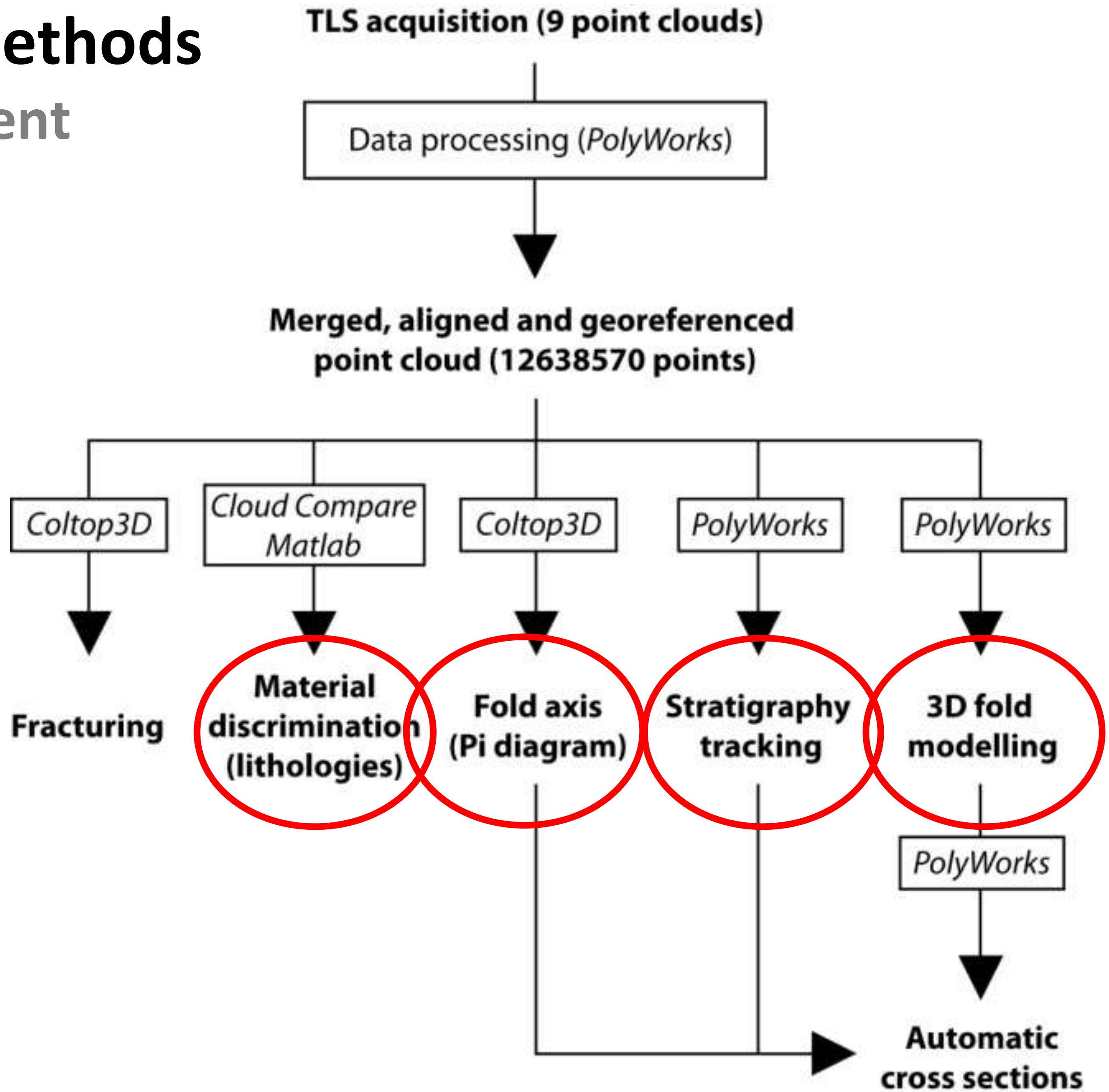
Adopted methods
Data collection



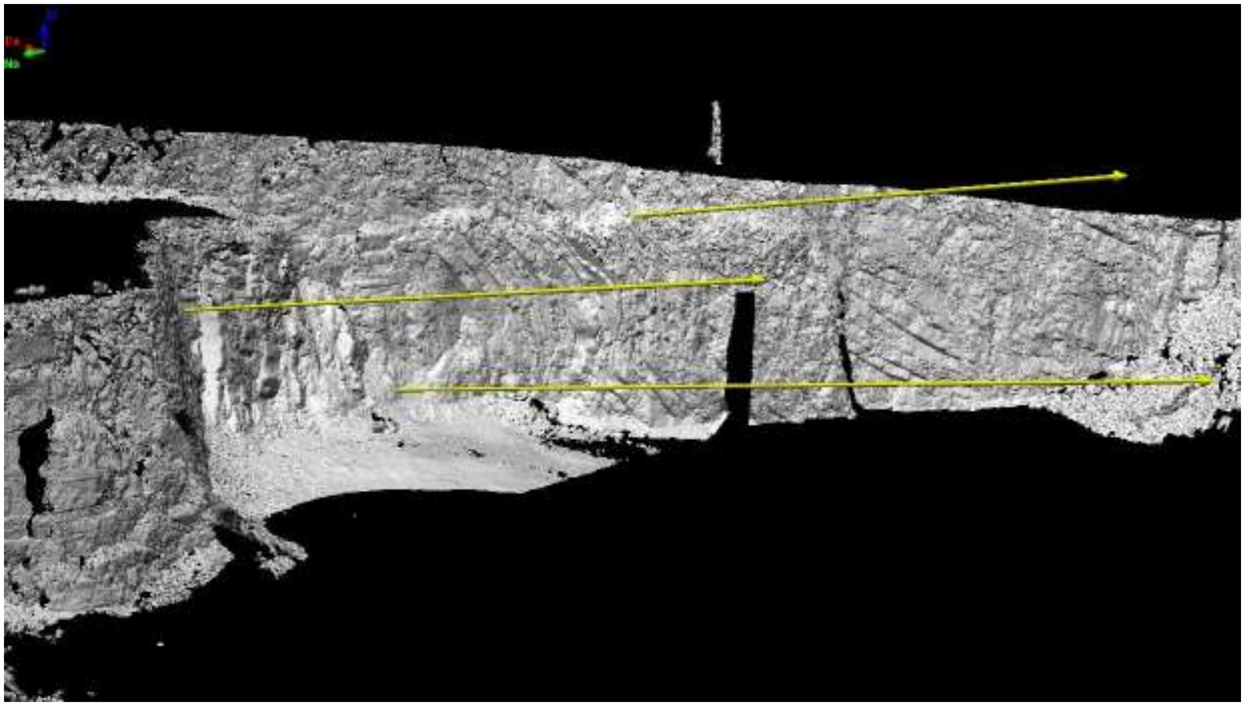
Complete point cloud of the study area (Leica scan station + Optech acquisitions)
→ 12’638’570 points

Adopted methods

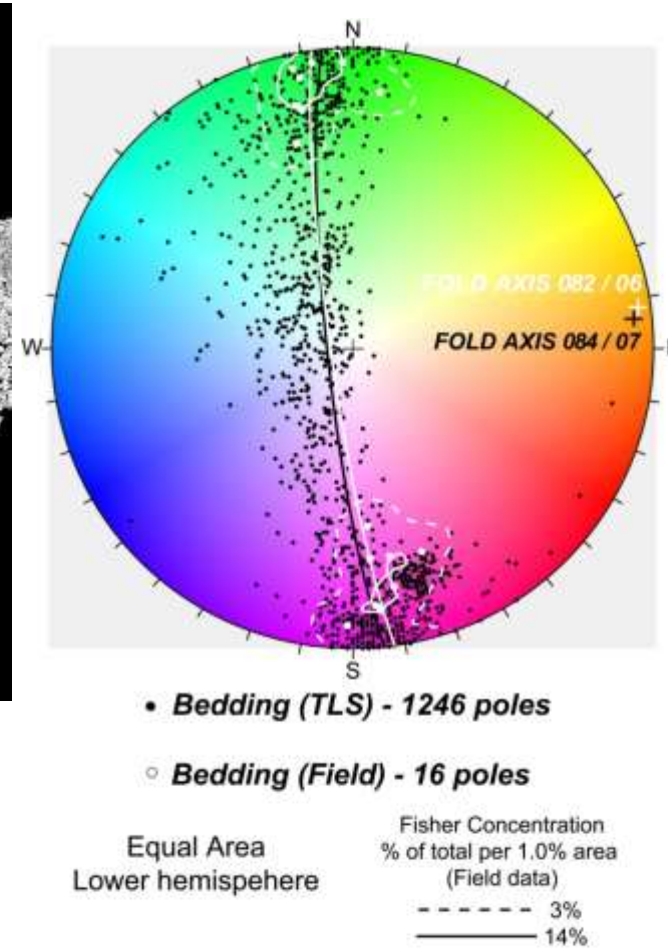
Data treatment



Fold axis reconstruction



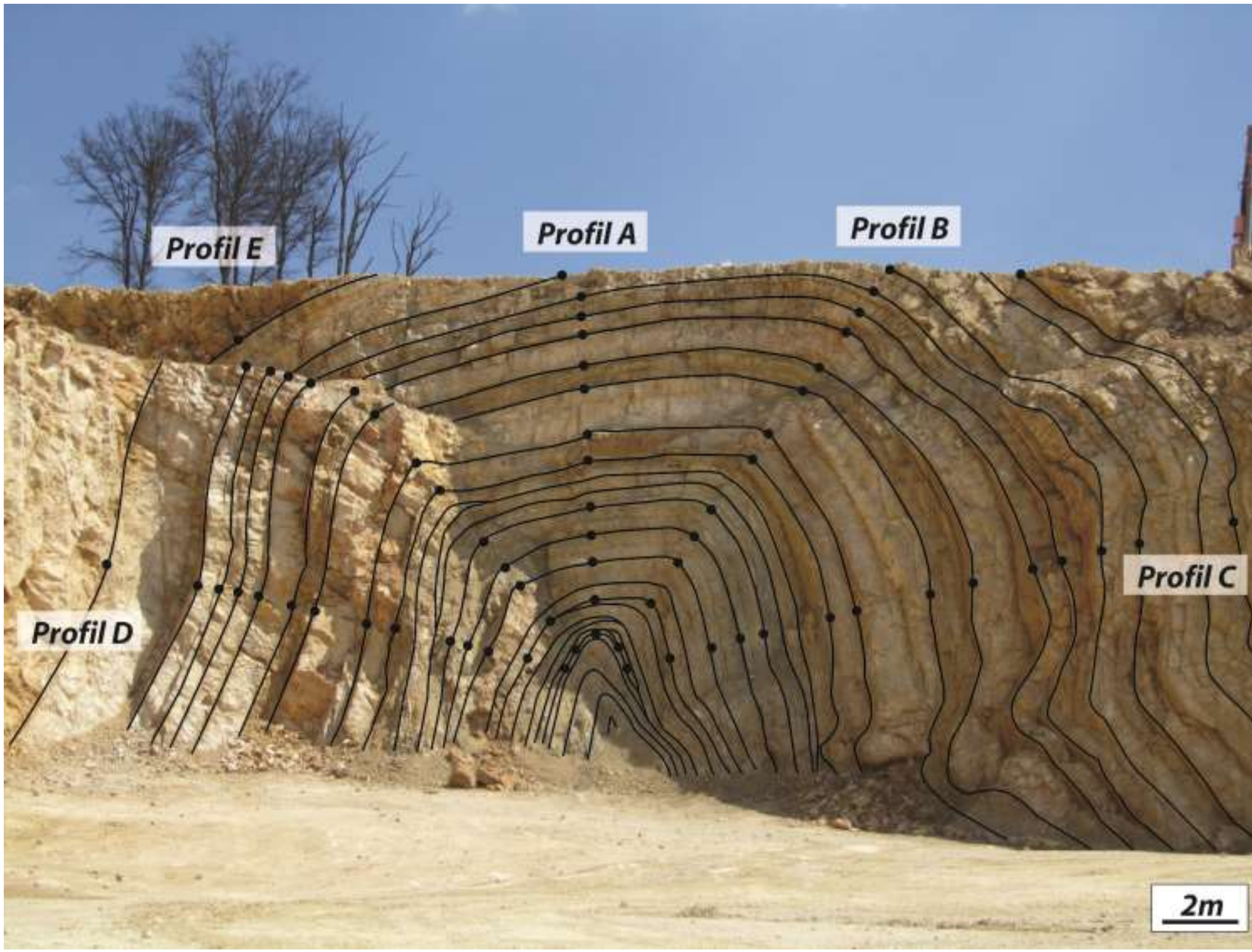
TLS point cloud with fold axis



Pi diagram from Coltop3D

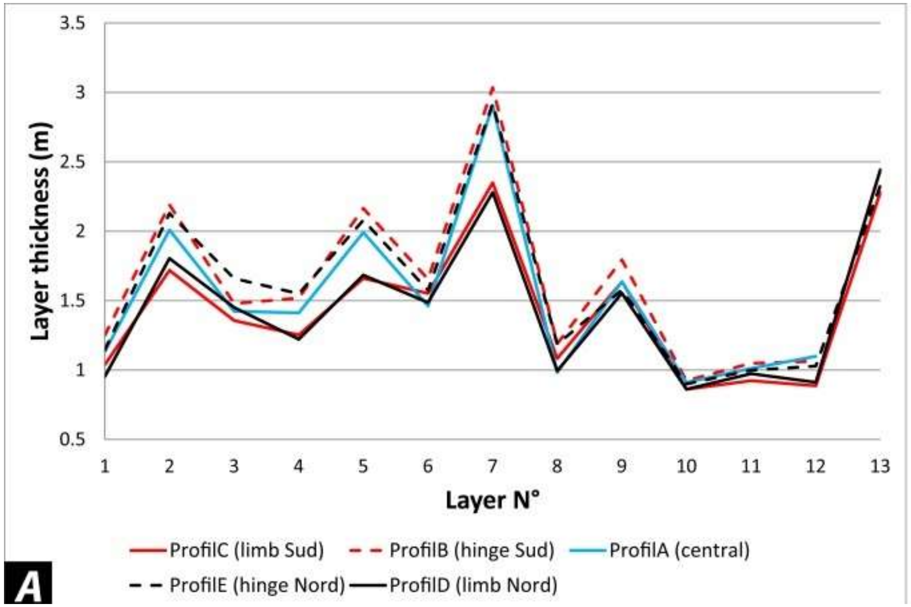
Stratigraphy tracking -> Beds thickness

14 layer boundaries tracked along **5 profiles.**

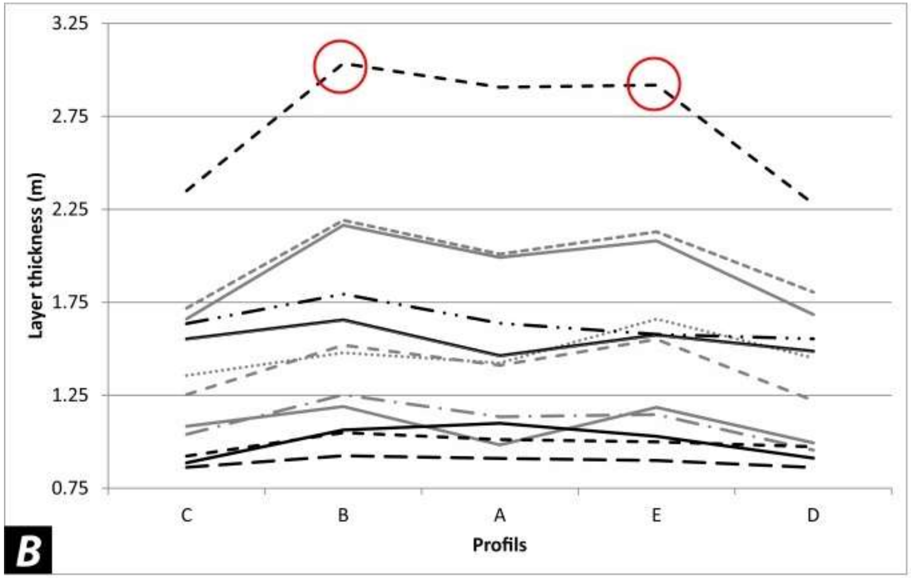


Location of the five profiles, all perpendicular to fold axis

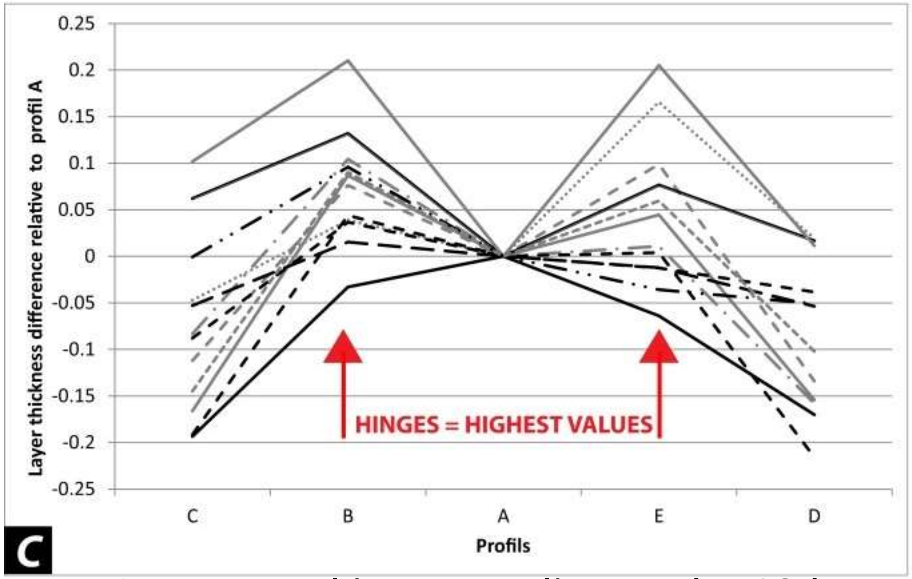
Stratigraphy tracking (TLS data)



Layers tracking according to the 13 layers

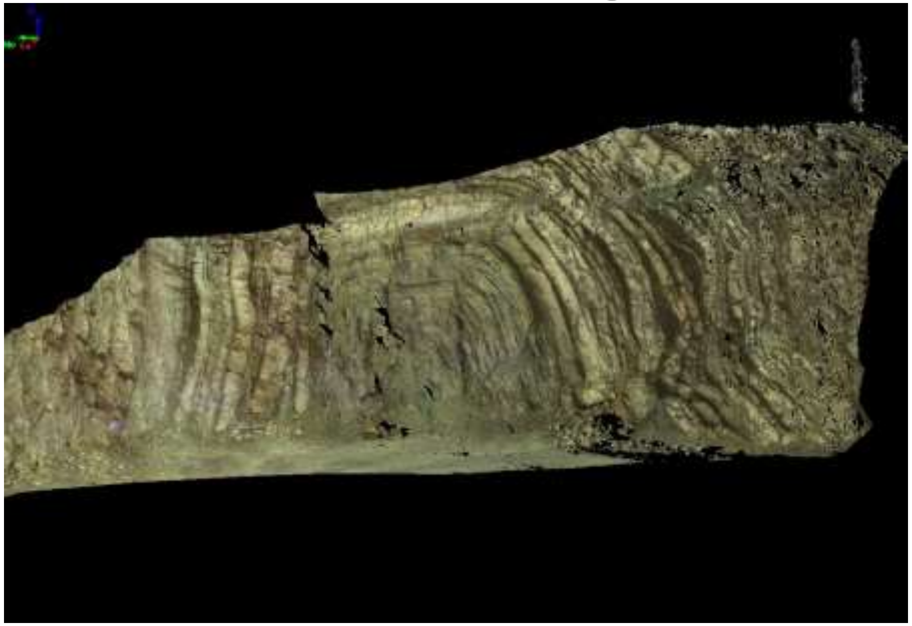


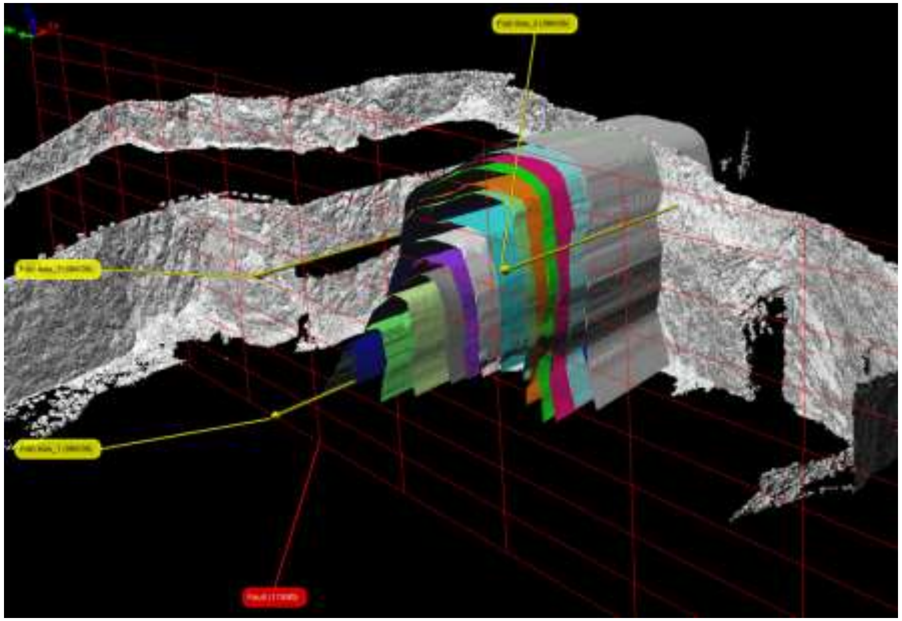
Layers tracking according to the 5 profiles

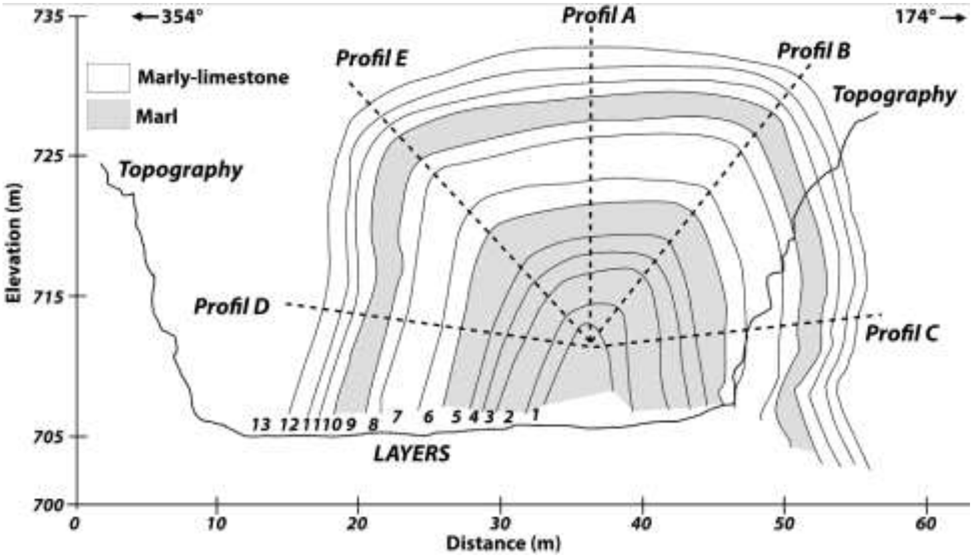


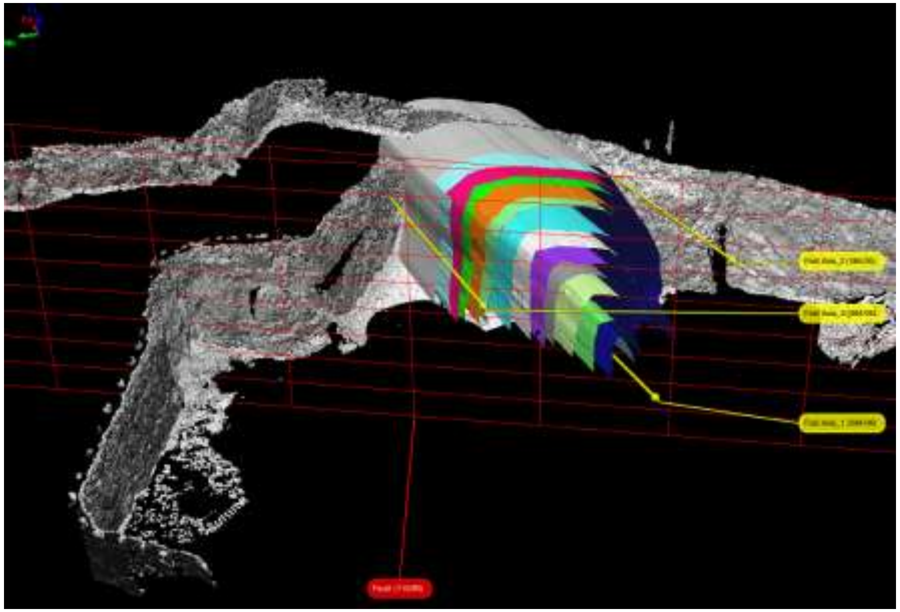
Layers tracking according to the 13 layers relative to profile A (centered on zero)

3D fold modelling – cross sections

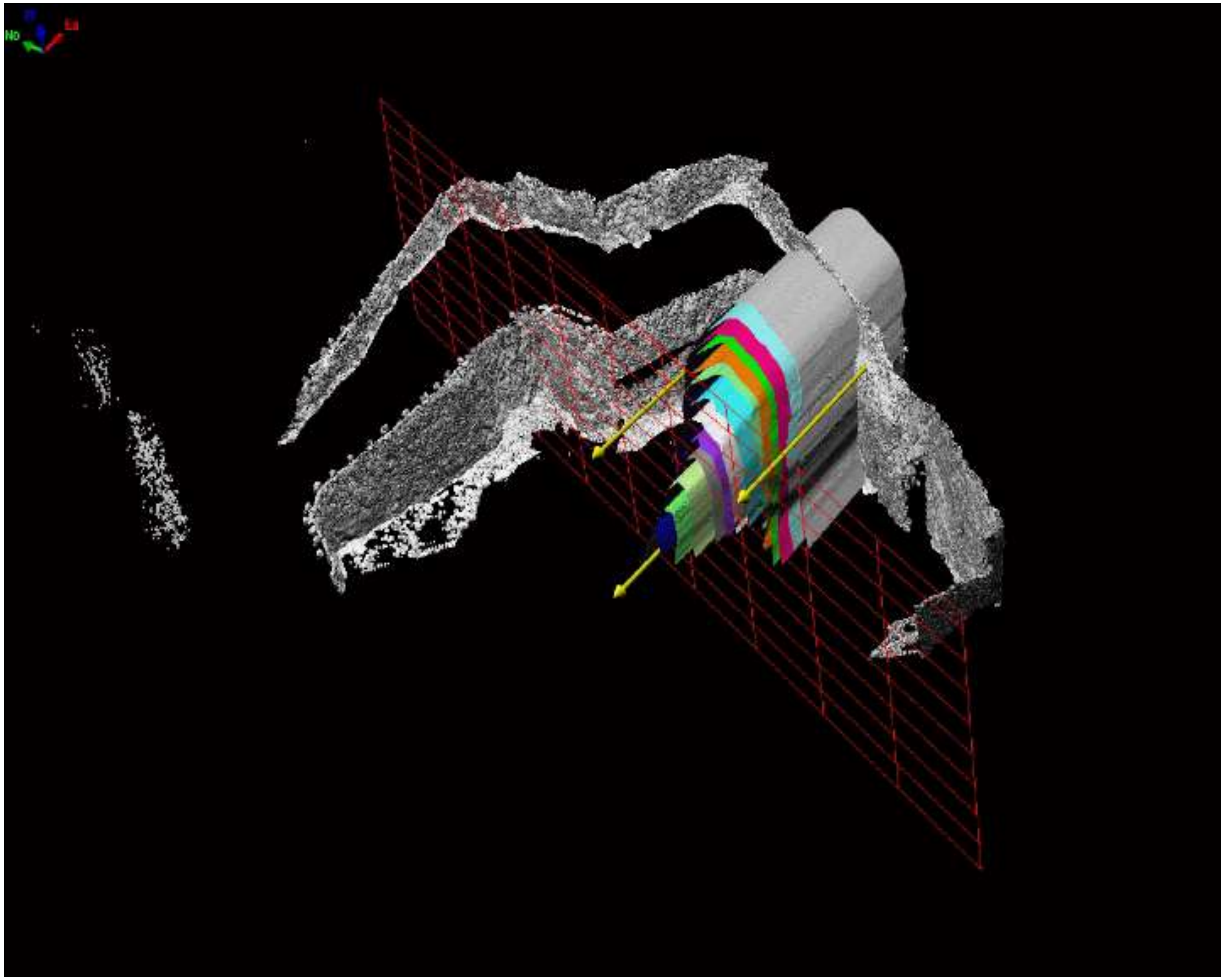






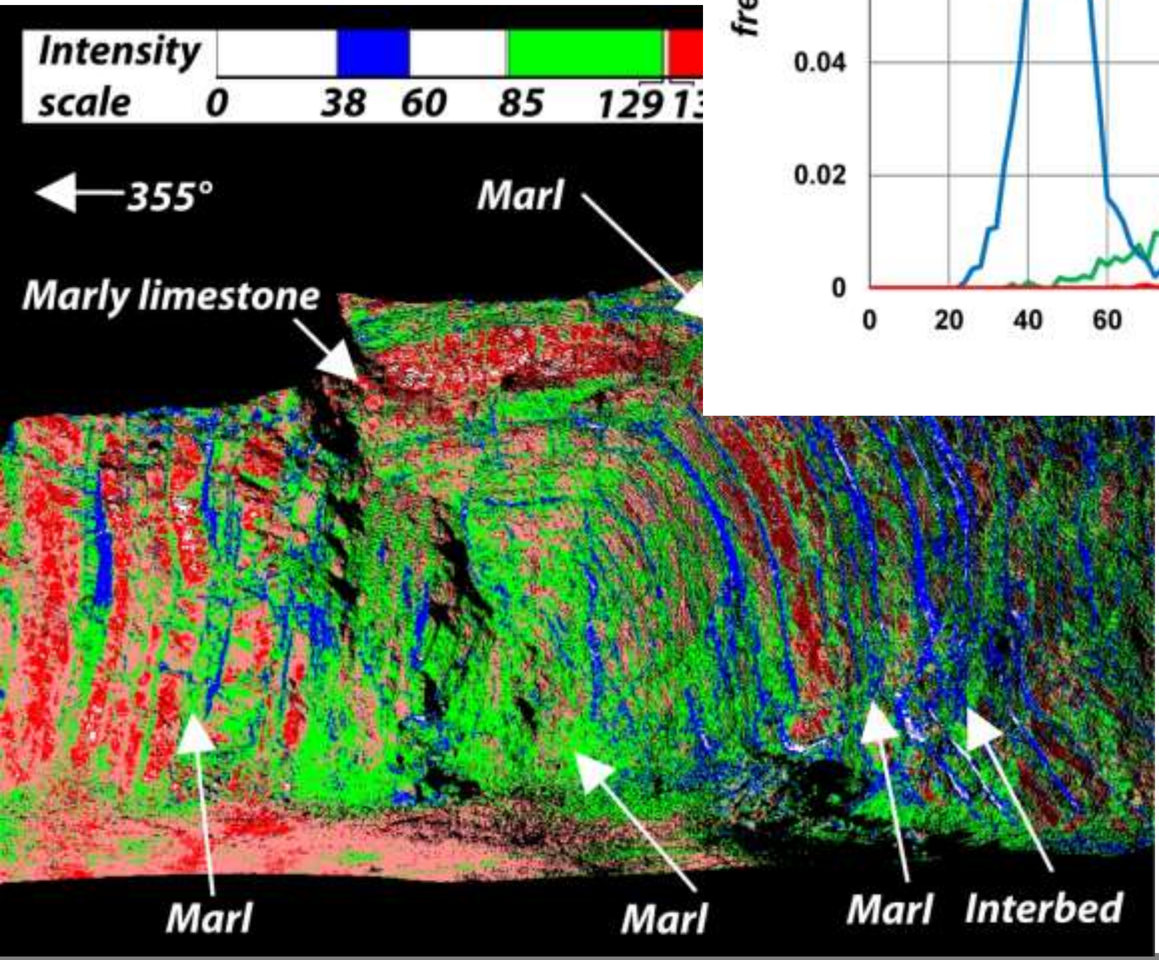


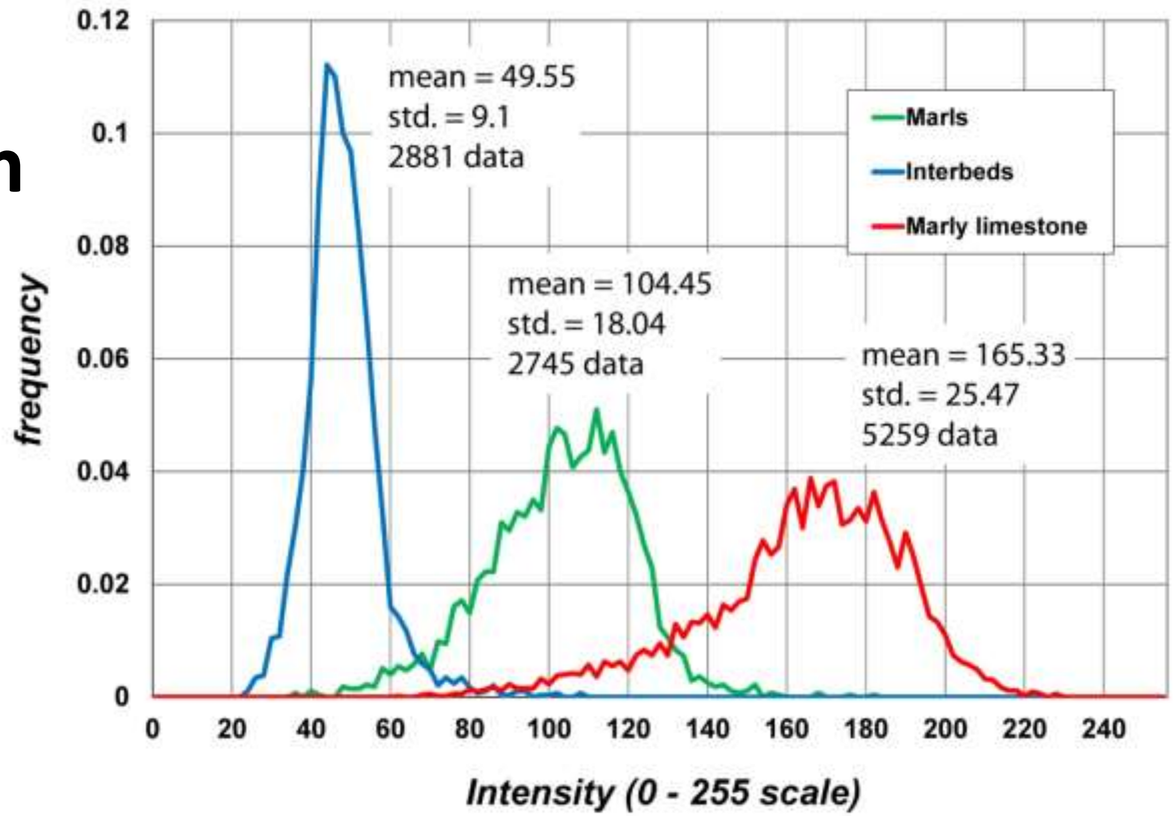
3D fold modelling



Complete point cloud of the study area (Leica scan station + Optech acquisitions)
→ 12'638'570 points and 3D fold model mesh.

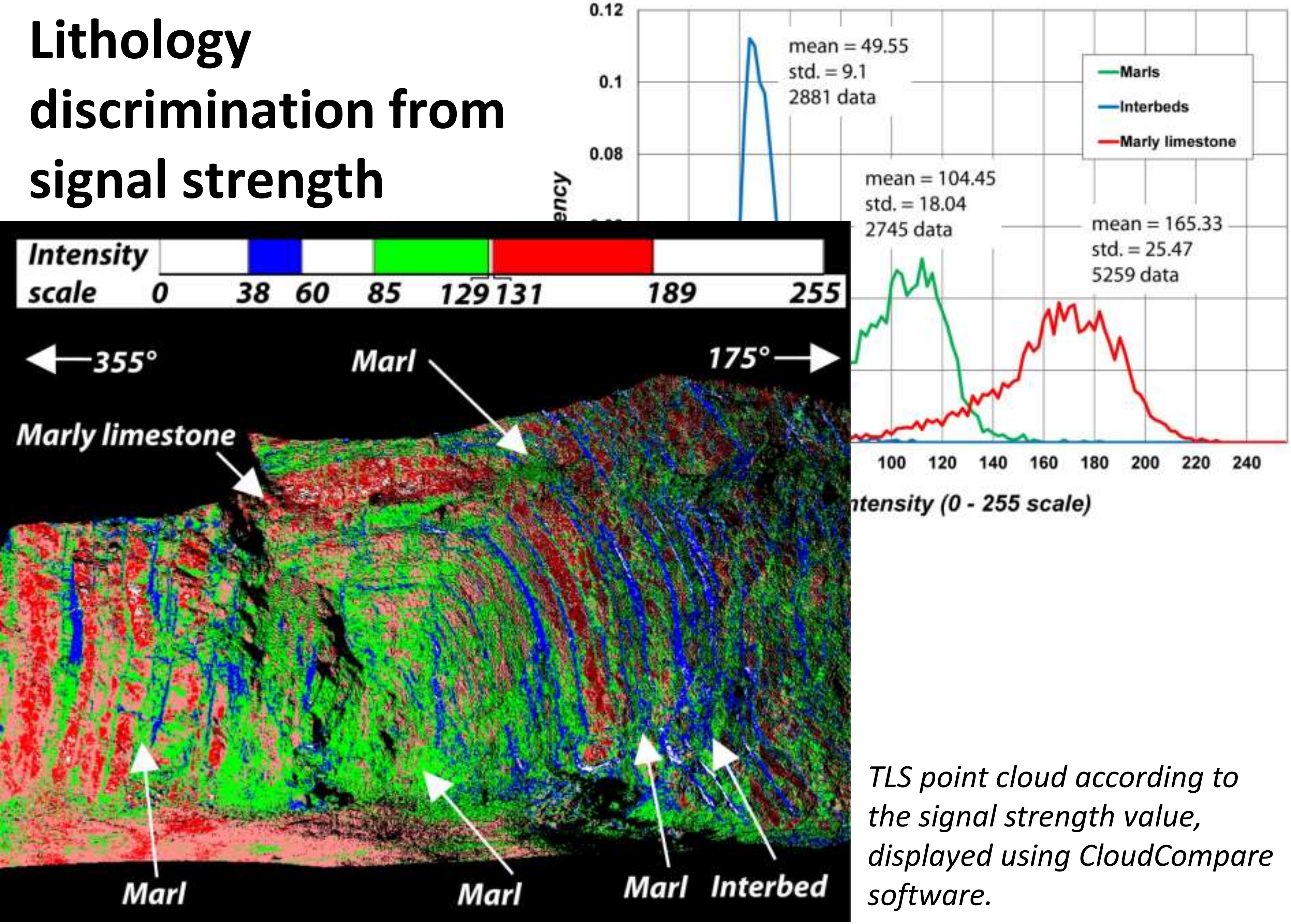
Lithology discrimination from signal strength





Probability plot of the signal strength intensity for the three main lithologies.

Lithology discrimination from signal strength



TLS point cloud according to the signal strength value, displayed using CloudCompare software.

Site-specific interpretive points

- Quarry site: presence of sub-vertical fault ends the continuation of the box-fold anticline to the SW. Continuation limited to the NE as well.
- Box fold interpreted as secondary fold of the Caquerelle anticline … fold axis diverges from the main anticline …

  → Tectonic relationships between box fold and main anticline deserve more work

- Flexural slip folding mechanism according to slickensides.

- **Broadening** of the layers thickness at the **hinges** compared to the limbs ranging between **1 to 26%**; especially marly layers. Central area thickened as well → material transfert towards the center of the fold?

- Stronger deformation observed in the core of the box fold (mainly marls) → layers tracking much more difficult because of thrust faults

Methodology conclusive points

Advantages

- TLS methods for stratigraphy and structural characterization: **accurate, fast, efficent**.

  → Very High Resolution, quantity of data, acquisition time.

- Stratigraphy tracking: vertical slopes not quite accessible by other means …
- 3D fold model: dynamic visualization and data extraction (meshs and cross-sections).
- First step towards semi-automatic vertical mapping based on signal strength.

Actual limitations and required improvements → Towards automation

- 3D model: Data processing automation and more robust interpolation → complex structures reconstruction.
- Signal strength: Corrective filters implementation → avoid intensity bias in order to depend on material properites only.