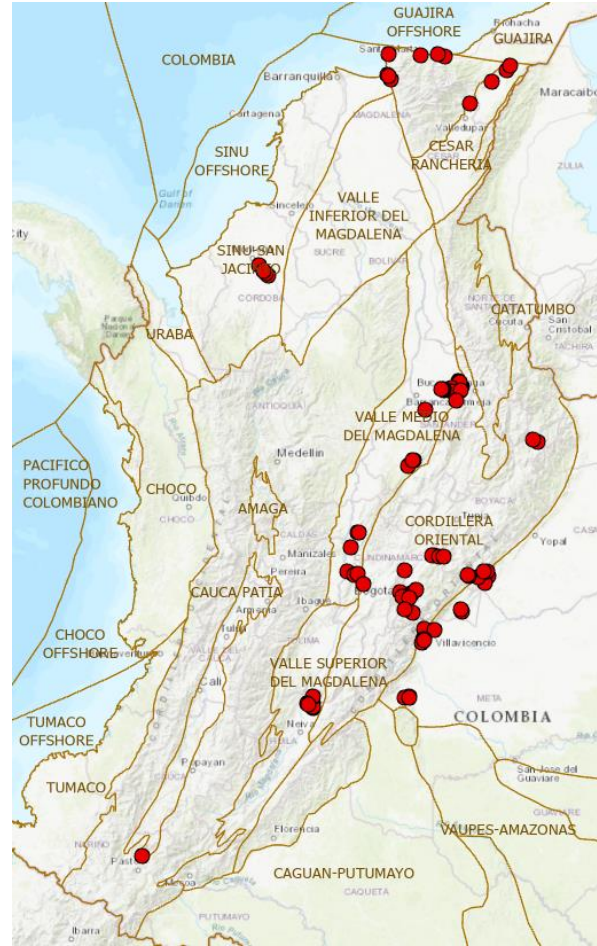# Understanding and quantifying reservoir heterogeneities using Digital Outcrop Models

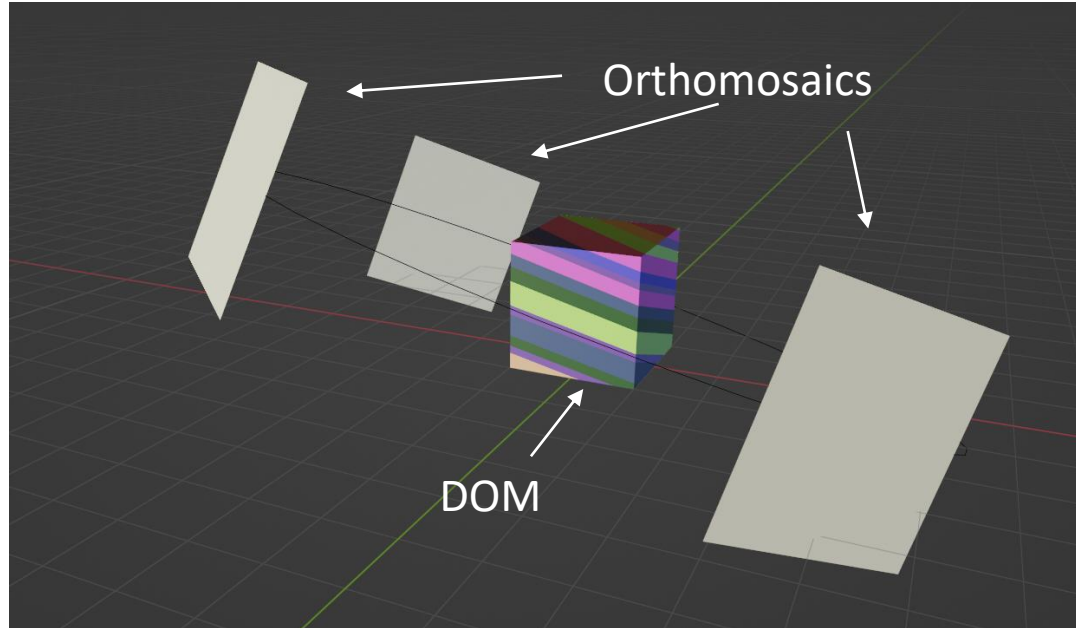Mauricio Baquero, MSc

Germán Bayona, PhD

Corporación Geológica Ares
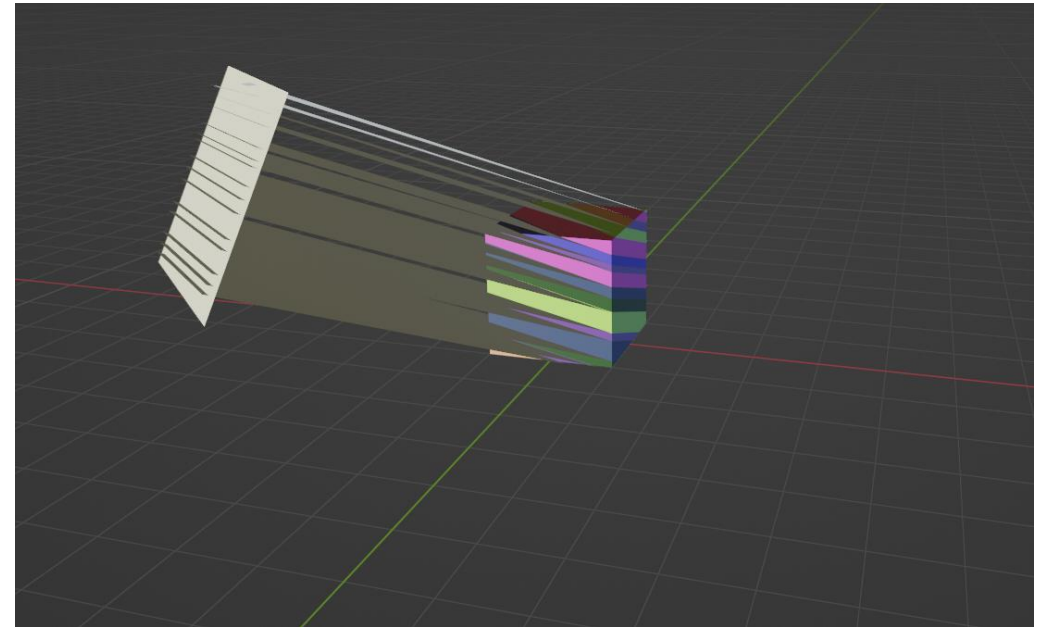
DIGITAL OUTCROP MODELS
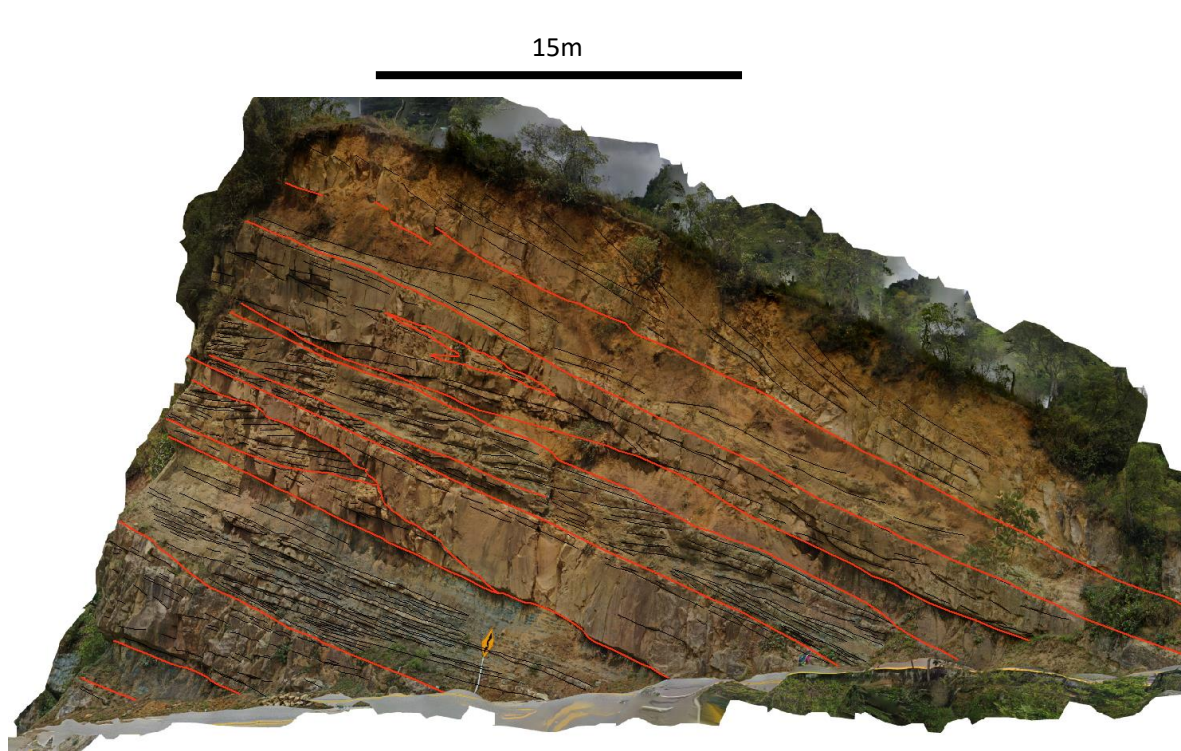

Ares DOM collection

ORTHOMOSAICS

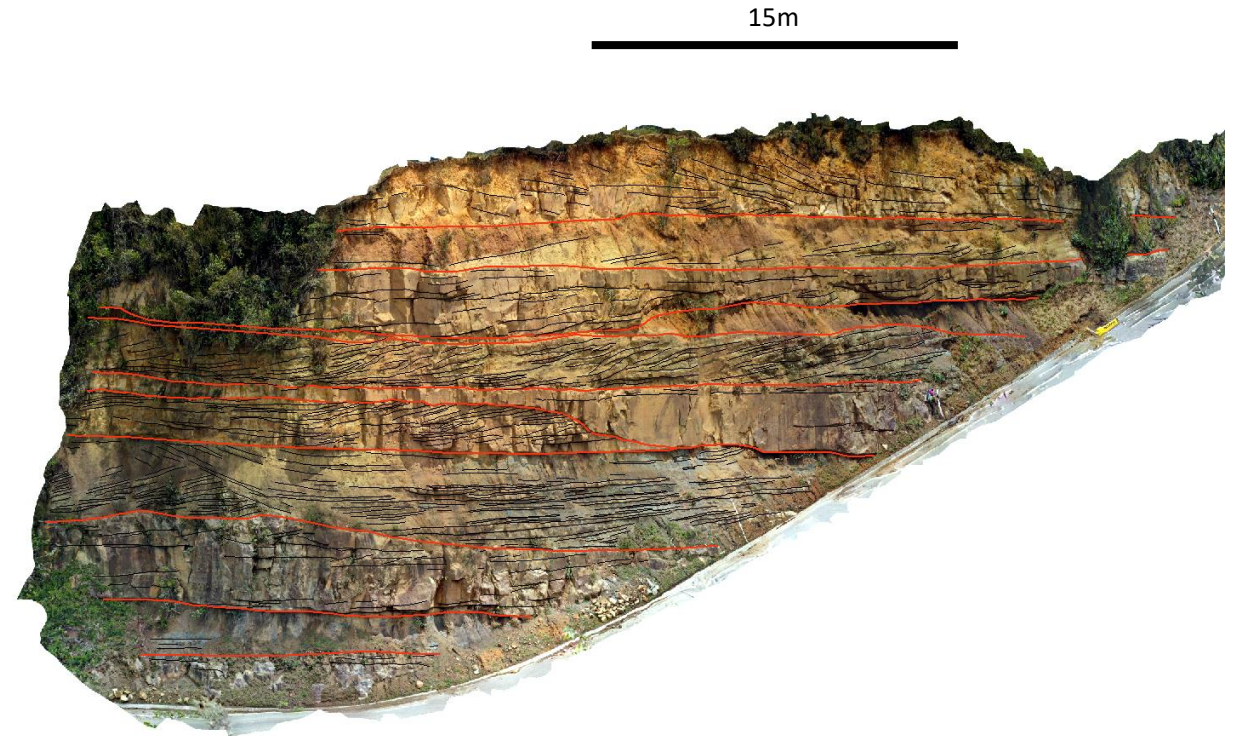Multiple bed-perpendicular possible plane locations.

True bed projections.

BED-PERPENDICULAR ORTHOMOSAIC INTERPRETATIONS

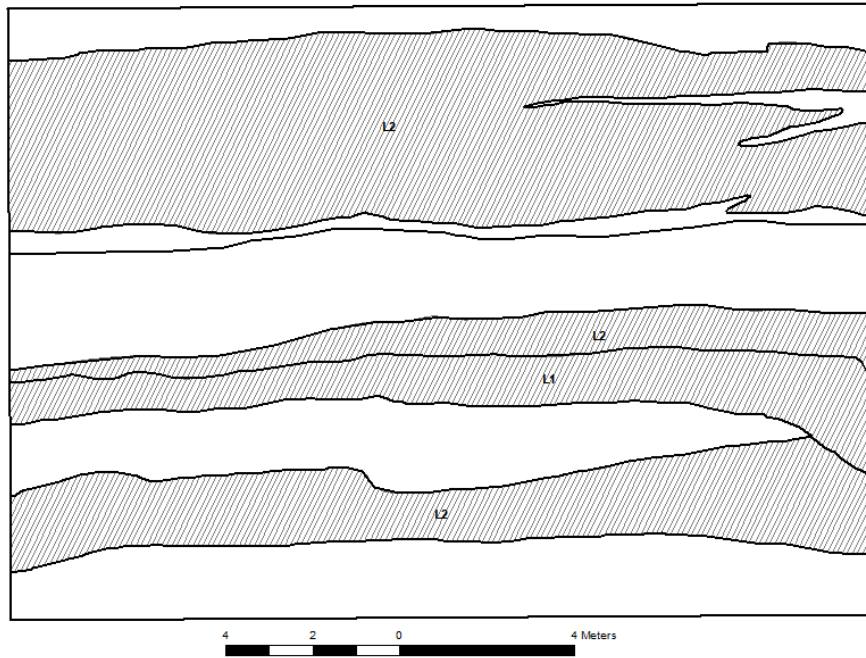Strike-view orthomosaic

Dip-view orthomosaic

EVALUATION WINDOW

PRESENCE INDEX (PI)

Indicates the percentage of lithofacies of interest (LFI) occupying an evaluation window.

Lithofacies of Interest (LFI) = L1, L2

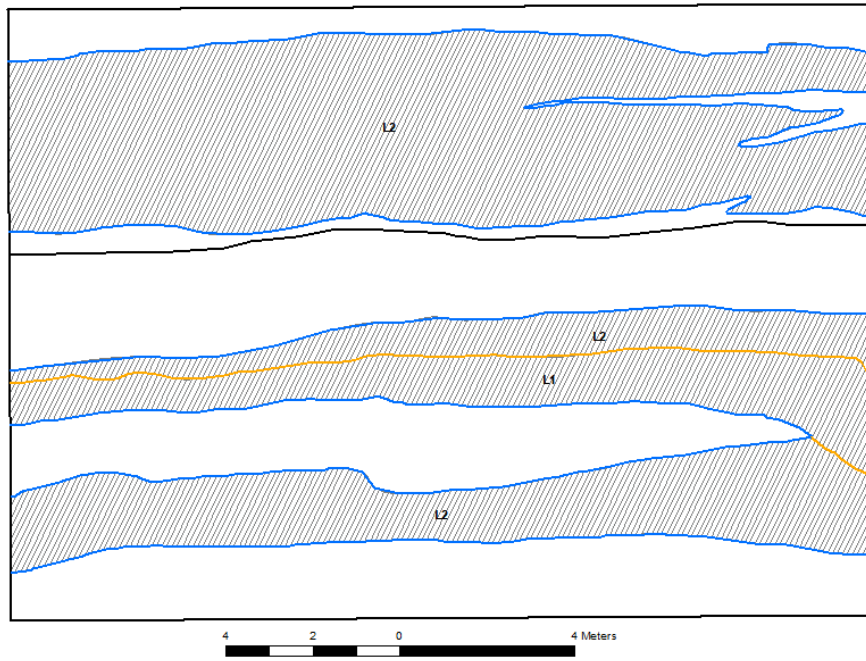PI = ∑ LFI area / EW area

PI = 148.54m^2 / 276.06m^2

PI = 0.54

PI = 1 when 100% is occupied by LFI bodies.

(LFI=Lithofacies of Interest)

CONNECTION INDEX (CI)

Proportion of LFI contacts that effectively are connecting LFI bodies.

Lithofacies of Interest (LFI) = L1, L2

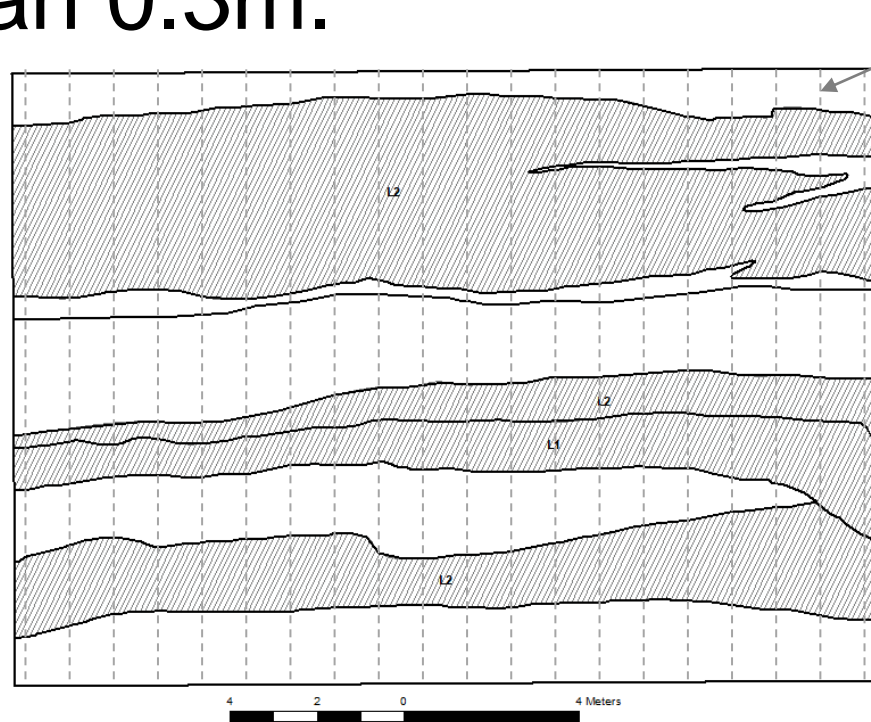CI = ∑ length contacts LFI-LFI / ∑ length contacts LFI

CI = 21.76m / 161.16m

CI = 0.14

CI = 1 when all LFI body contacts are connecting to other LFI bodies.

(LFI=Lithofacies of Interest)

THICK BEDS INDEX (TI)

Proportion of LFI bodies with average thickness higher than 0.3m.

probes

Lithofacies of Interest (LFI) = L1, L2

TI = # LFI bodies with average thickness > 0,3m / # total LFI bodies
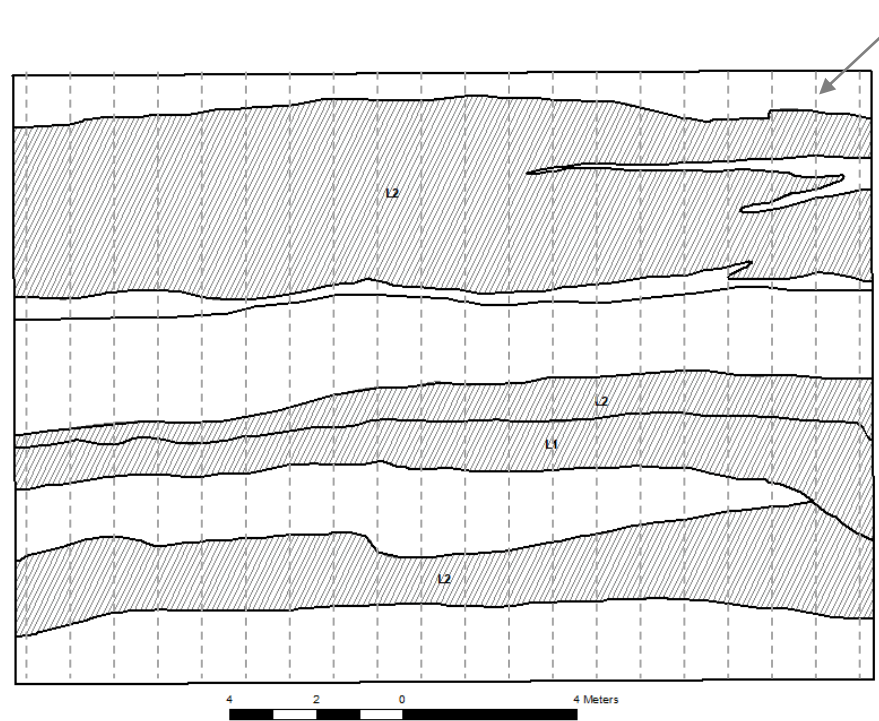
TI = 4 / 4

TI = 1

TI = 1 when all LFI bodies average thickness are above 0,3m.

(LFI=Lithofacies of Interest)

THICKNESS CONSTANCY INDEX (TCI)

Indicates thickness change of LFI bodies.

Lithofacies of Interest (LFI) = L1, L2

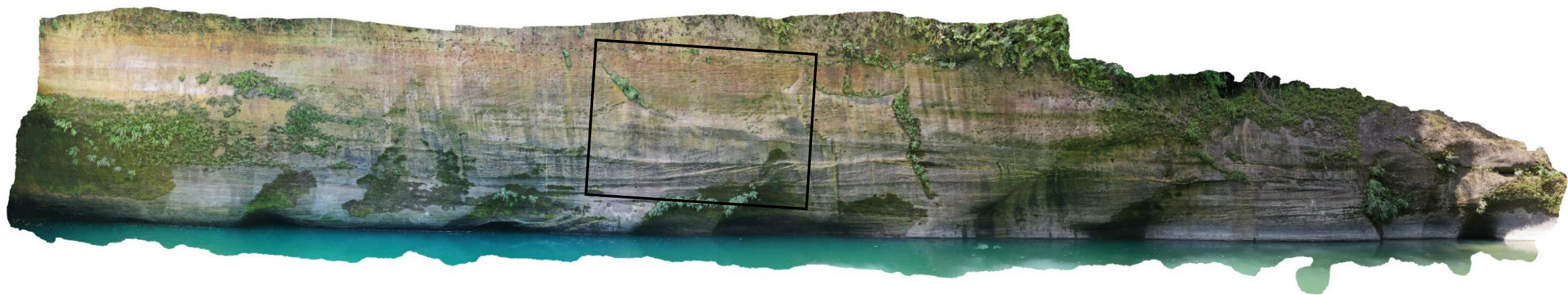TCI = average (min thickness of each LFI body / max thickness of each LFI body)

TCI = average (2.99/4.46, 0.31/1.04, 0.75/2.54, 1.06/2.56)

TCI = average (0.67, 0.30, 0.29, 0.41)

TCI = 0.42

TCI = 1 when thickness of all LFI bodies keep constant.

(LFI=Lithofacies of Interest)

Example 1:
100% Sandstones

Jerarquía de Superficies
- 1
- 2
- 3
- 4
- 5

INDEX	VALUE
PRESENCE	1.00
CONNECTION	1.00
THICK BEDS	0.9
THICKNESS CONSTANCY	0.69

L1
L2
L3
L4
L5

0   1   2   4 Meters

☐ LFI (Lithofacies of Interest)

Bayona y Baquero, 2020

LITOFACIES
- L1 (yellow)
- L2 (orange)
- L3 (light green)
- L4 (olive green)
- L5 (teal)

LFI
(Lithofacies of Interest)

0   2   4   8 Meters
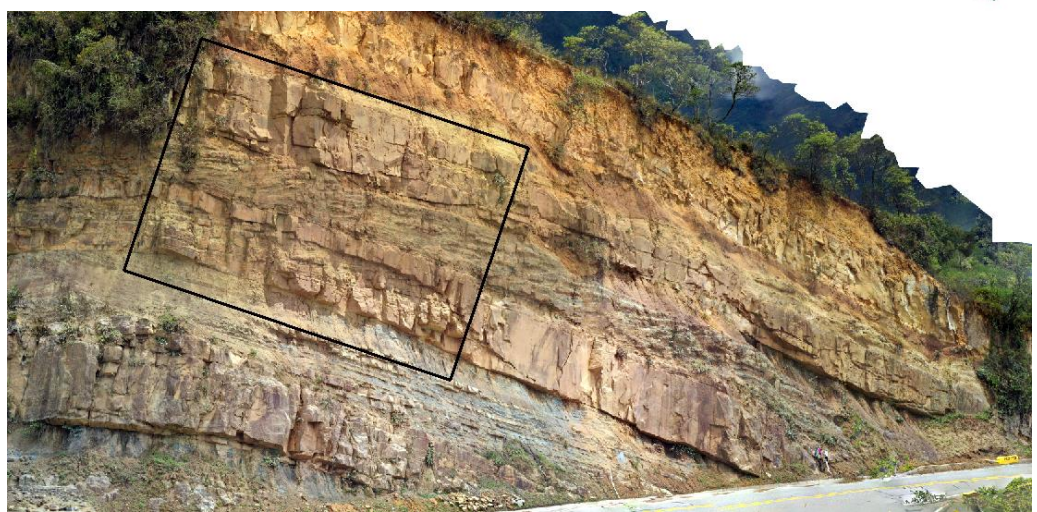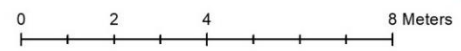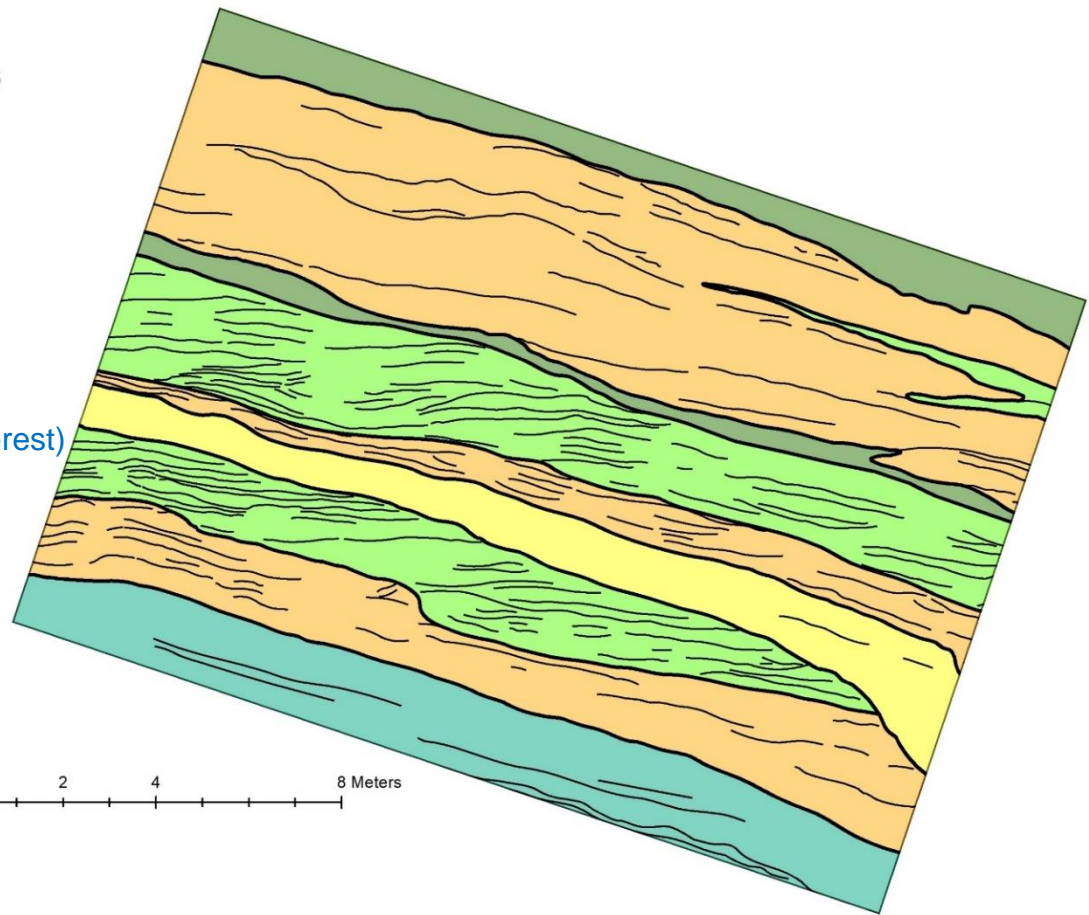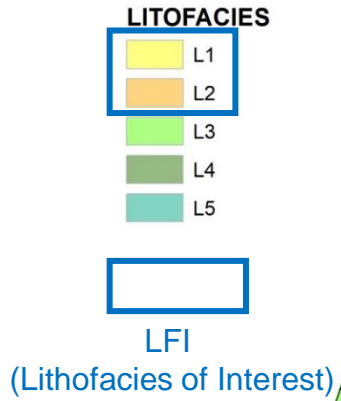
Example 2:
Partially connected sandstones

INDEX	VALUE
PRESENCE	0.54
CONNECTION	0.14
THICK BEDS	1.00
THICKNESS CONSTANCY	0.42

Example 3:
Vertically unconnected sandstones

LITOFACIES
- G_01+G_02
- G_02c
- G_03
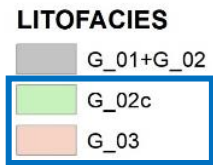
LFI
(Lithofacies of Interest)
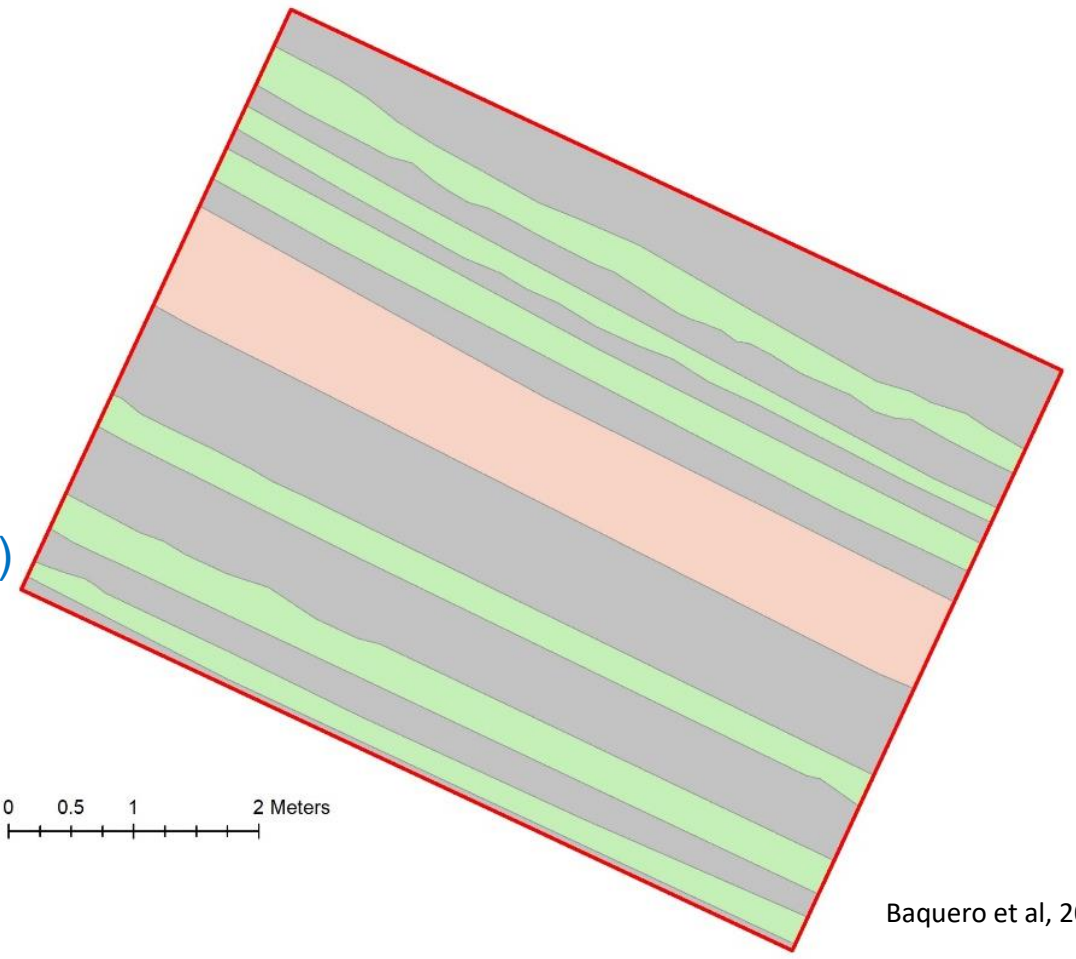
INDEX	VALUE
PRESENCE	0.44
CONNECTION	0.00
THICK BEDS	0.29
THICKNESS CONSTANCY	0.75

0   0.5   1   2 Meters

Baquero et al, 2019

Reservoir Index Comparison
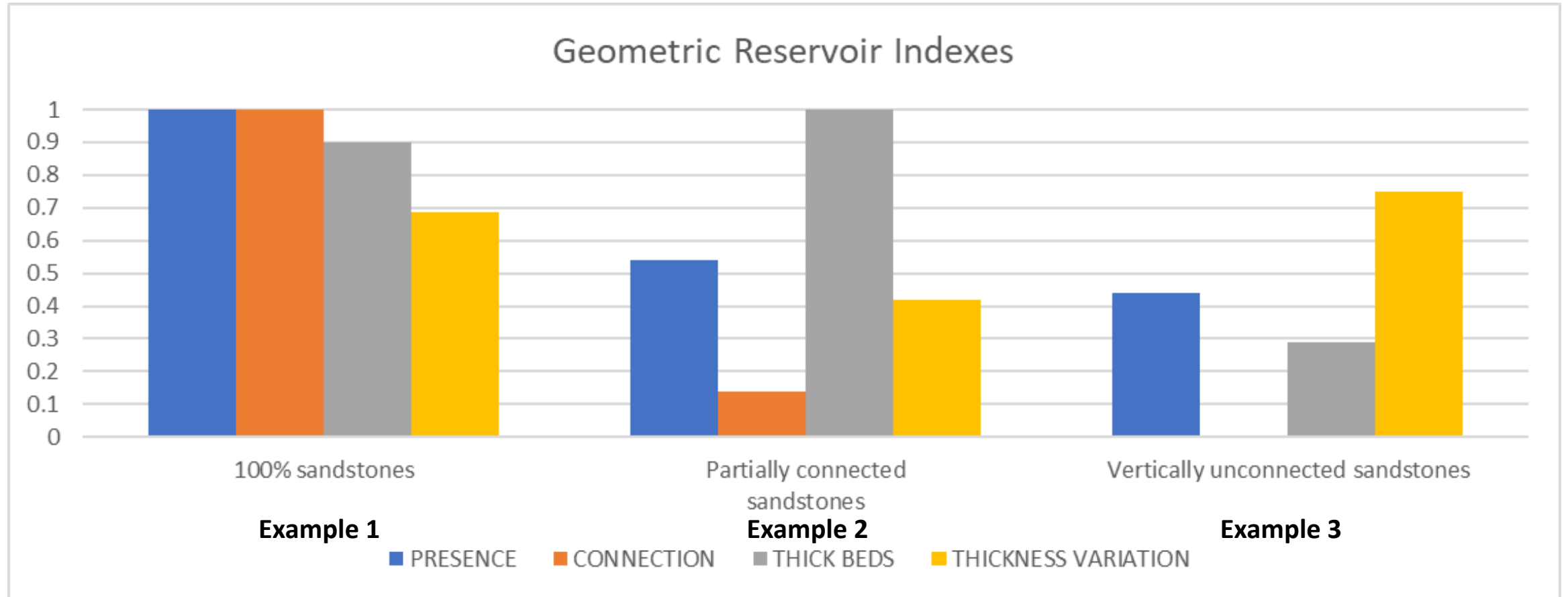
Example 3: Vertically unconnected sandstones

Fracture abundance measurements
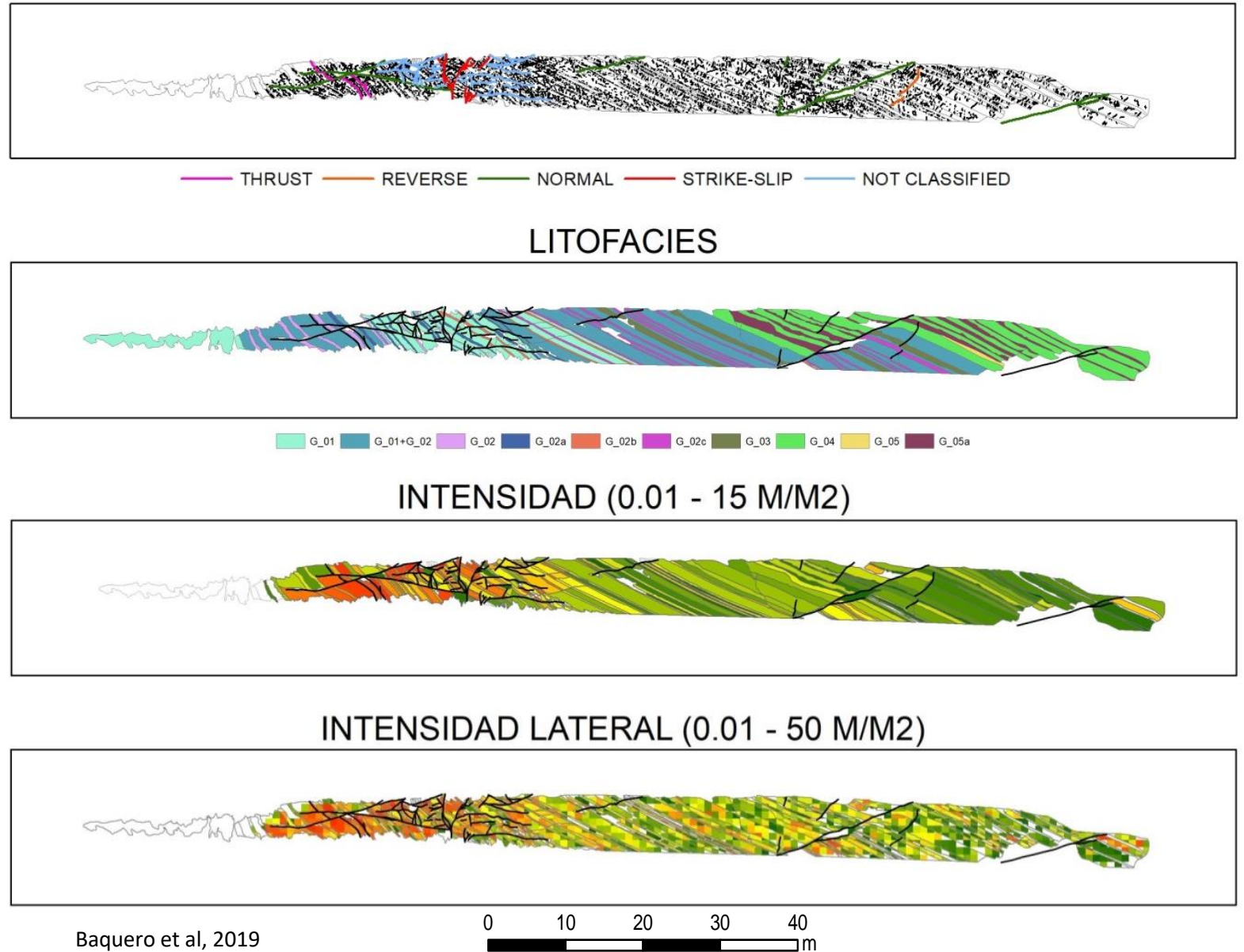
THRUST — REVERSE — NORMAL — STRIKE-SLIP — NOT CLASSIFIED

LITOFACIES

G_01 G_01+G_02 G_02 G_02a G_02b G_02c G_03 G_04 G_05 G_05a

INTENSIDAD (0.01 - 15 M/M2)

INTENSIDAD LATERAL (0.01 - 50 M/M2)

Baquero et al, 2019

0 10 20 30 40 m

Other applications

Fracture abundance measurements

10m

50m

Other applications

Fracture abundance measurements

10m

Density

	0,01 fractures/m2 - 0,07 fractures/m2
	0,07 fractures/m2 - 0,28 fractures/m2
	0,28 fractures/m2 - 0,38 fractures/m2
	0,38 fractures/m2 - 0,51 fractures/m2
	0,51 fractures/m2 - 0,75 fractures/m2

Intensity

	0,02 m/m2 - 0,09 m/m2
	0,091 m/m2 - 0,35 m/m2
	0,35 m/m2 - 0,48 m/m2
	0,48 m/m2 - 0,55 m/m2
	0,55 m/m2 - 0,65 m/m2
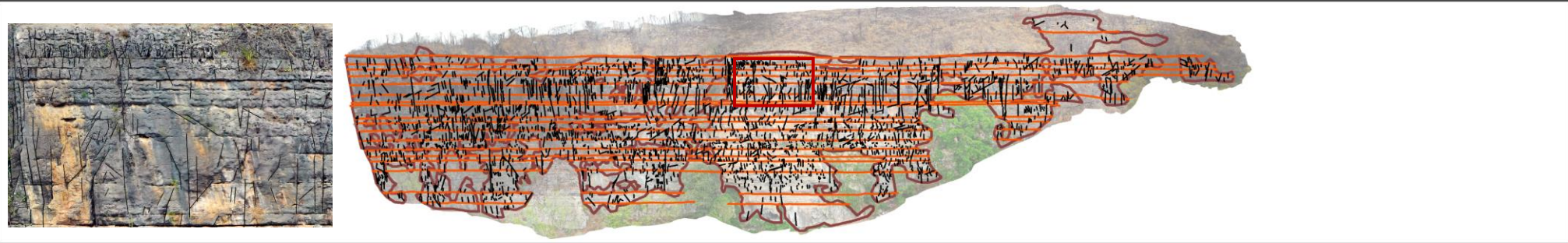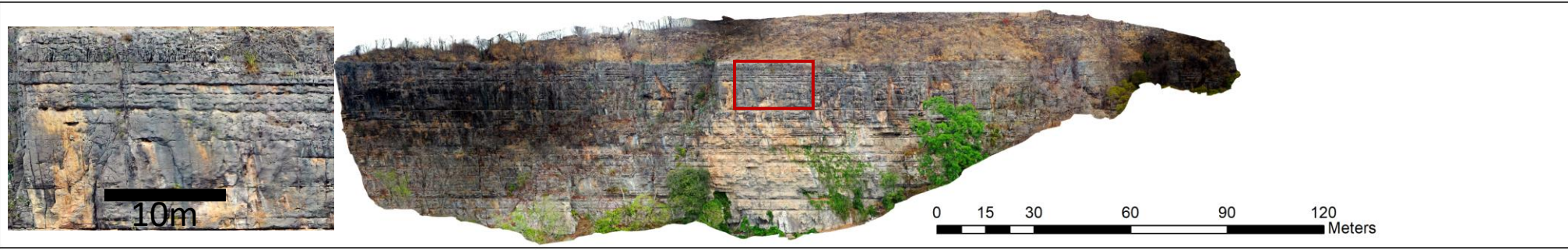
METHODOLOGICAL SUMMARY

PHOTOGRAMMETRY **+** **FIELD GEOLOGY** **+** **SPATIAL ANALYSIS** **=** **2D QUANTIFICATION OF RESERVOIR BEDS**

(Photo-based DOM construction)

(Lithofacial and structural descriptions)

(Geometrical and topological)

(Presence, Connectivity, Thick Beds, Thickness Constancy, Fracture Abundance)

MAIN IDEAS

- Orthomosaics from DOMs allows for easy, automatic calculations on geometric aspects of beds and structures.

- Field work supplies data necessary to characterize lithofacial aspects of interpreted beds.

- Reservoir indices provide a means for inter and intra reservoir analog comparisons.

WORK IN PROGRESS
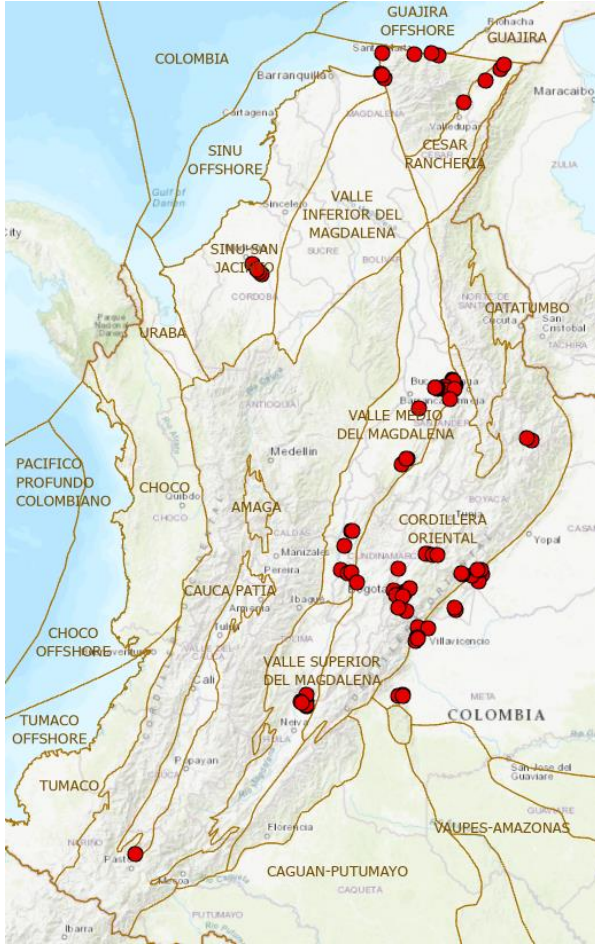
- Ares DOM collection will be available at **Stratbox** virtual platform (Imaged Reality) :
  - ✓ Outcrop-scale reservoir index database.
  - ✓ Virtual field trips and courses.

- Integration of petrophysical analyses from subsurface reservoir beds.

- Development of new 2D and 3D quantification techniques.

Thank you

- Mauricio Baquero, mbaquero@cgares.org
- Germán Bayona, gbayona@cgares.org