Low Cost 3D Mapping Using a Commercial Drone/UAV: Application in Structural Geology*

Riccardo Rocca[1]

Search and Discovery Article #42054 (2017)**
Posted April 17, 2017

*Adapted from oral presentation given at AAPG International Conference & Exhibition, Barcelona Spain, April 3-6, 2016

[1]Repsol Exploration S.A. (riccardo.rocca@repsol.com)

Abstract

This presentation describes an experience of mapping a geological structure with a commercial drone/UAV (Unmanned Aerial Vehicle). Being based in Venezuela, an appropriate area for the acquisition was identified in the Andes Cordillera where a major strike slip fault (Boconó Fault) intersects geomorphic features modeled by the latest glaciation. This fault is a major tectonic lineament oriented SW-NE, extending more than 300 km along the Venezuelan Andes and accommodating a dextral slip on the order of 1 cm/year. This motion has displaced various landscape features that cross the fault, in particularly the "Los Zerpa" moraine system, located a few kilometers NE of the locality "Apartaderos". The moraine formed during the last glaciation that ended 10,000 years ago; its northern tip crosses the Boconó Fault and is displaced 100 m towards the NE; this corresponds to a rate of 1 cm/year, which is consistent with GPS measurements.

To perform the test, an area of 400 by 600 m was covered over the moraine system, acquiring images at an initial altitude of 60 meters and with a 70% overlap. A total of about 300 images were acquired in two flights 20 minutes long. They were later elaborated with Pix4D, a dedicated software for UAV mapping, generating a single georeferenced map and a 3D digital model. The analysis of the 3D digital model has permitted to clearly identify various geomorphic features related to the interaction between the Boconó Fault and the moraine deposits: tectonic scarps identifying the fault trace; 90° sharp bend of the stream running down the glacial valley, where it gets captured and deviated along the fault strike; 100 m dextral displacement of the lateral moraines and glacial valley as they cross the fault; two terraces witnessing past periods of fluvial infill within the glacial valley, later eroded when the fault activity opened a fluvial escape through the right-lateral moraine; the abandoned fluvial valley that used to drain the moraine system before it was breached by the fault. In conclusion this experience has proven that UAV technology can be a useful tool in geological field work: acquisition can be made in remote impervious areas with difficult access; maps can be acquired at low cost and high resolution (typically a few cm per pixel); 3D models are generated at true scale and can be used to measure distances, thicknesses, and volumes; geological features can be observed from the most favorable point of view.

Selected References

Audemard, Franck A., Beck Christian, and Carrillo Eduardo, 2010, Deep-seated gravitational slope deformations along the active Boconó Fault in the central portion of the Mérida Andes, western Venezuela: Geomorphology, v. 124, p. 164-177.

DJI. Website accessed April 8, 2017.
http://www.dji.com

Dutch Steven, 2008, Plate Tectonics and the Evolution of Central America and the Caribbean. University of Wisconsin. Website accessed April 8, 2017.
https://www.uwgb.edu/dutchs/CostaRica2008/CR-PT.HTM

Purdue University, The January 12, 2010, Haiti Earthquake, Seismotectonic context of the Caribbean plate. Website accessed April 8, 2017.
http://web.ics.purdue.edu/~ecalais/haiti/figures/

SAFARI. Website accessed April 8, 2017.
https://safaridb.com

Schubert, C., 1983, Tectonics and Sedimentation: an example from the Mérida Andes (Venezuela): Acta Geologica Hispanica, v. 18/3, p. 207-215.

Tjaland Egil, 2014, Geological mapping with UAV and 3D Modelling. Website accessed April 8, 2017.
https://www.youtube.com/watch?v=pKtNZS43aDc

Low cost mapping with drone

Riccardo Rocca

April 2016

REPSOL

Basin Studies
Geology Division

GEOLOGY DIVISION

Index

Drones / UAVs and their applications in geology

Test in the Venezuelan Andes: Boconó fault - Los Zerpa Moraine

- **Regional framework**
- **Drone acquisition and 3D model**
- **3 exercises**

Conclusions

UAV: Unmanned Aerial Vehicle

Commercial drone: DJI Phantom

REPSOL

Technical features:

Weight: 1.2 Kg
Size: 350 mm (diagonal)
200 mm (height)

Control distance: 400-800 m

Camera: 14 Megapixels
Resolution @ 100 m: 4 cm

Typical flight:
- Autonomy: 20 minutes
- Speed: 5 m/s
- Height: 50-100 m
- Length: 5 km
- Survey area: 400x400 m

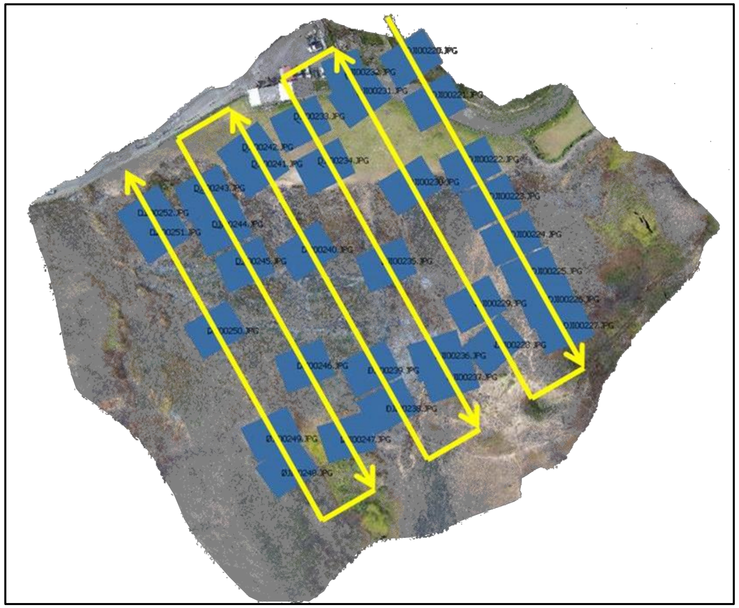
DJI Phantom 2 Vision Plus (obsolete)
www.dji.com

Equipped with GPS, digital compass and barometer, can hold position, direction and altitude.

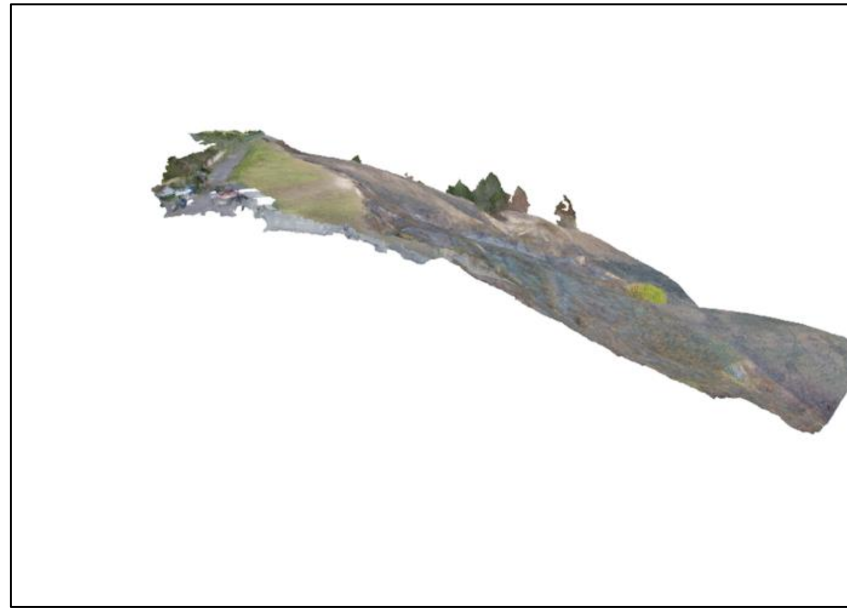
Can fly autonomously along a route saved in memory.

UAV mapping

Images acquisition and merge

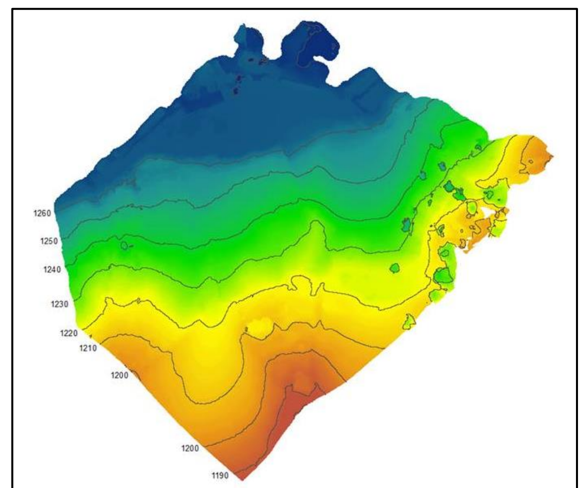


3D model



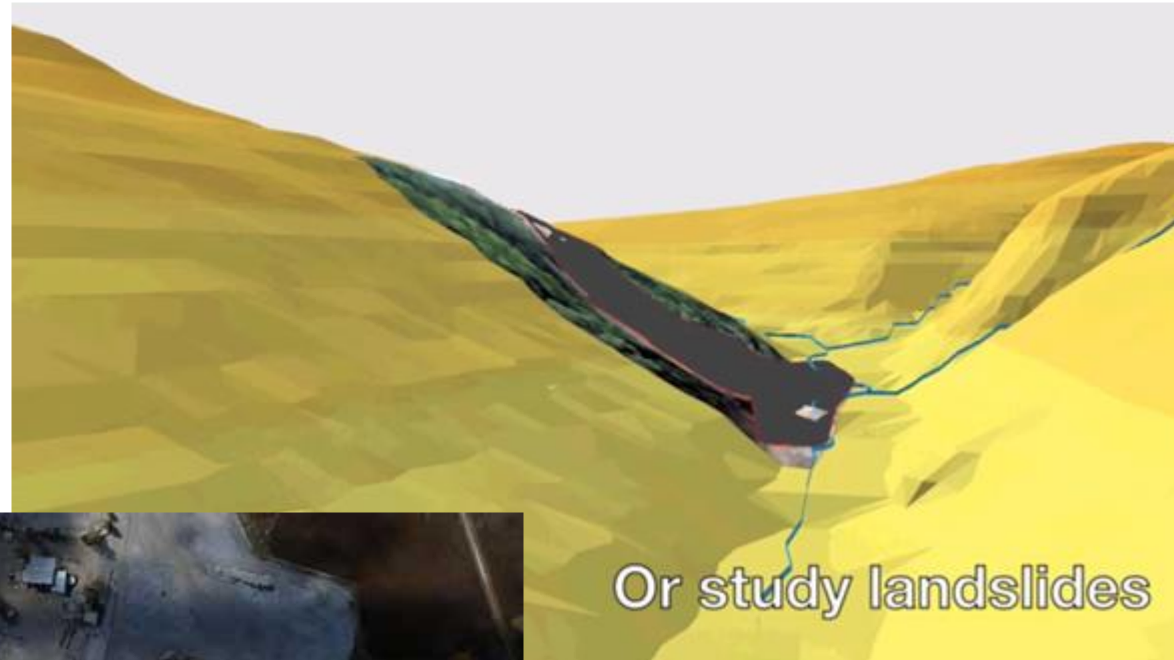
Georeferenced image

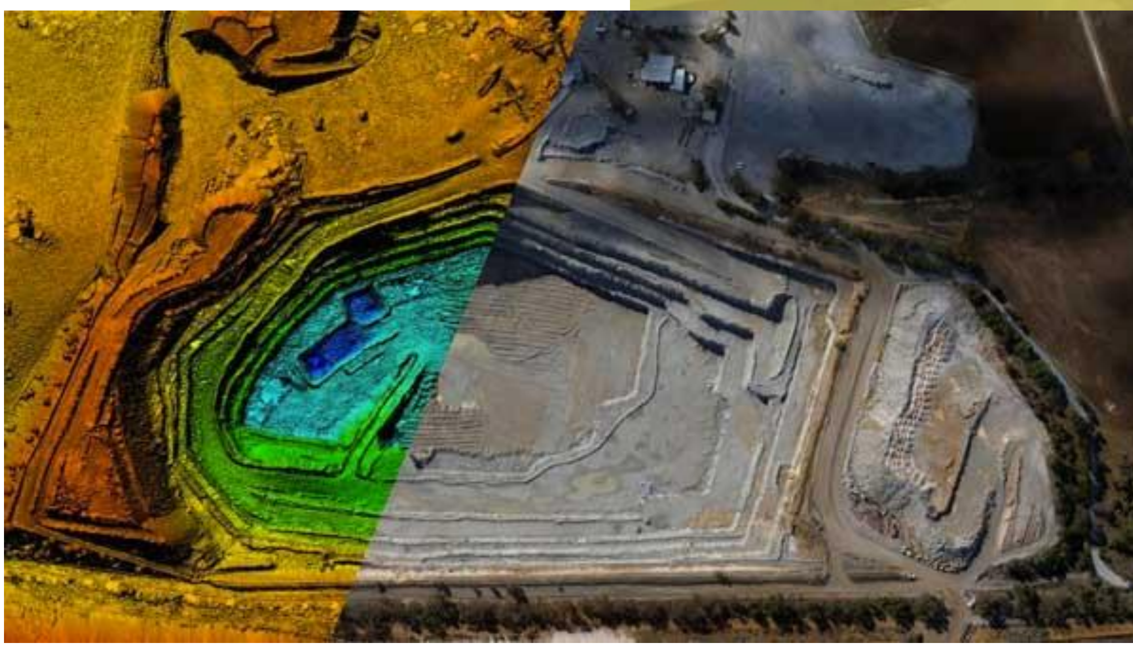
2D grid



Applications in Geology

Mapping
3D rendering
Area/Volume calculation





Safari: repository of geological outcrop data from clastic sedimentary systems

REPSOL

SAFARI | Home | Data | Browse | Standard | Wiki | Modern | About | Control Panel | Support | Log out

http://safaridb.com

Uni Research CIPR
University of Aberdeen

Geometric Data
Extract and analyse geometric data on architectural elements.

Knowledge Base
Wiki pages containing information on architectural elements, depositional environments and reservoir modelling.

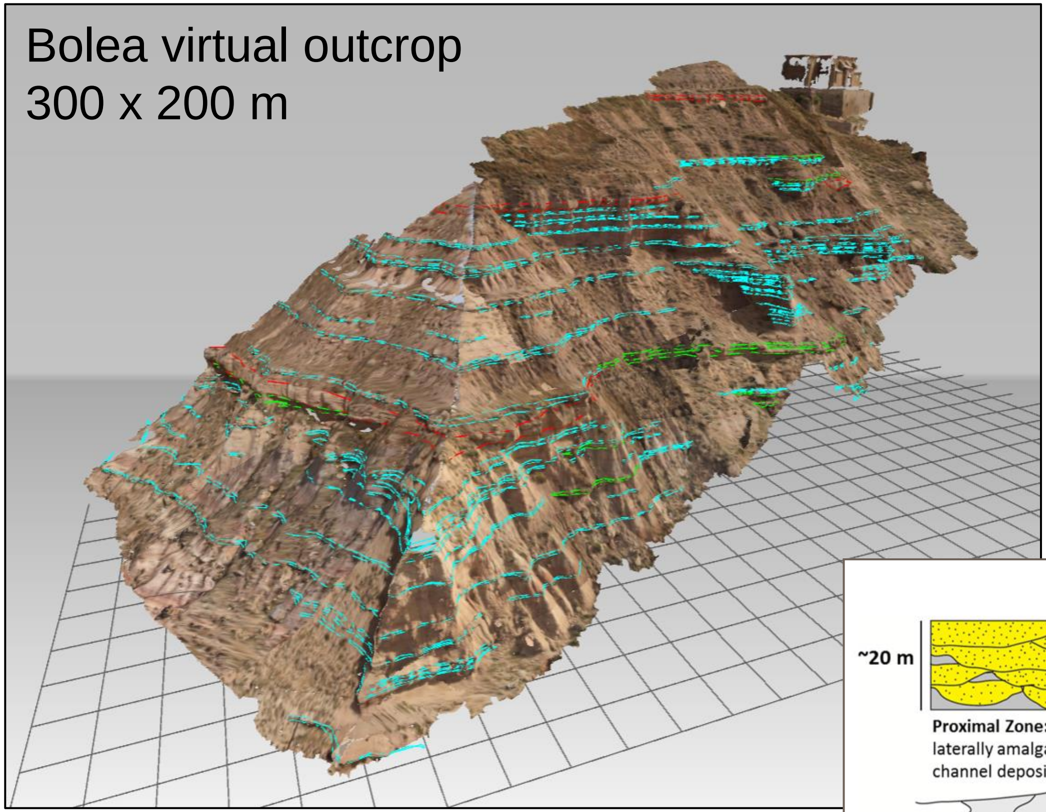
Modern Analogues
Find a map view of a modern analogue.

Browse Outcrops
Browse and search a complete list of outcrops in the db.

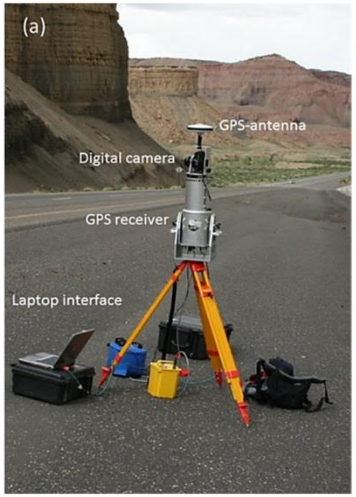
Standard
Access and download the SAFARI standard.

About
General information and tour of the Safari project.

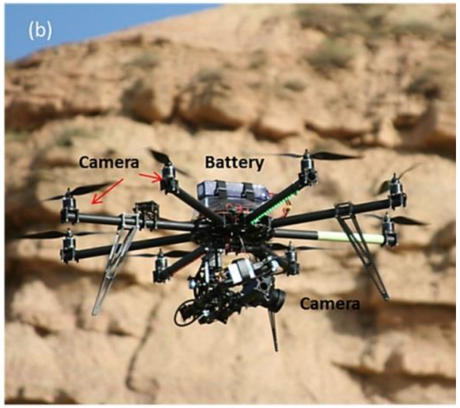
Virtual outcrops: Spain - Ebro basin

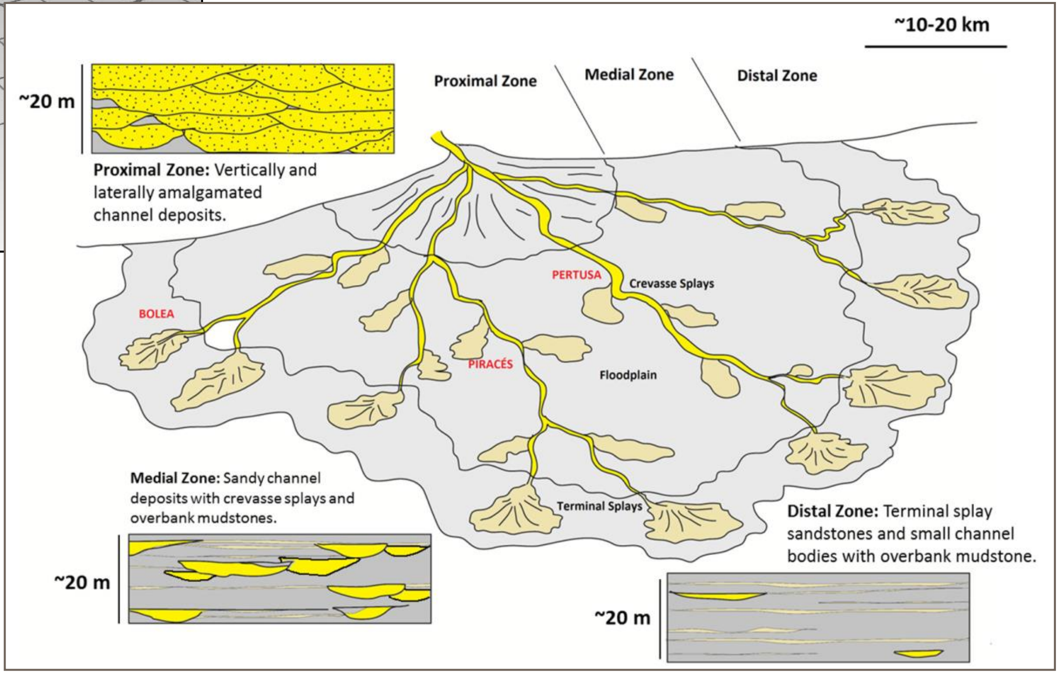


LiDAR scanner



UAV camera

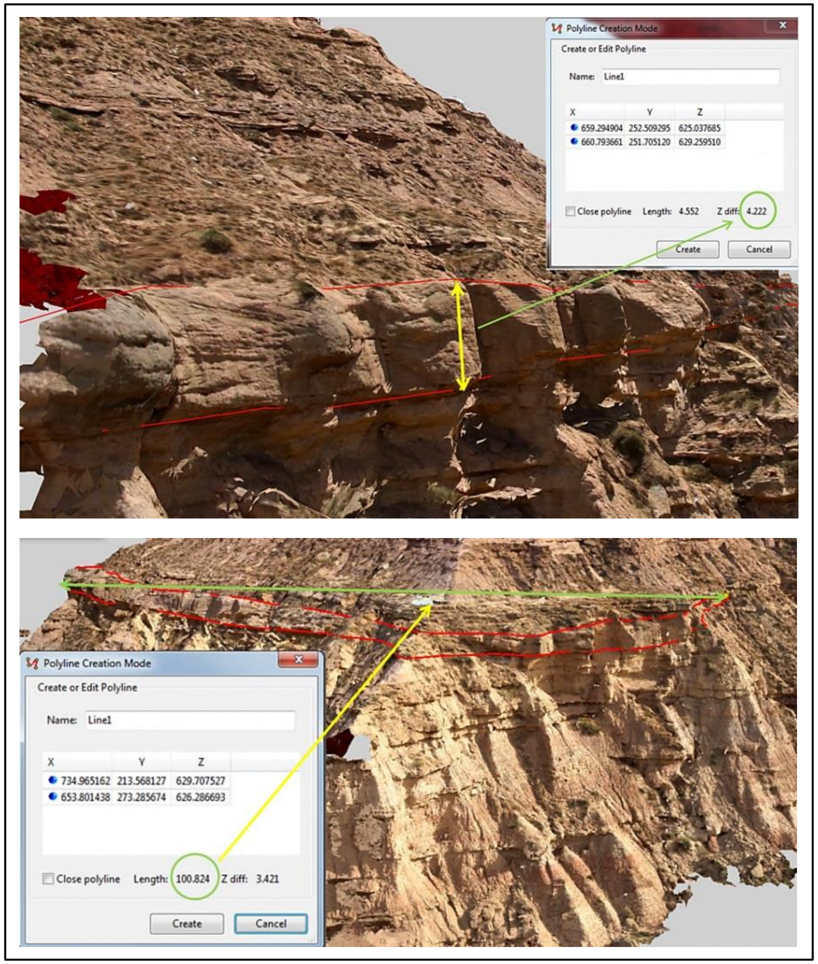




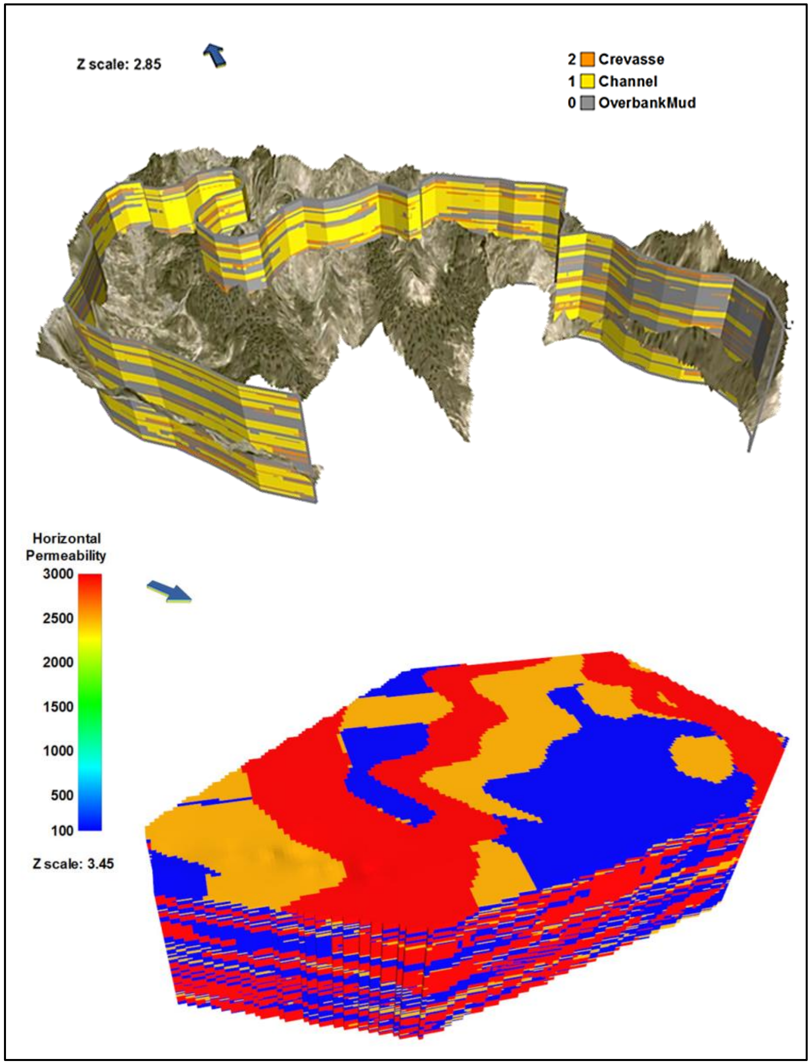
LiDAR and UAV data were collected to build three virtual outcrop models for the quantitative analysis of variations across the system:

- Pertusa: Upper medial zone
- Piracés: Lower medial zone
- Bolea: distal zone

Practical uses of a virtual outcrop



Sandstone bodies can be interpreted and their geometry be measured on the virtual model to populate the Safari statistic database



Input to facies and geocellular models to test flow simulations

Applications in Geology: Training

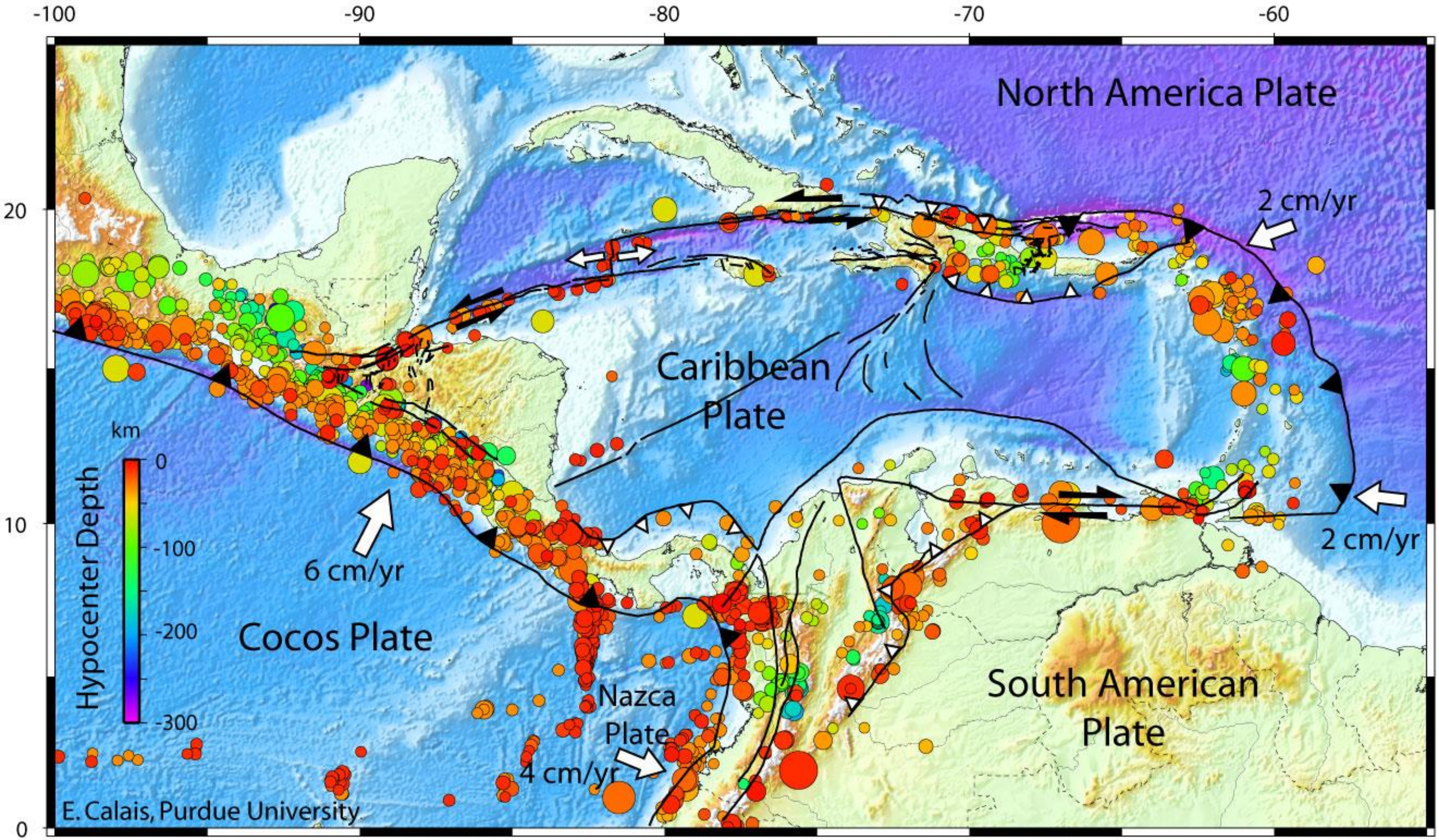
Virtual field-trip on a virtual outcrop
Project sponsored by Statoil – Trondheim

https://www.youtube.com/watch?v=pKtNZS43aDc

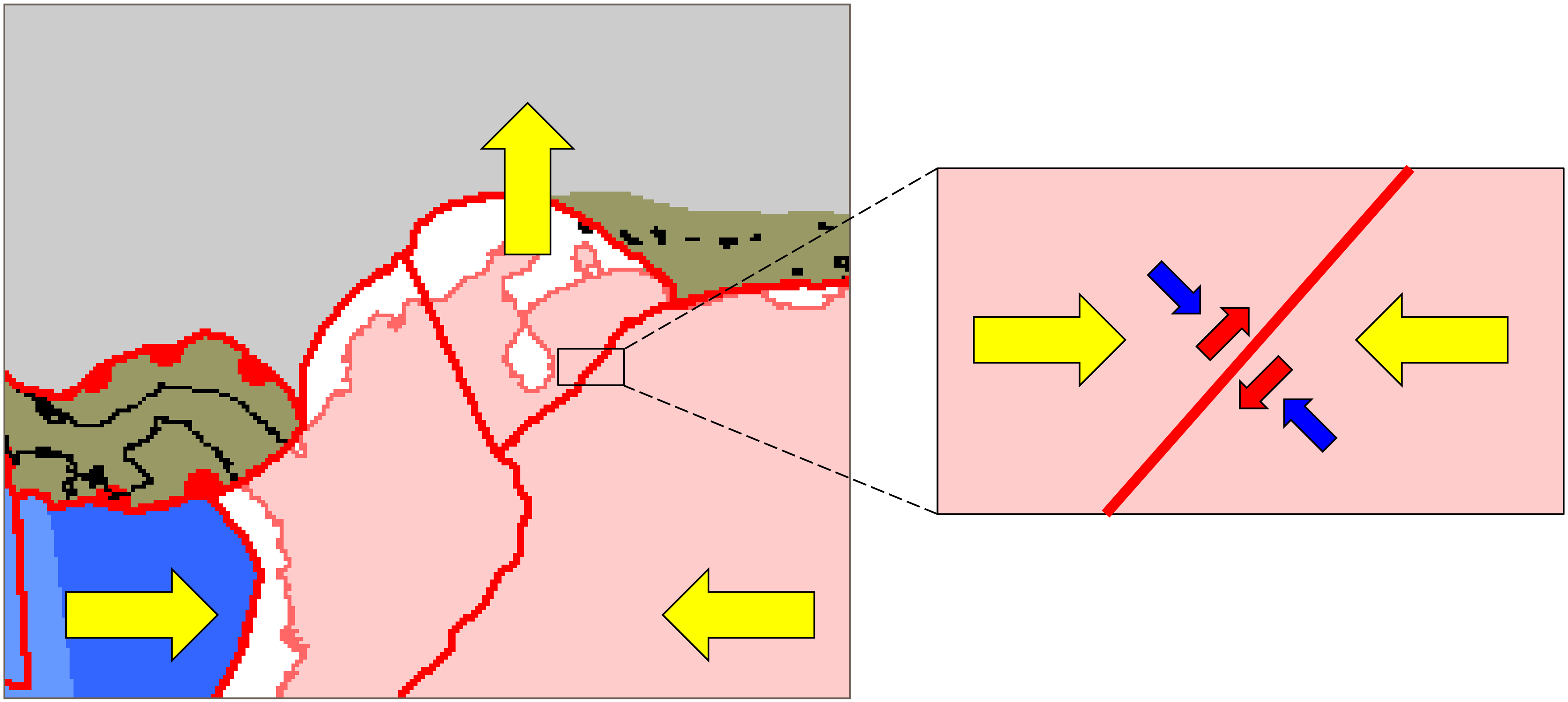
Drone test
Geological background

Caribbean and Central America tectonic framework

Seismicity from the USGS/NEIC database (1974 to present)



Maracaibo block and Venezuelan Andes: Physiography and Structural elements

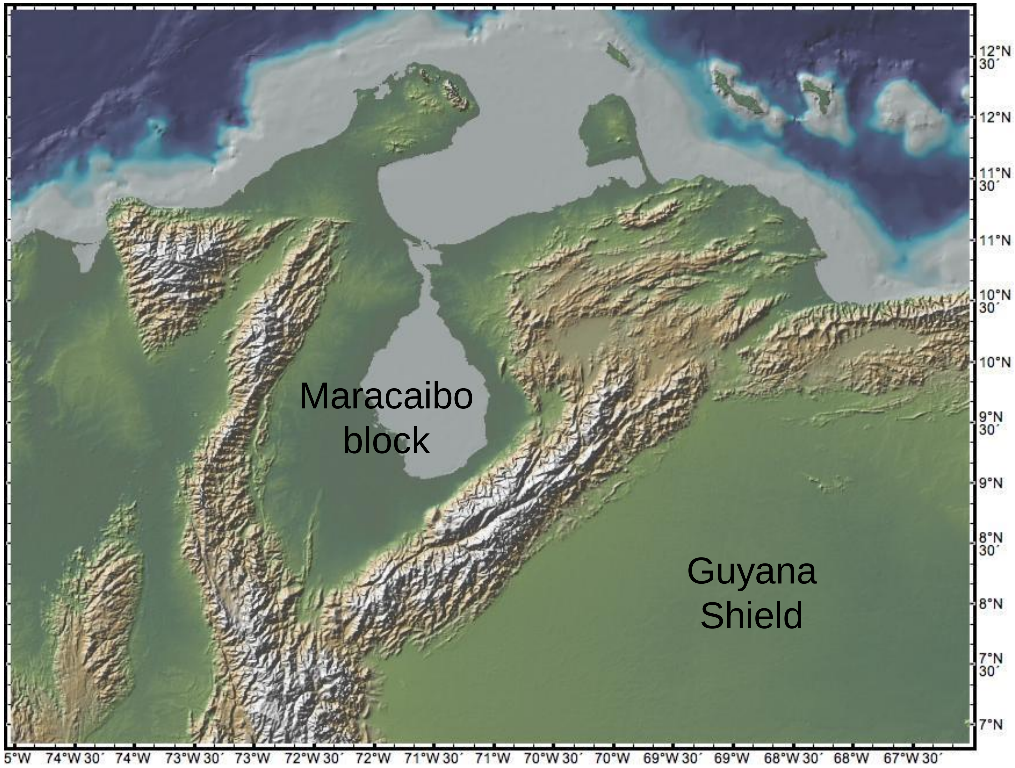


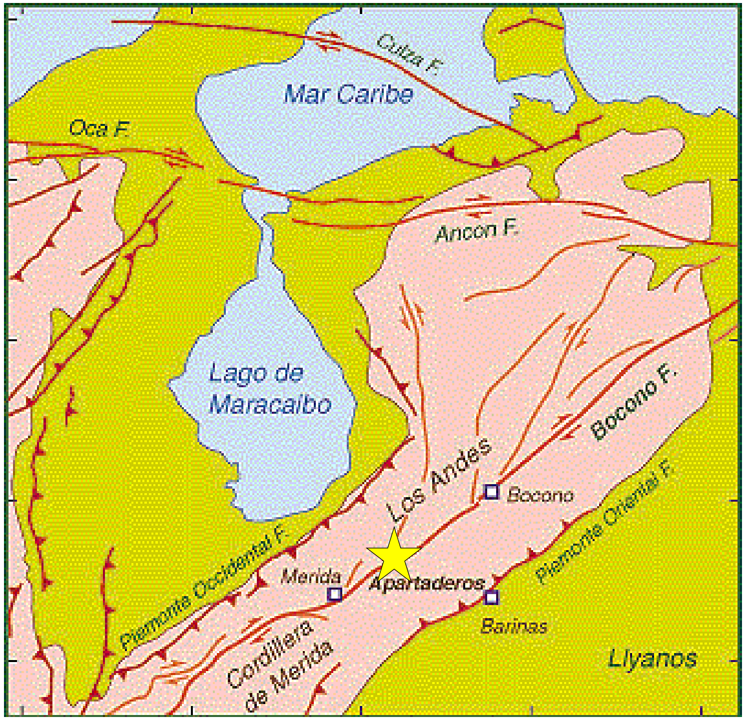
The convergence of the Nazca plate against the Guyana shield has led to the northward extrusion of the Maracaibo block.

The convergence between the Maracaibo block and the Guyana Shield is oblique along the Boconó fault and can be subdivided into:

- Compressional component (orthogonal to the fault)
- Lateral component (parallel to the fault)

Maracaibo block and Venezuelan Andes: Physiography and Structural elements





The oblique convergence between the Maracaibo block and the Guyana Shield has led to:

- rise of the Venezuelan Andes belt (Mio-Pliocene)
- right-lateral strike-slip movement along the Boconó fault

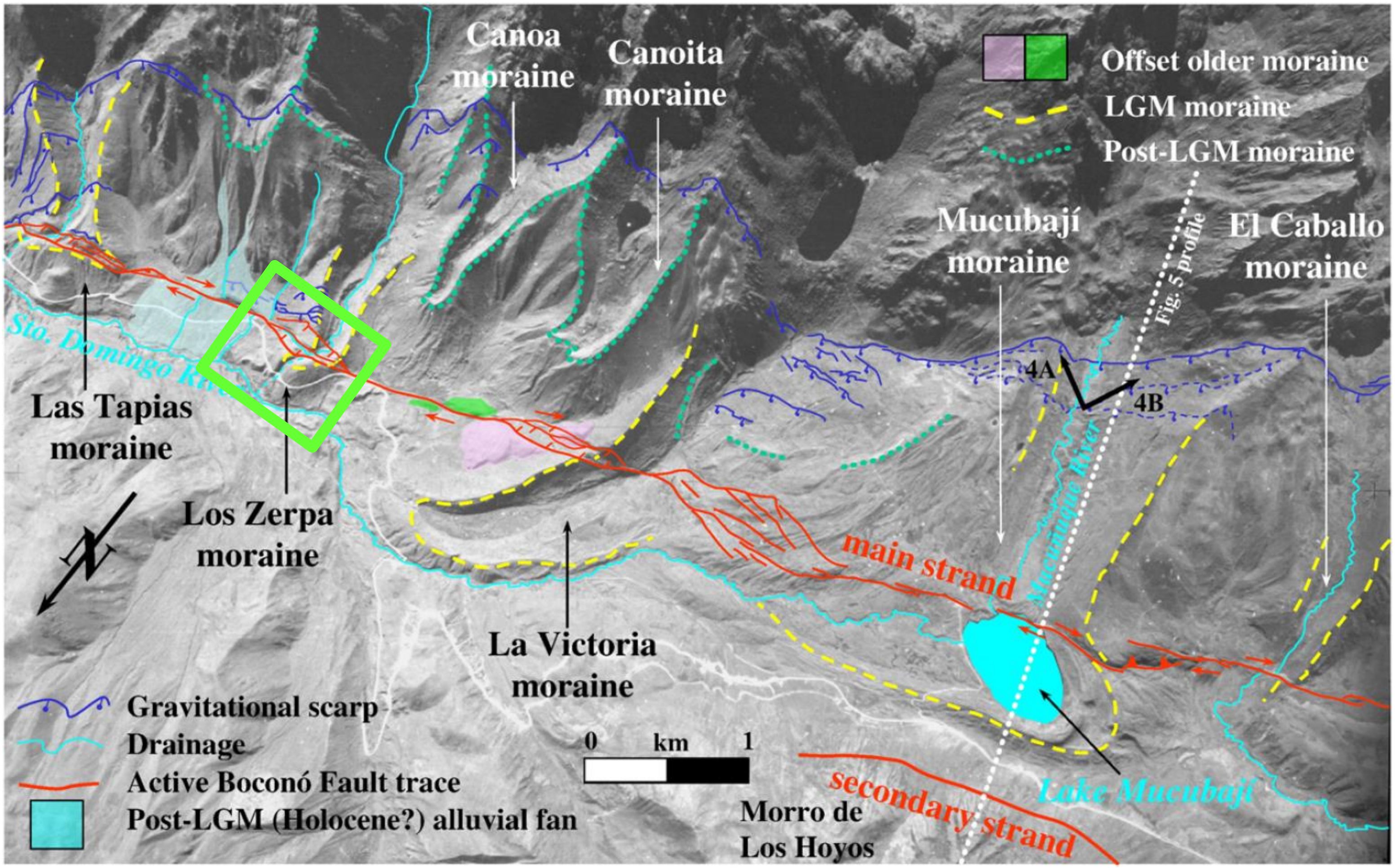
☆ Apartaderos: drone test location

Apartaderos: Boconó fault vs. topography

Several topographic features (3000-3500 m) appear displaced along the fault trace:

- rivers drainage
- glacial moraines (Pleistocene-Holocene)

"Los Zerpa" moraine selected for the test



"Deep-seated gravitational slope deformations along the active Boconó Fault in the central portion of the Mérida Andes, western Venezuela"
Franck A. Audemard, Christian Beck, Eduardo Carrillo - Geomorphology - 2010

Drone test in the Venezuelan Andes

Boconó fault - Los Zerpa Moraine

Drone acquisition

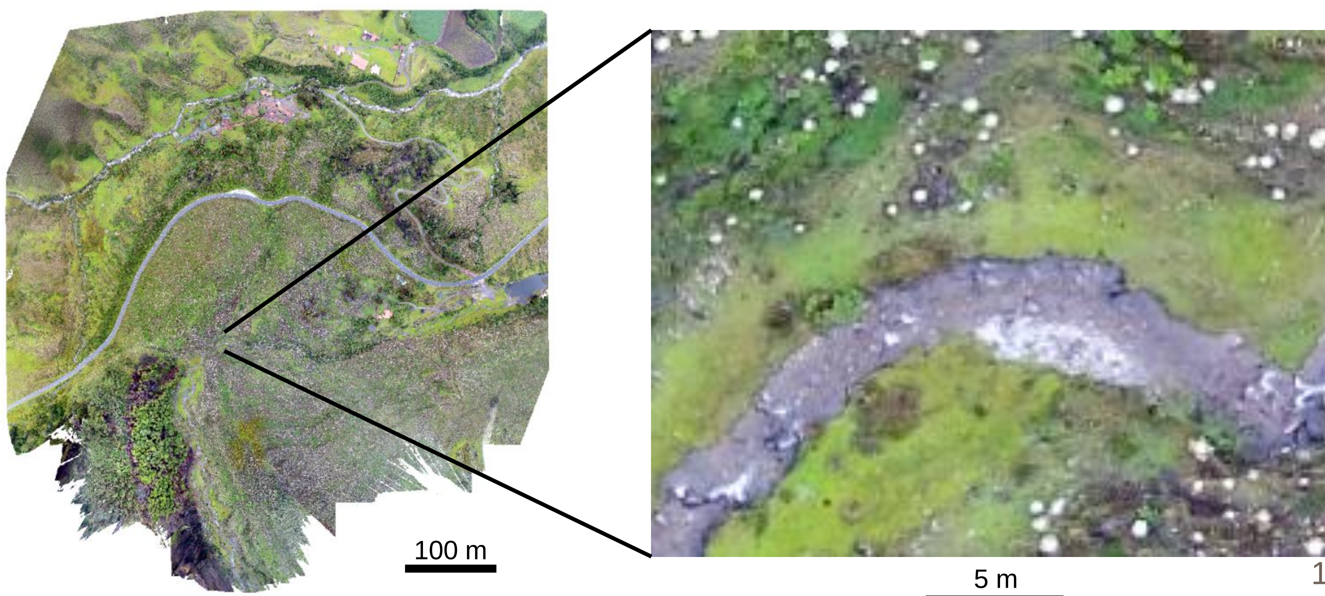
The acquisition was performed in August 2015, covering an area of 400 by 600 m over the moraine system.
The images were acquired at an initial altitude of 80 meters at take-off and with a 70% overlap.
A total of about 300 images were acquired in two flights 20 minutes long.
The picture shows the location of these images and the topography generated by processing them with Pix4D

3D Model

Resolution

Satellite image:
Grid size: 30 x 30 cm

Drone image:
Grid size: 5 x 5 cm



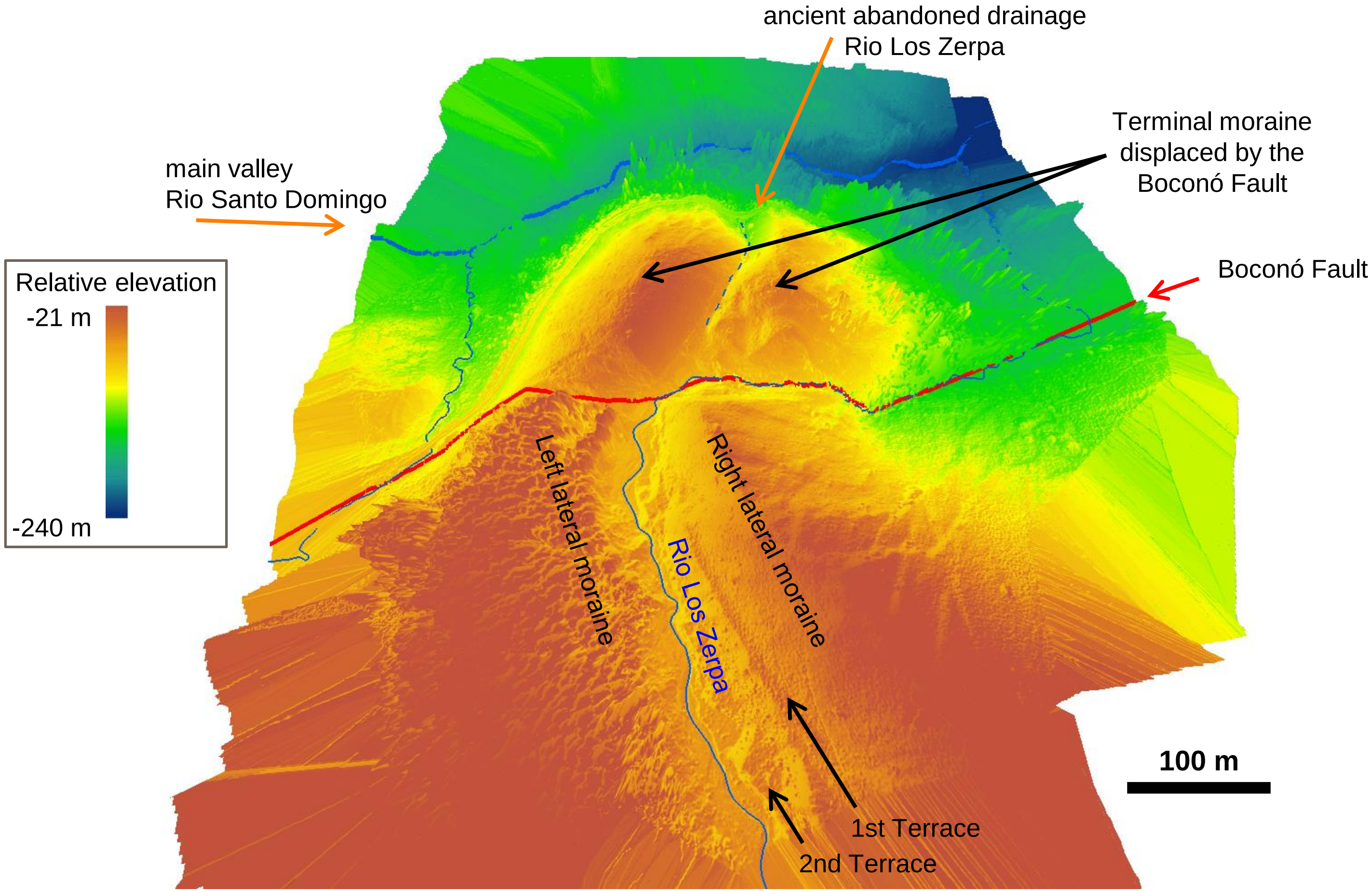
Exercise 1:

Highlighting the landscape

3D model (color-coded by relative elevation)

Several geomorphic features related to the interaction between the Boconó fault and the moraine deposits:

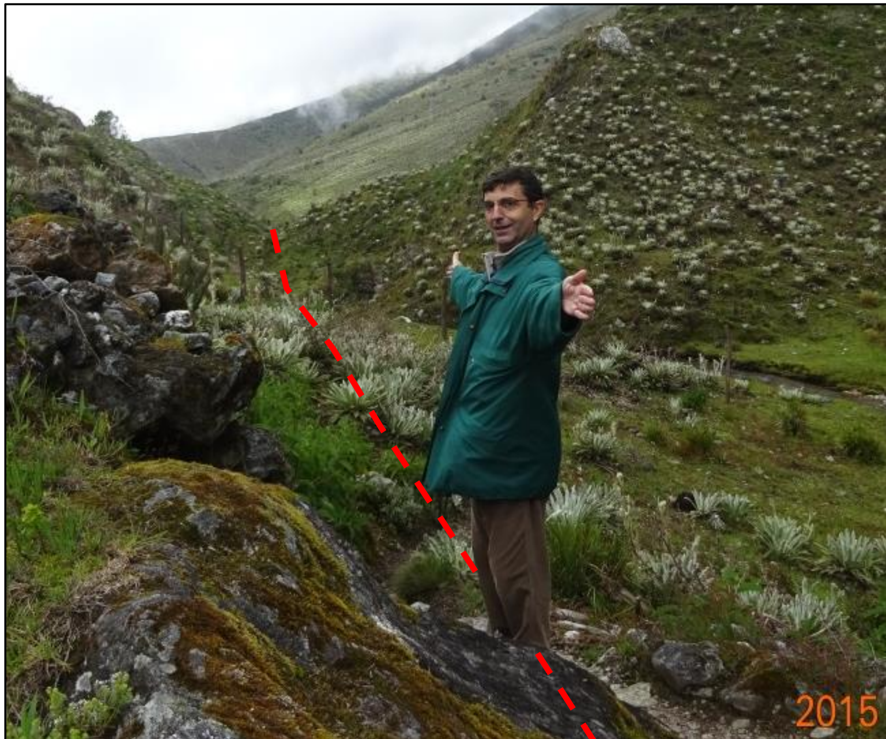
- the trace of the Boconó fault, marked by a series of aligned tectonic scarps
- the sharp bend of the Rio Los Zerpa, that deviates 90º when it intersects the fault trace
- the dextral displacement of the lateral moraines as they cross the fault
- two terraces witnessing past periods of fluvial infill and later erosion
- the ancient fluvial valley incised in the terminal moraine and now abandoned

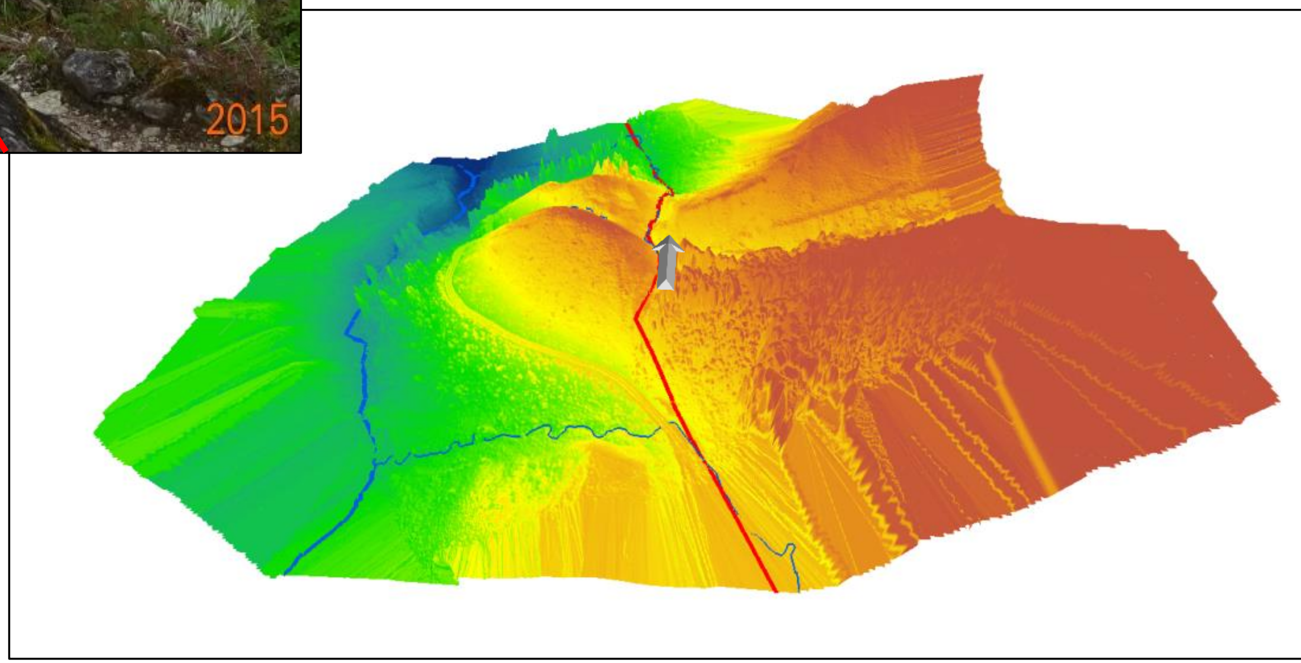


Exercise 2:

Modeling the fault displacement

Fault model

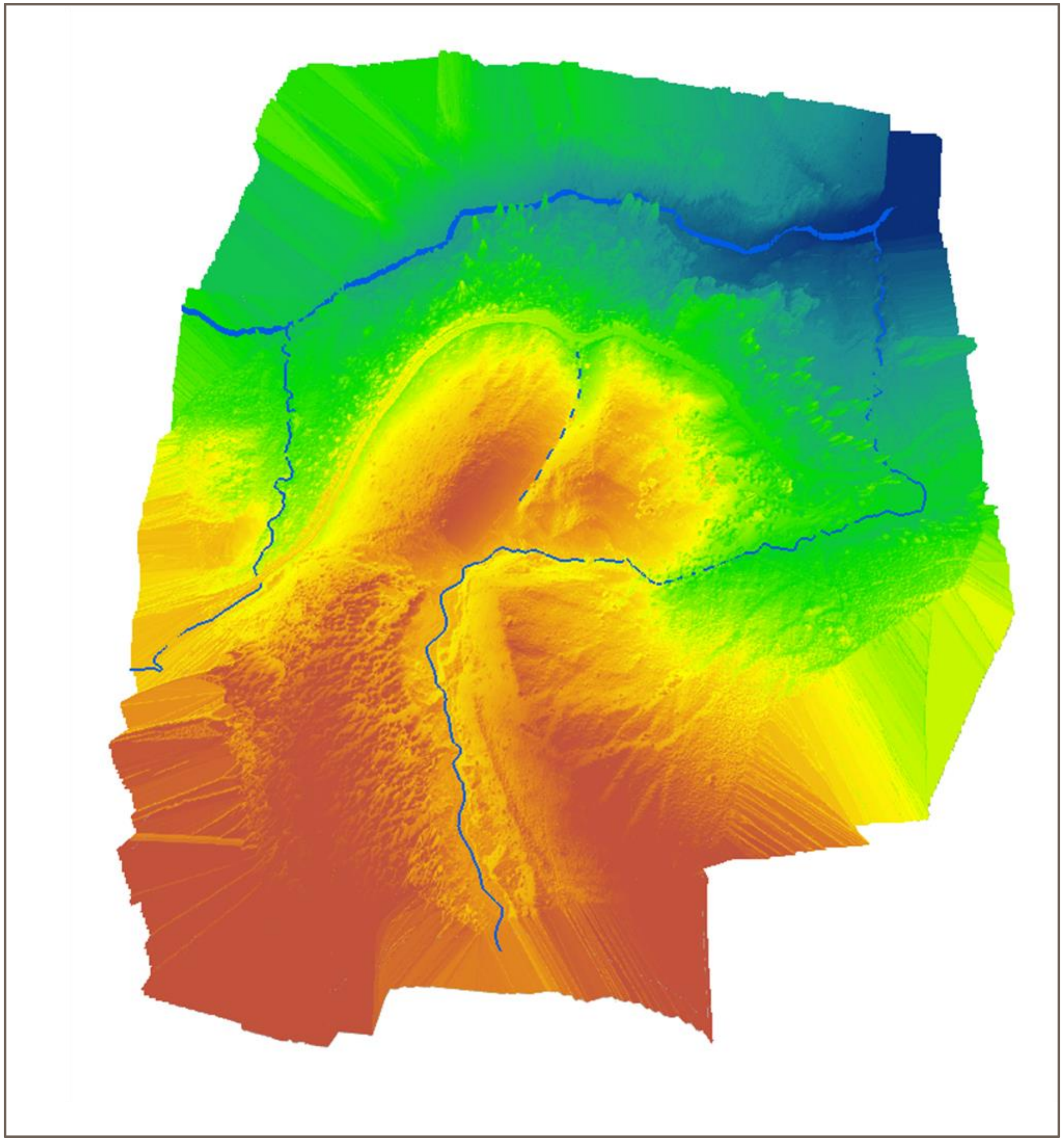




Fault model

The fault trace is highlighted by:

- scarps in the topography
- present day drainage

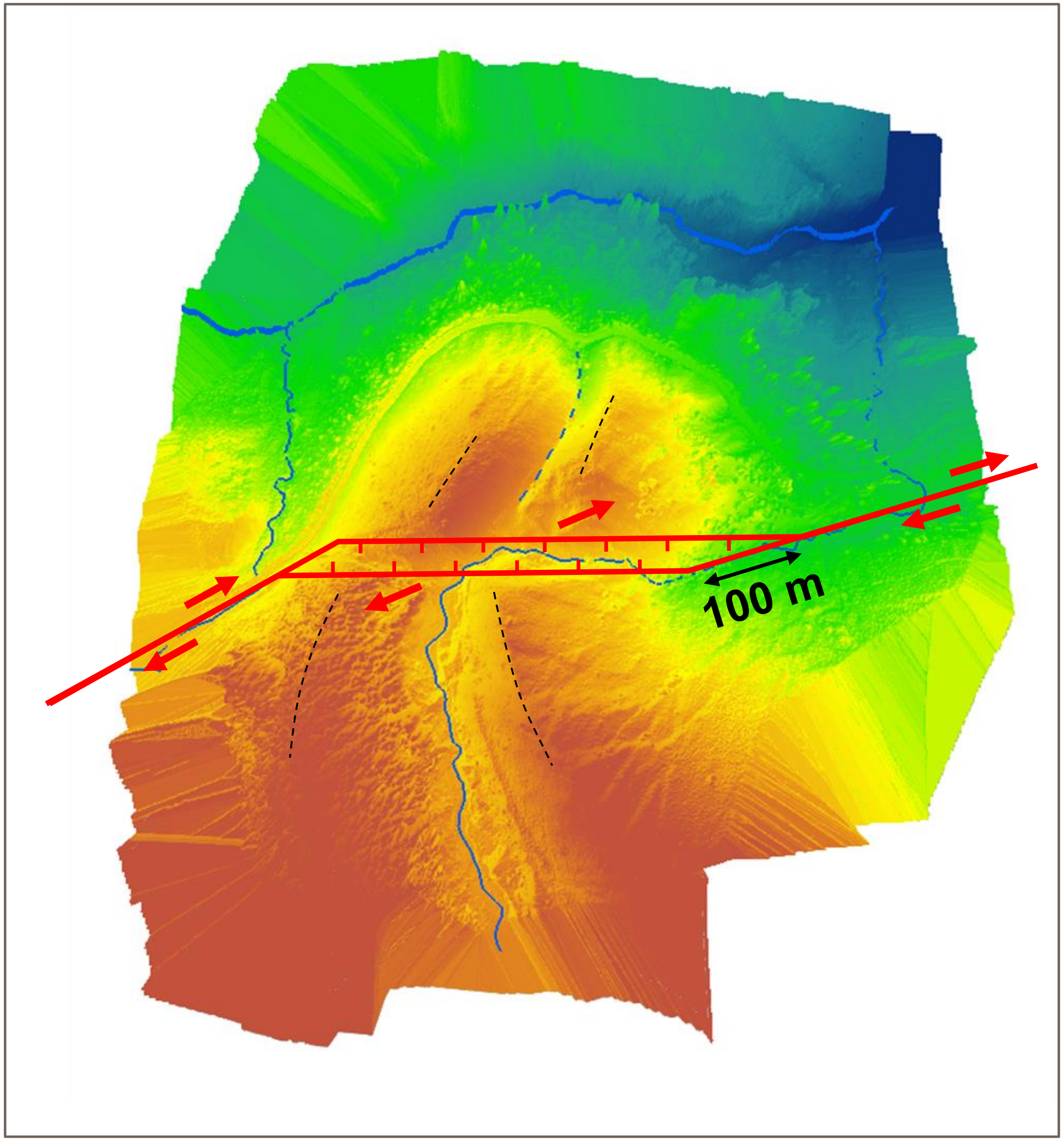


Fault model

The deviation in the fault trace is interpreted as a releasing bend associated with a small transtensional graben

The fault displacement is highlighted by:

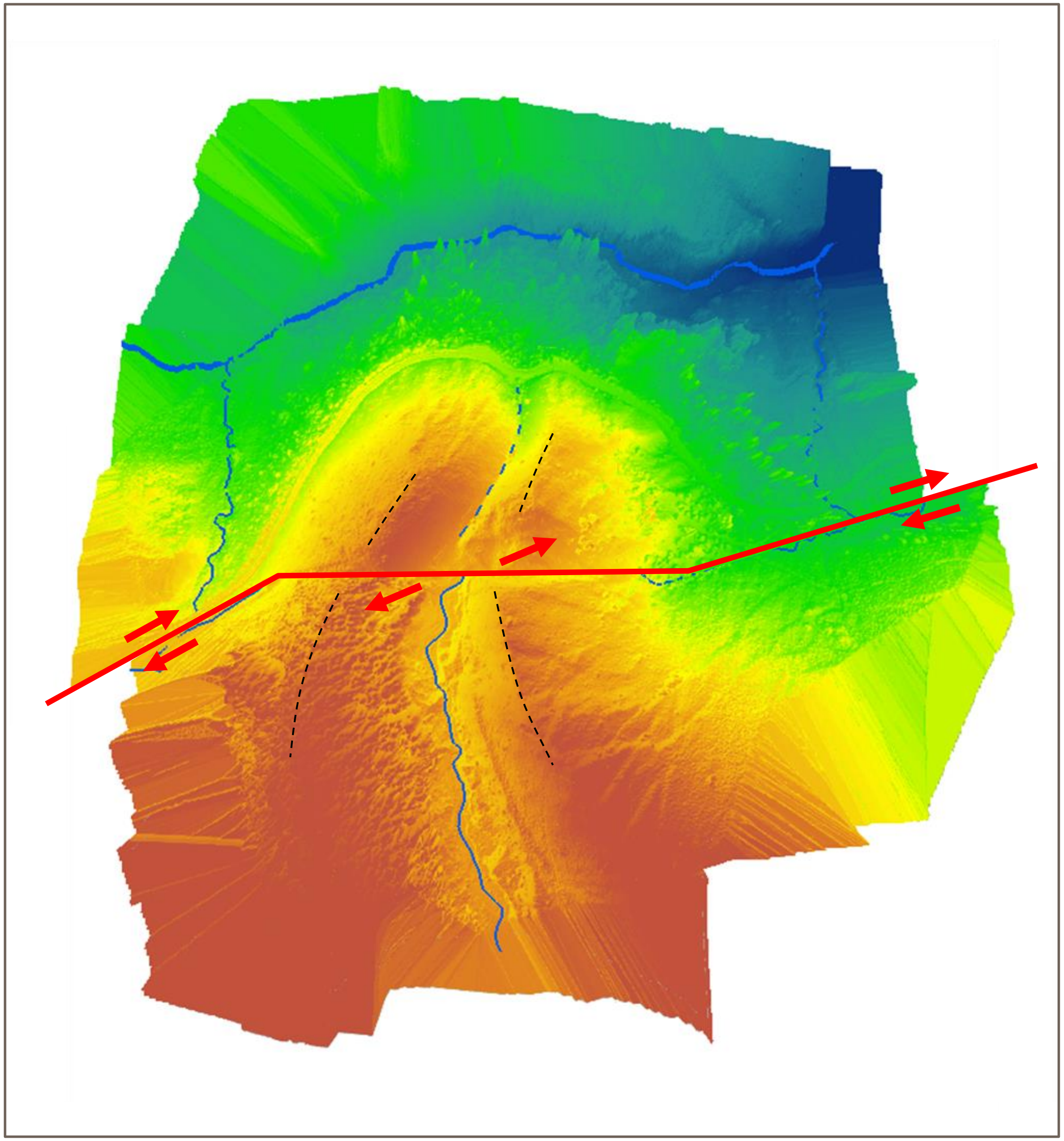
- displaced drainage
- displaced topographic crests



Fault model

Reconstructing the original fault setting brings to align:

- the displaced portions of the moraine crests
- the present day fluvial valley with the ancient abandoned drainage



Boconó fault: displacement velocity

Age of glacier retreat: 16000 years

Current displacement along the Boconó Fault: 100 m

Velocity of displacement: 100 m / 16000 years = 6.3 mm / year

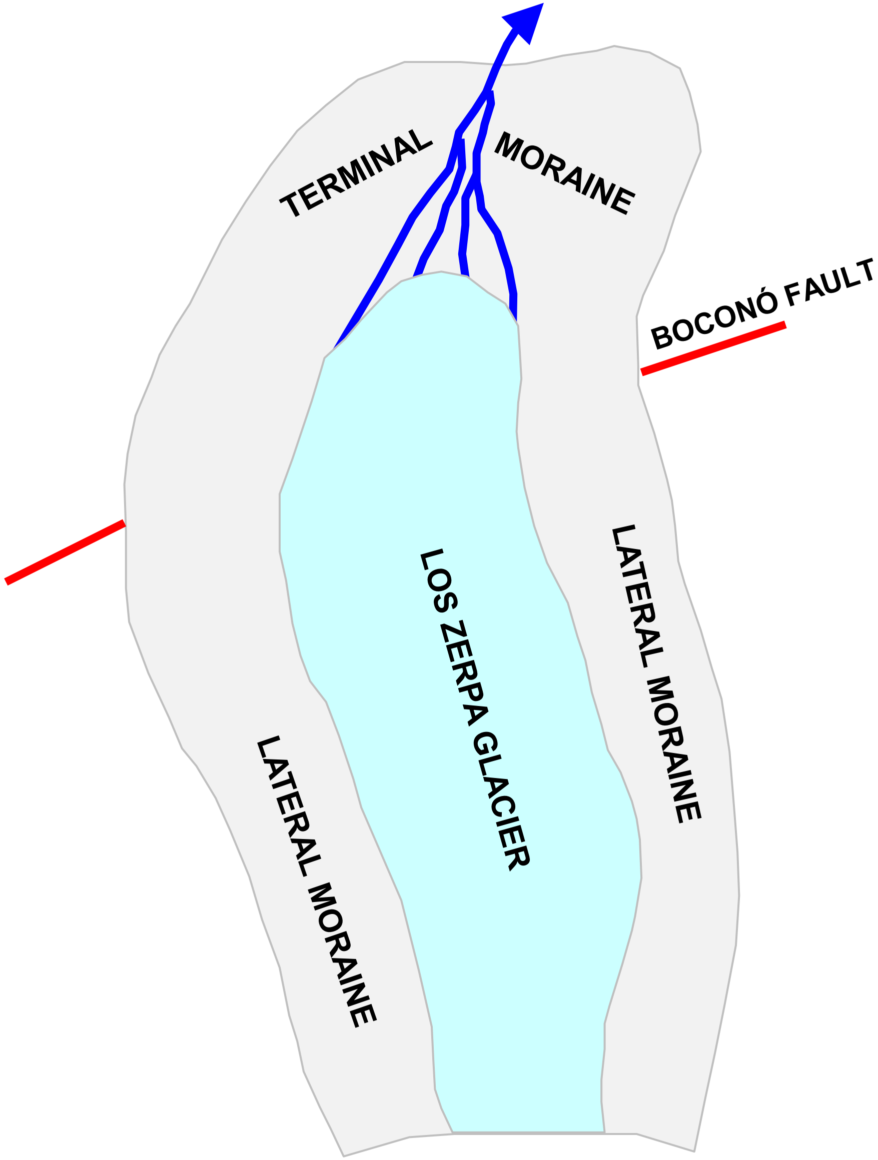
Regional velocity measured with GPS: 12 mm /year

=> The Boconó fault contributes to half of the total regional displacement

Exercise 3:

Modeling the drainage evolution

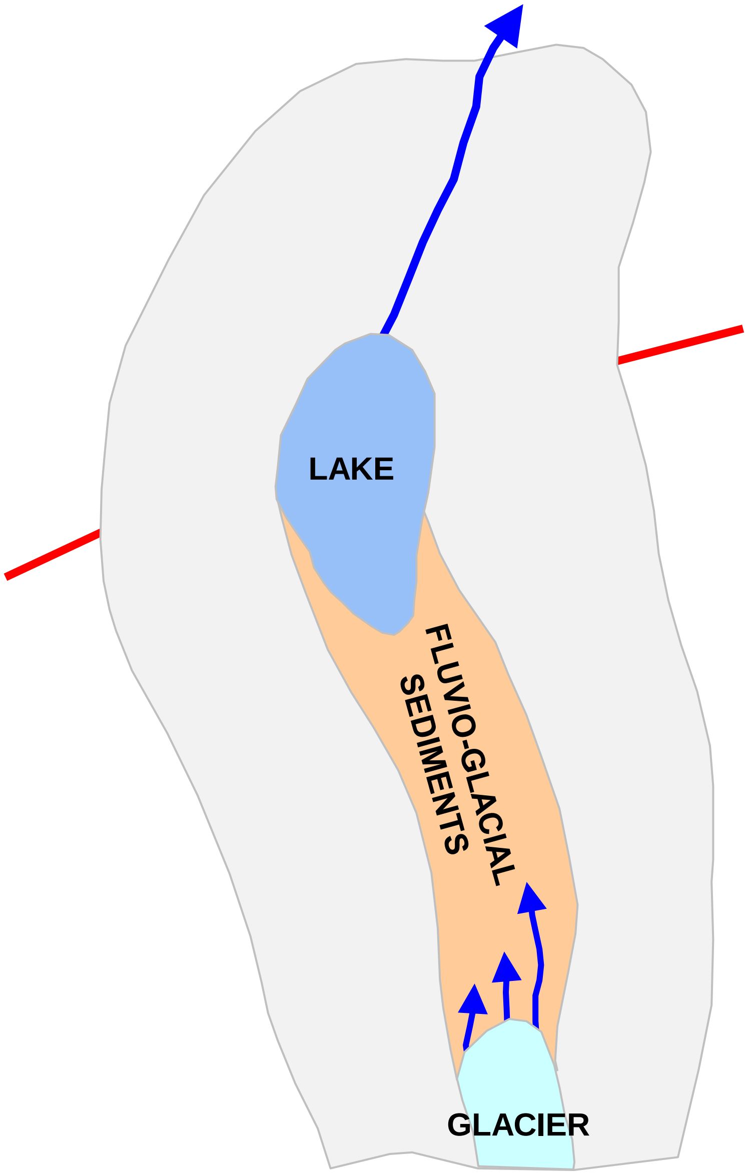
Geological evolution: Glacier advance



"Tectonics and Sedimentation: an example from the Mérida Andes (Venezuela)"
C. Schubert - Acta Geologica Hispanica - 1983

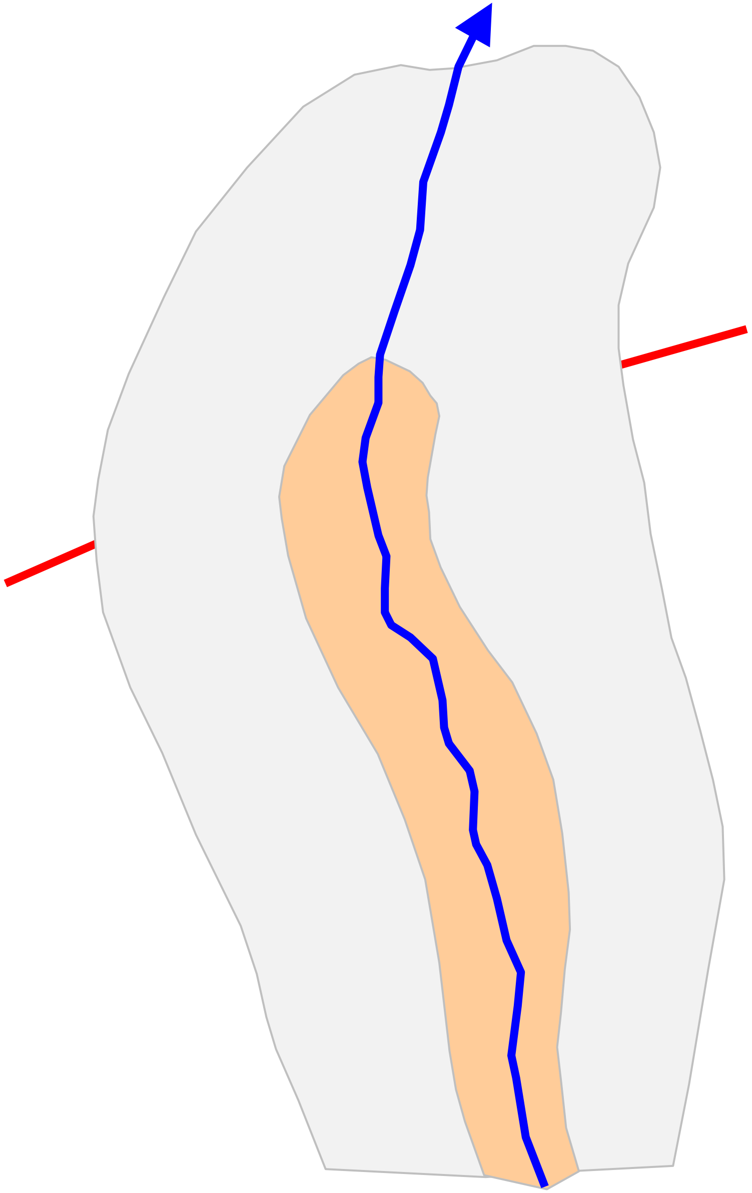
- 18,000 - 13,000 years B.P., the valley of the Los Zerpa river was occupied by a glacier, which deposited the moraines that bound the valley today.
- The glacier melt-water drained over and through the end moraine.

Glacier retreat



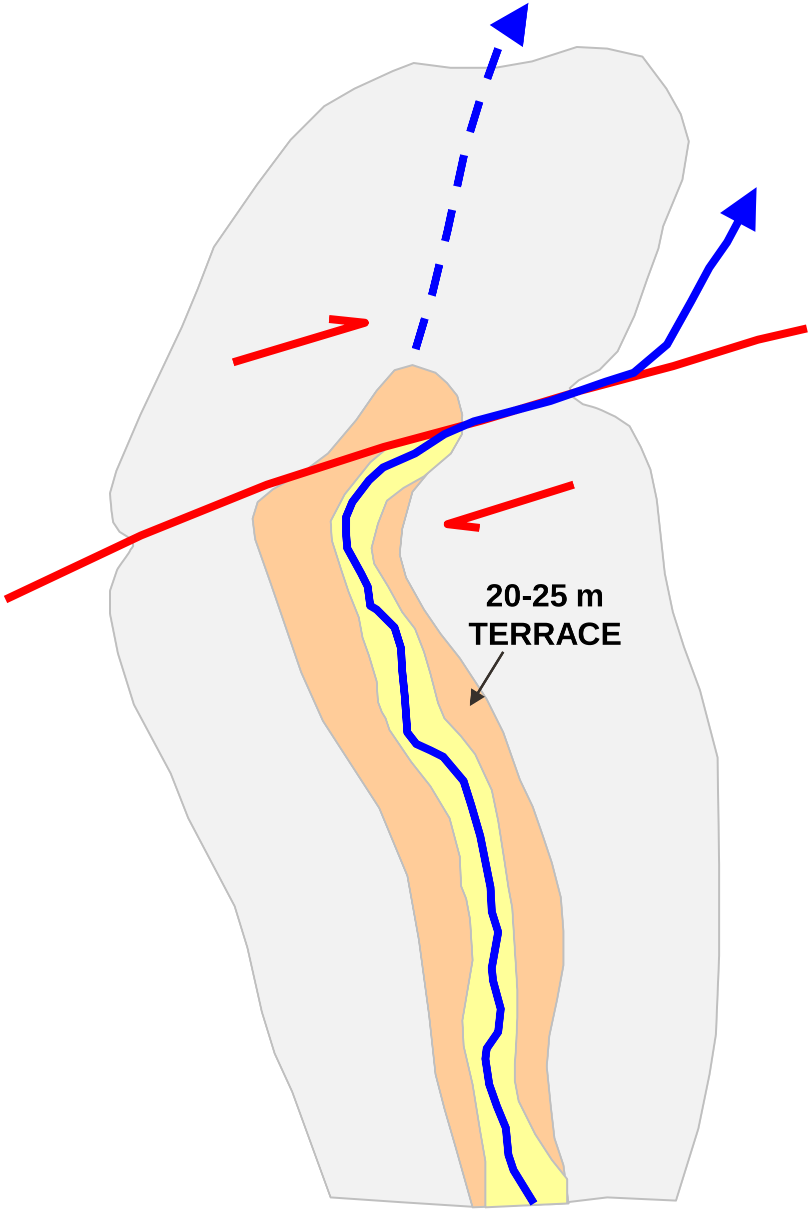
- When the glacier retreat began, a lake probably was dammed in the lower part of the valley.
- Fluvio-glacial sediments were deposited in the rest of the valley.
- Outward drainage continued through the terminal moraine.

Fluvioglacial sedimentation



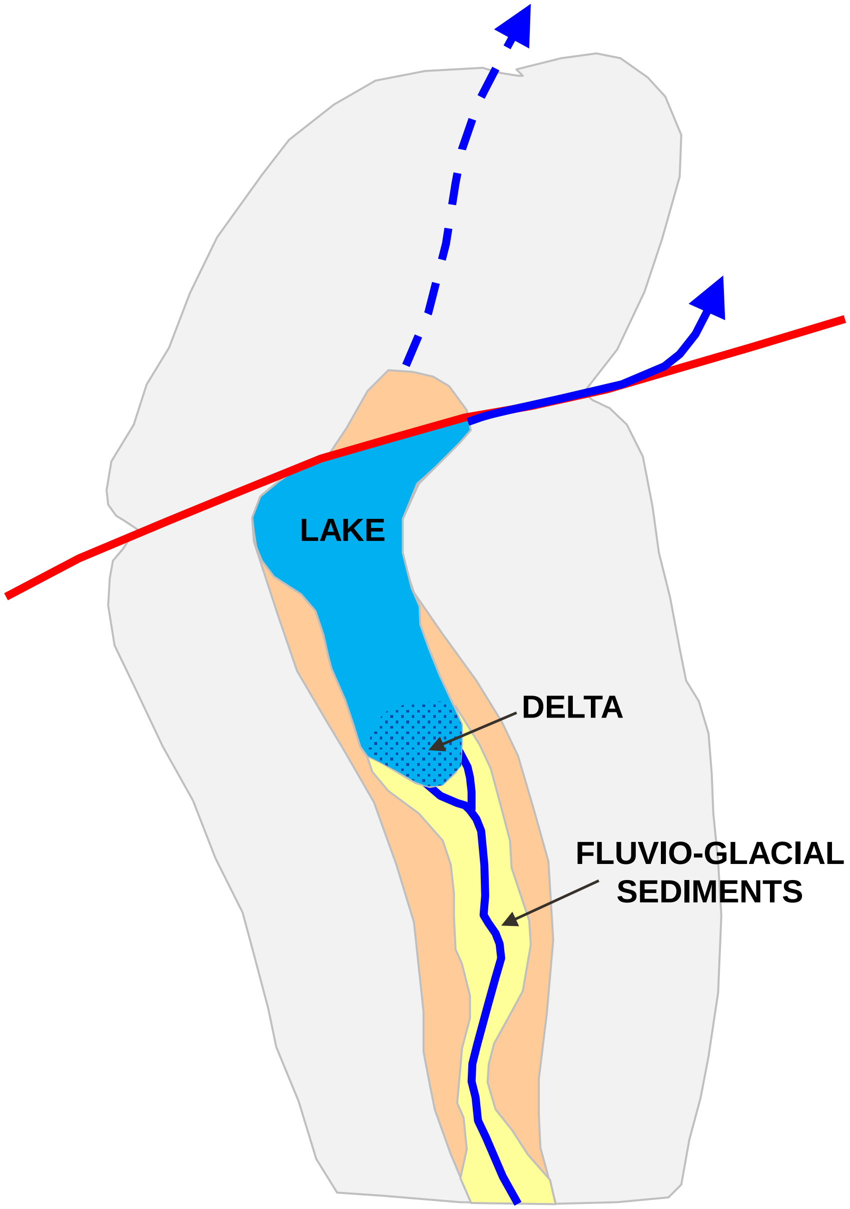
- Fluvioglacial sedimentation continued until the valley was filled to an elevation of 20-25 m above the present-day river level.
- An alluvial plain of the Los Zerpa river formed at this elevation draining through the terminal moraine.

Boconó fault offset



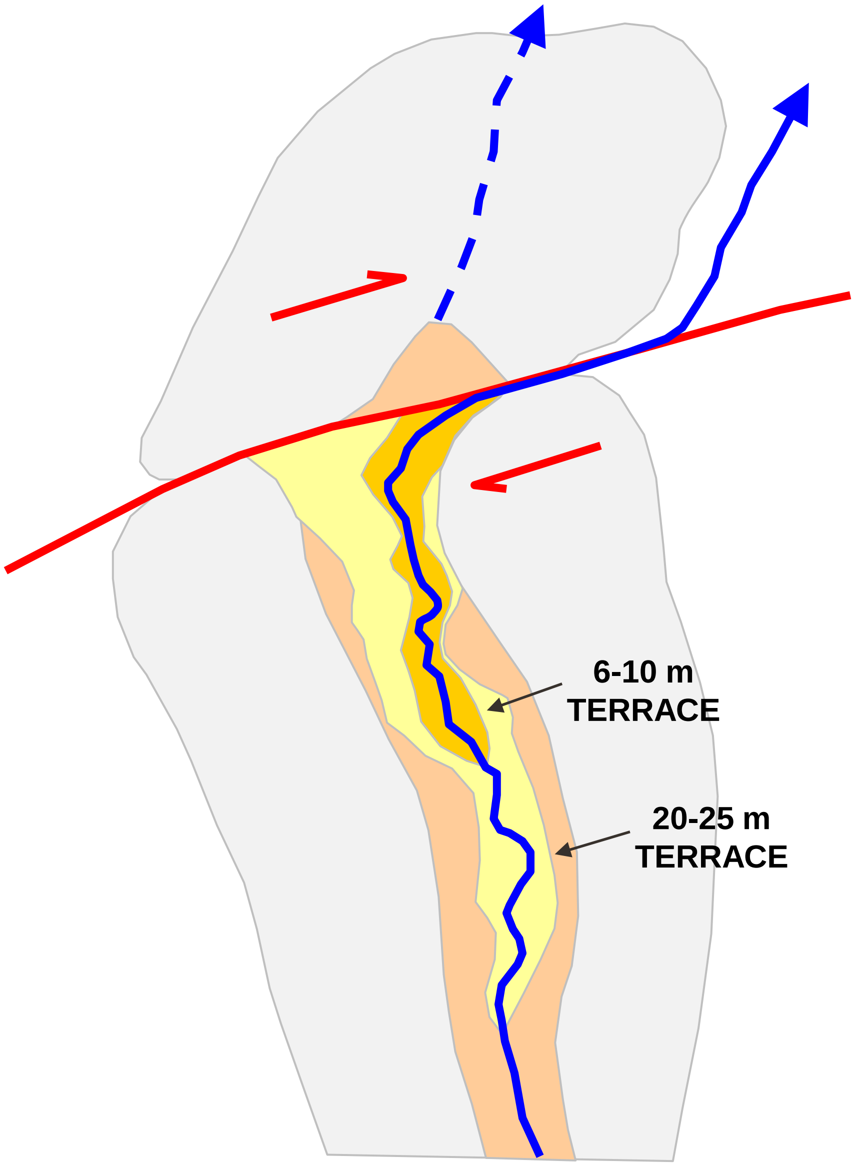
- Right-lateral offset along the Boconó fault opened a breach through the right lateral moraine.
- The Los Zerpa river started to drain through it.
- The old drainage over and through the terminal moraine was abandoned.
- The Los Zerpa river gradient increased, as well as its erosive power.
- The river incised the fluvio-glacial fill of the previous stage and originated a 20-25 m terrace.

New sedimentary cycle



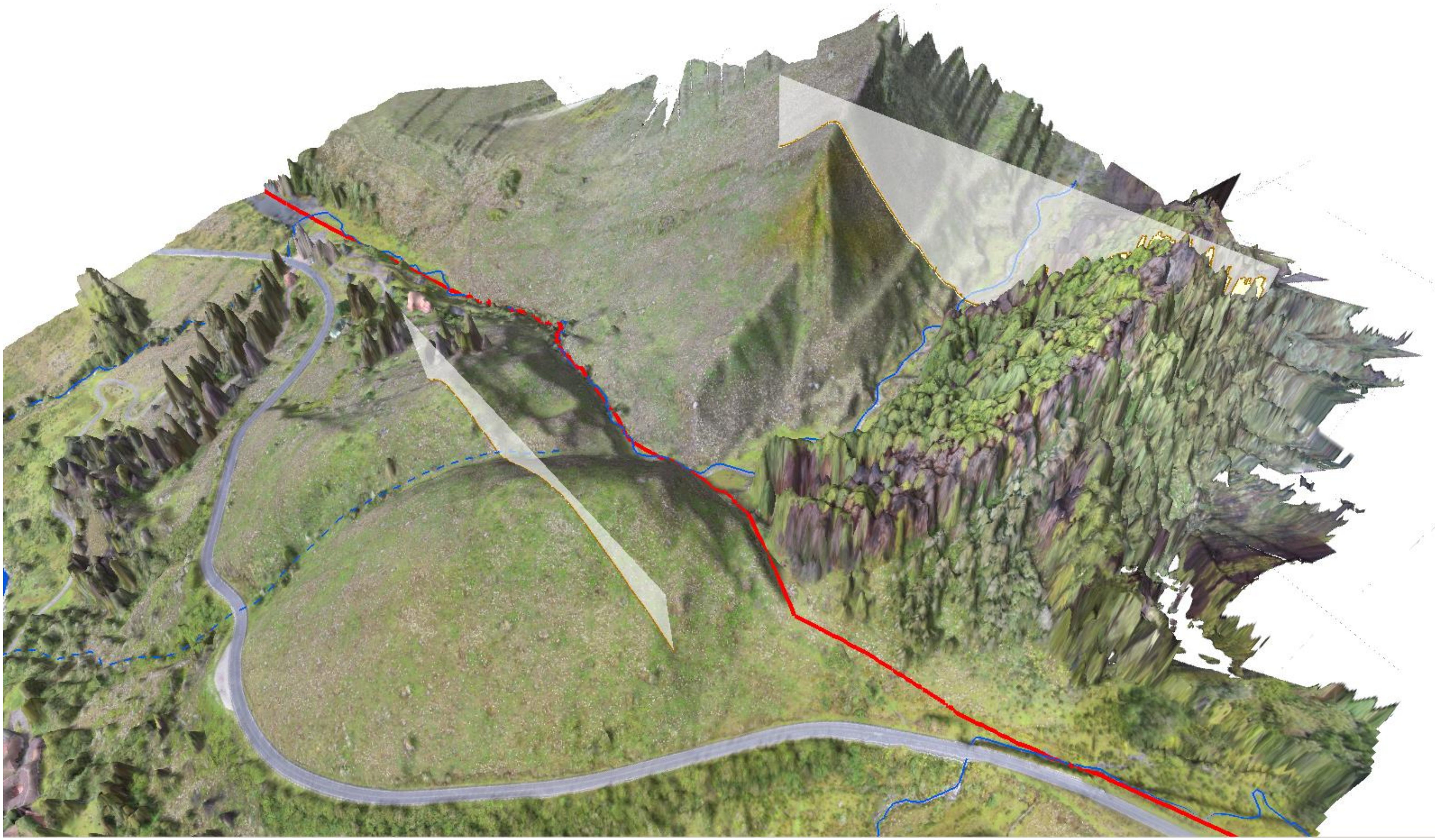
- The breach along the fault trace eventually was closed giving rise to a new sedimentary cycle within the morainic valley.
- A lake was formed in the lower part of the valley.
- It probably drained through the same locality of the previous breach, but at a higher level.
- Fluvioglacial sediments were deposited on an alluvial plain in the higher part of the valley.

Present day

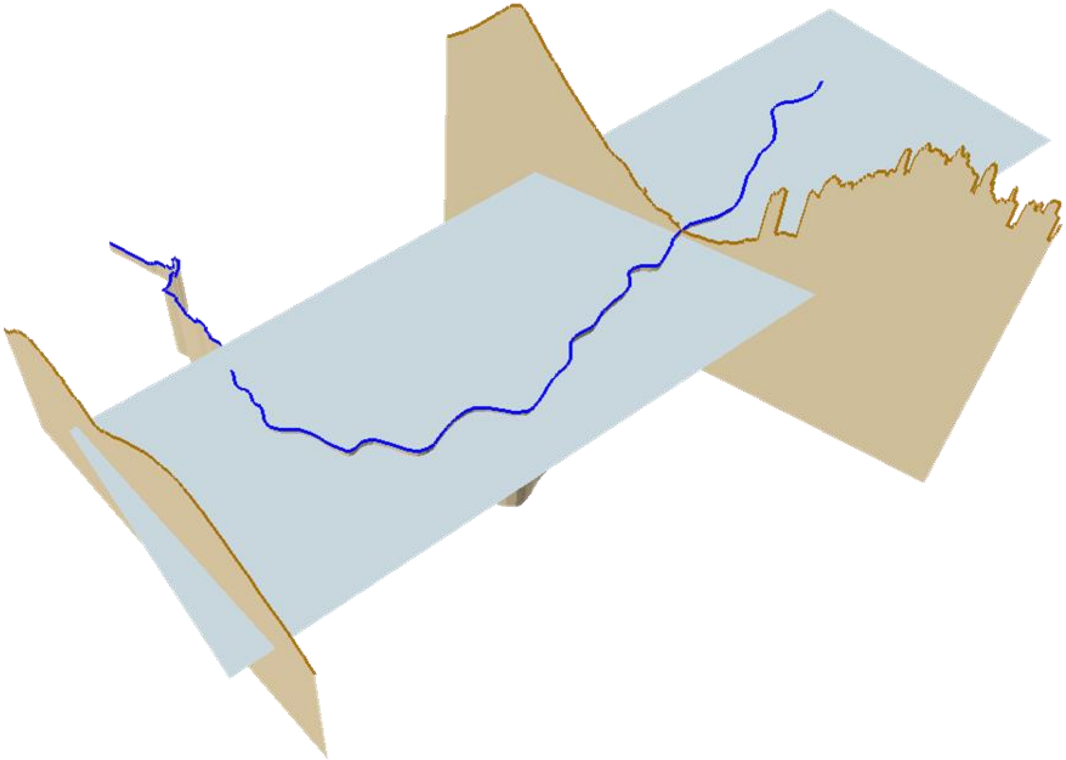


- Thus, we arrive at the present geological conditions.
- Renewed right-lateral offset along the Boconó fault re-opened the breach through the right lateral moraine.
- The lake was drained
- The Los Zerpa river incised the sediments, and formed a second terrace 6-10 m above the present day river level.

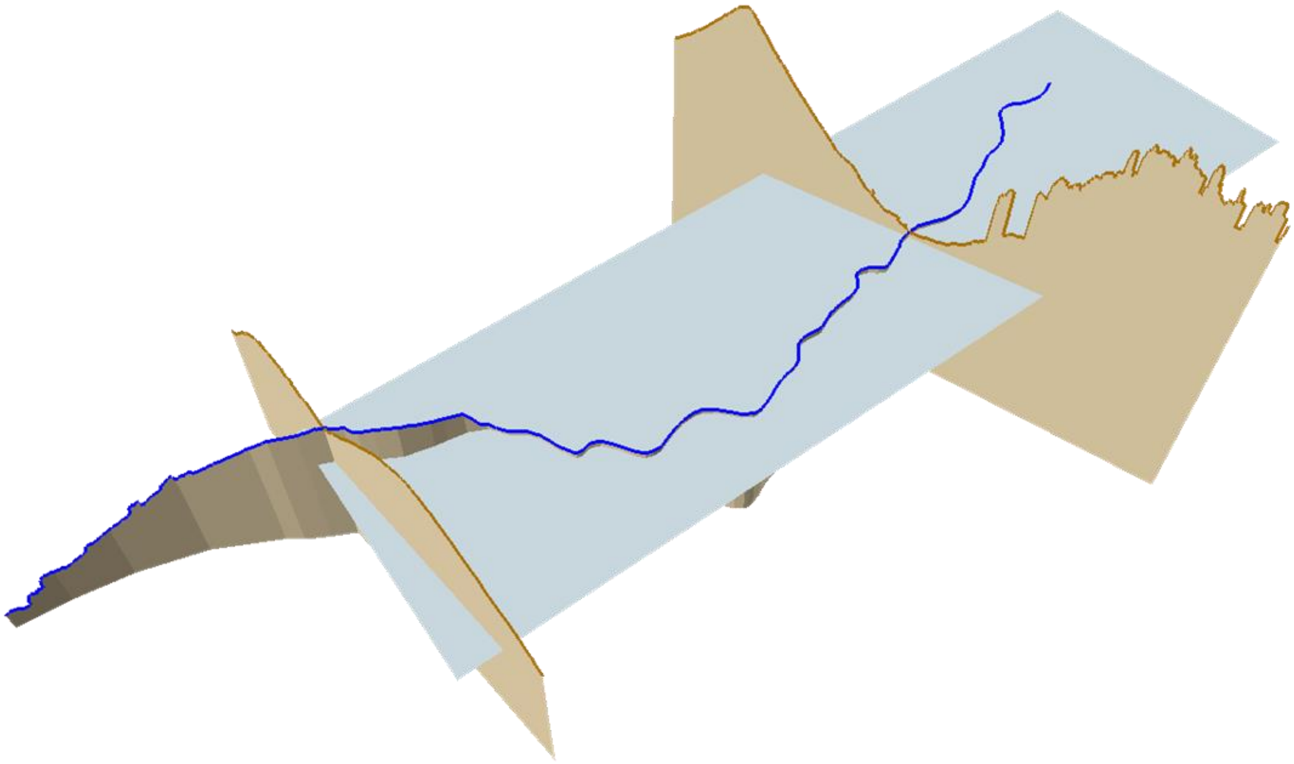
Defining 2 cross sections



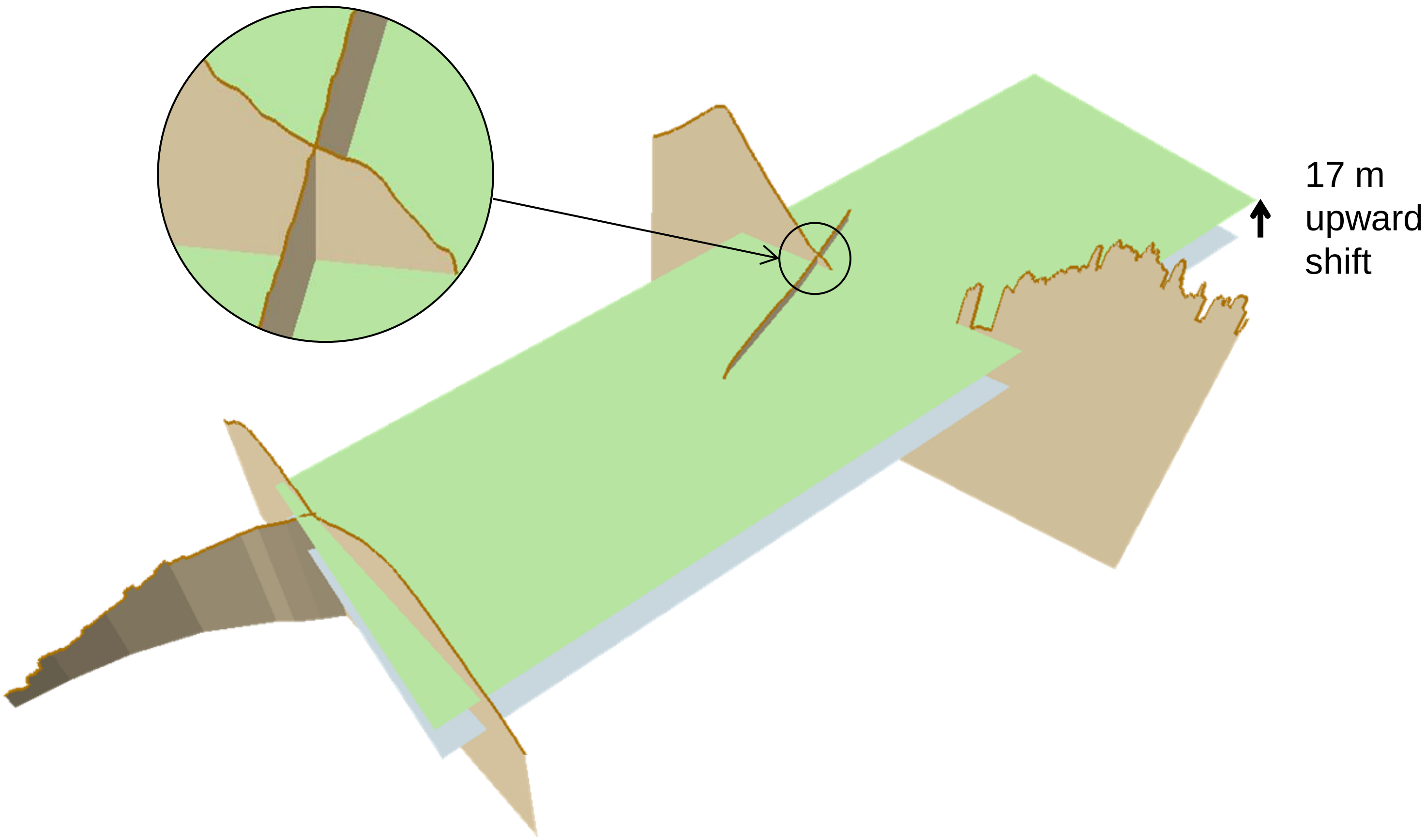
Modeling the slope of the present day river valley



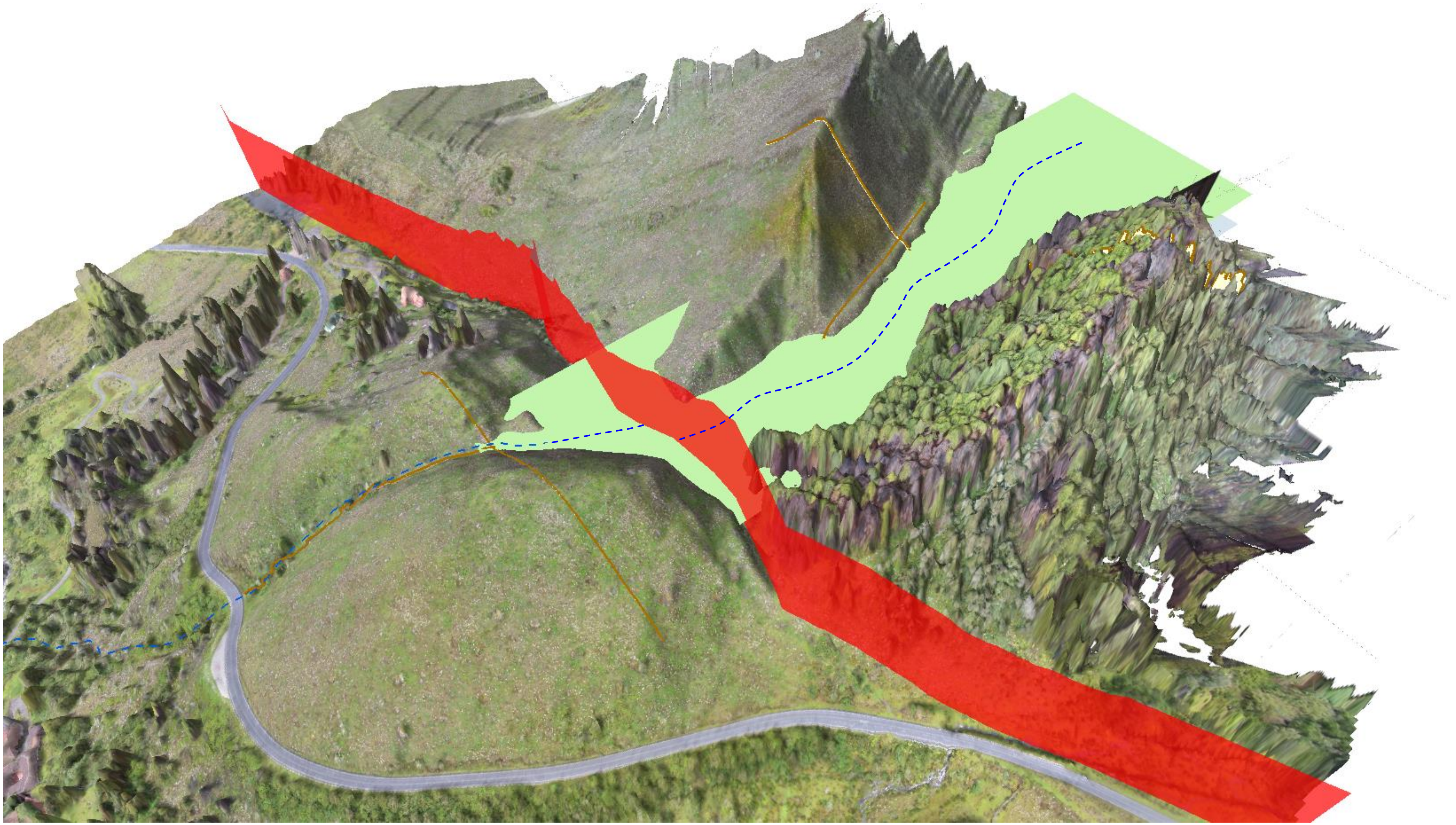
The present day river should flow updip in order to reach the abandoned valley



In order to reach the abandoned river valley a higher alluvial plain should be considered aligned with the terrace on the flank of the moraine



Fluvial drainage modeled at the time when the alluvial plain was filling the glacial valley



Conclusions

- This test has proven that UAV technology can be a useful tool in geological field work
- Acquisition can be made in remote impervious areas with difficult access
- Maps can be acquired at low cost (one man job) and high resolution (a few cm per pixel)
- 3D models are generated at true scale and can be used to measure distances, thicknesses, dips and volumes
- Geological features can be observed from the most favorable point of view
- The model can be manipulated to test geologic concepts and interpretations