





Carste: Conceitos e Estudo de Análogos

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- Geóloga pela UnB.
- Ingresso na Petrobras em 2006.
- Especialização em Análise de Bacias pela UERJ.
- De 2007 à 2012 orientadora didática na Universidade Corporativa da Petrobras.
- 2012 Geóloga de Reservatórios no Centro de Pesquisas da Petrobras.
- Mestrado pela UFRJ.
- Doutoranda da UnB.













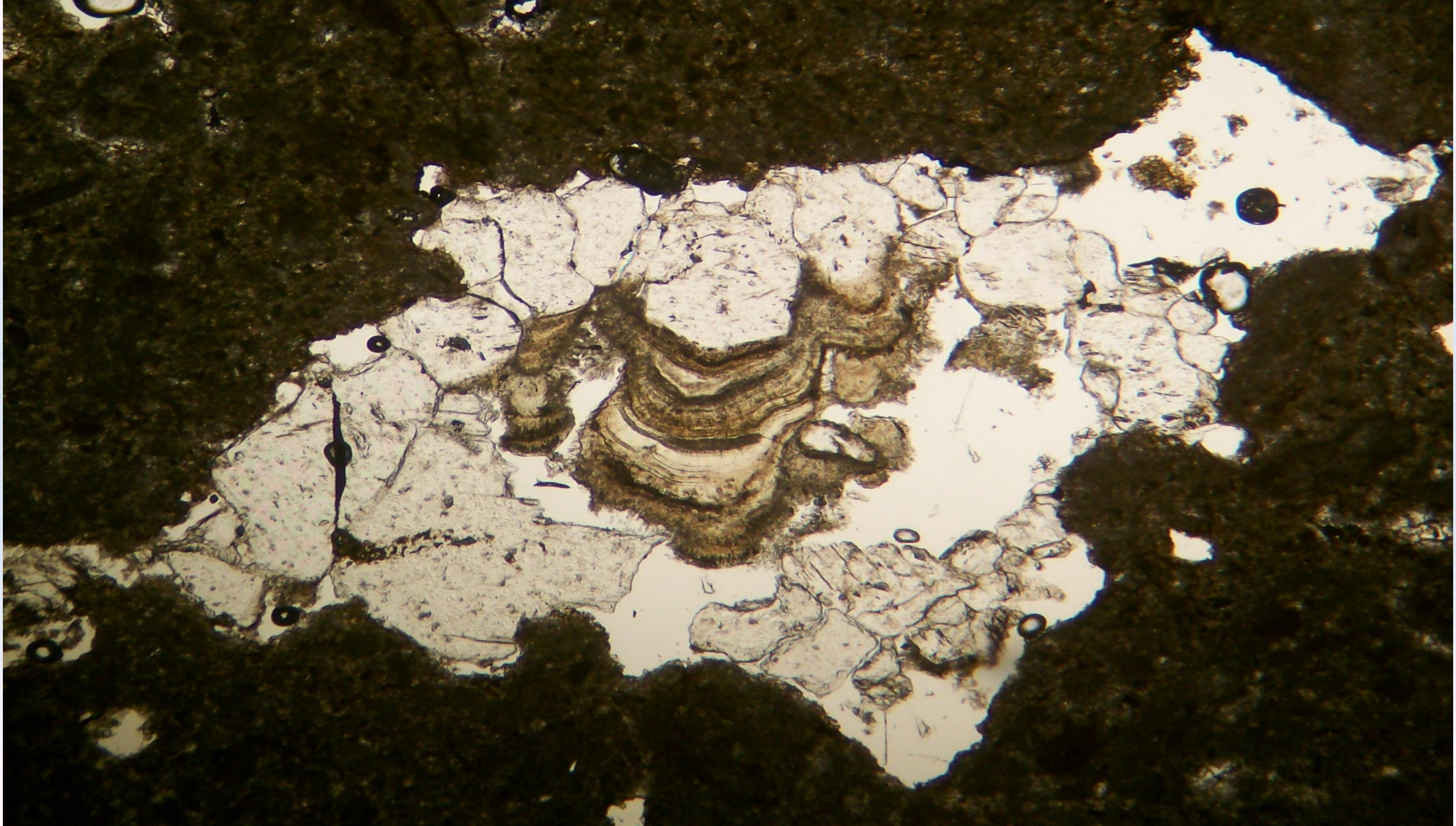
















Carstologia X Espeleologia

Processo X Geomorfologia













ATHANASII KIRCHERI
E SOC. JESU

MUNDUS SUBTERRANEUS,

in XII Libros digestus;

QUO

Divinum Subterrestris Mundi Opificium, mira Ergasteriorum Naturæ in eo distributio, verbo παναμόρφου Protei Regnum,

Universæ denique Naturæ majestas & divitiæ summa rerum varietate exponuntur, Abditorum effectuum Causæ acri indagine inquisitæ demonstrantur, cognitæ per Artis & Naturæ conjugium ad Humanæ vitæ necessarium usum vario Experimentorum apparatu, necnon novo modo & ratione applicantur.

AD

ALEXANDRUM VII.

PONT. OPT. MAX.

EDITIO TERTIA,

Ad fidem scripti exemplaris recognita, & prioribus emendatior: tum ab Auctore Româ submissis variis Observationibus novisque Figuris auctior.

TOMUS I.



AMSTELODAMI,

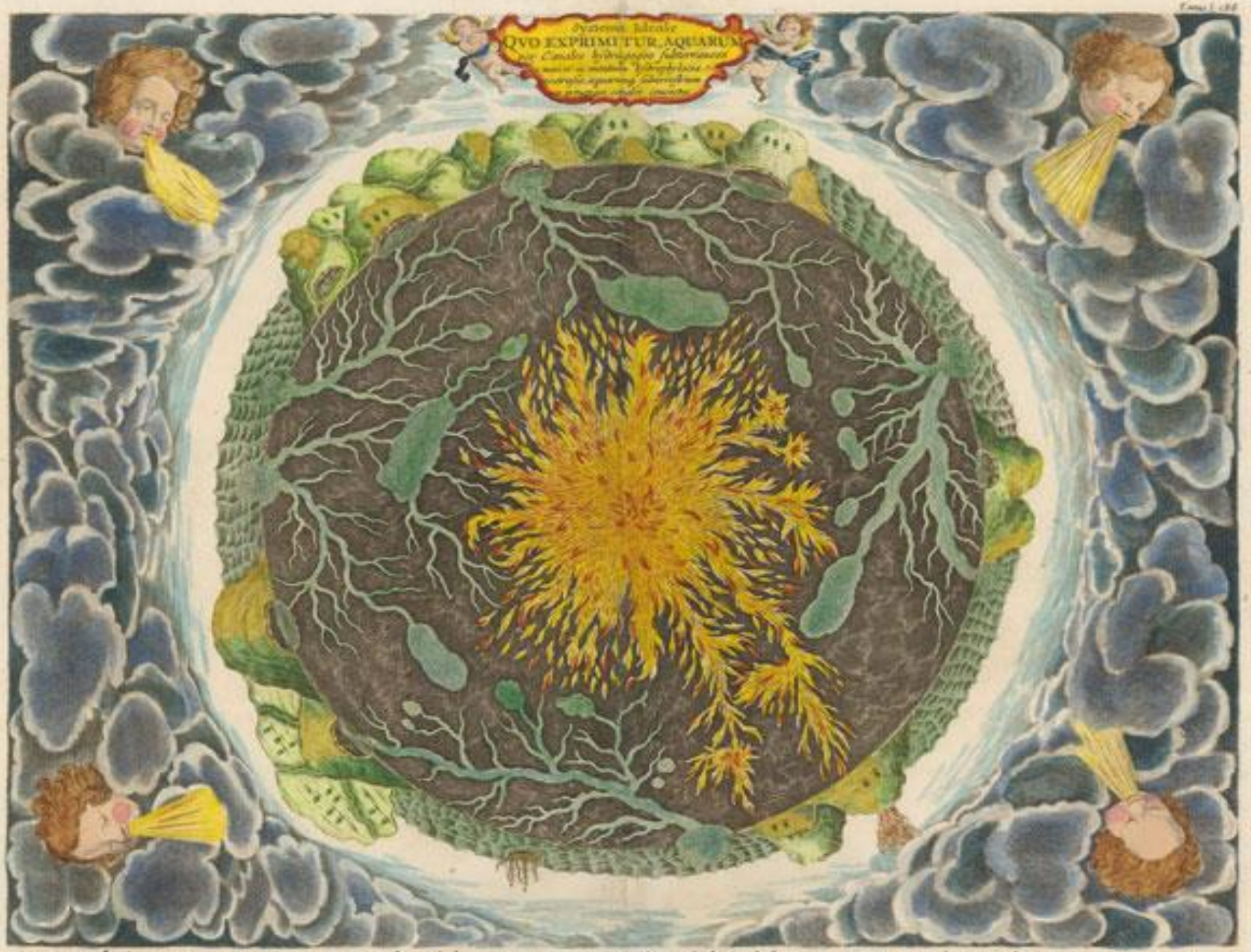
Apud JOANNEM JANSSONIUM à WAESBERGE & FILIOS,

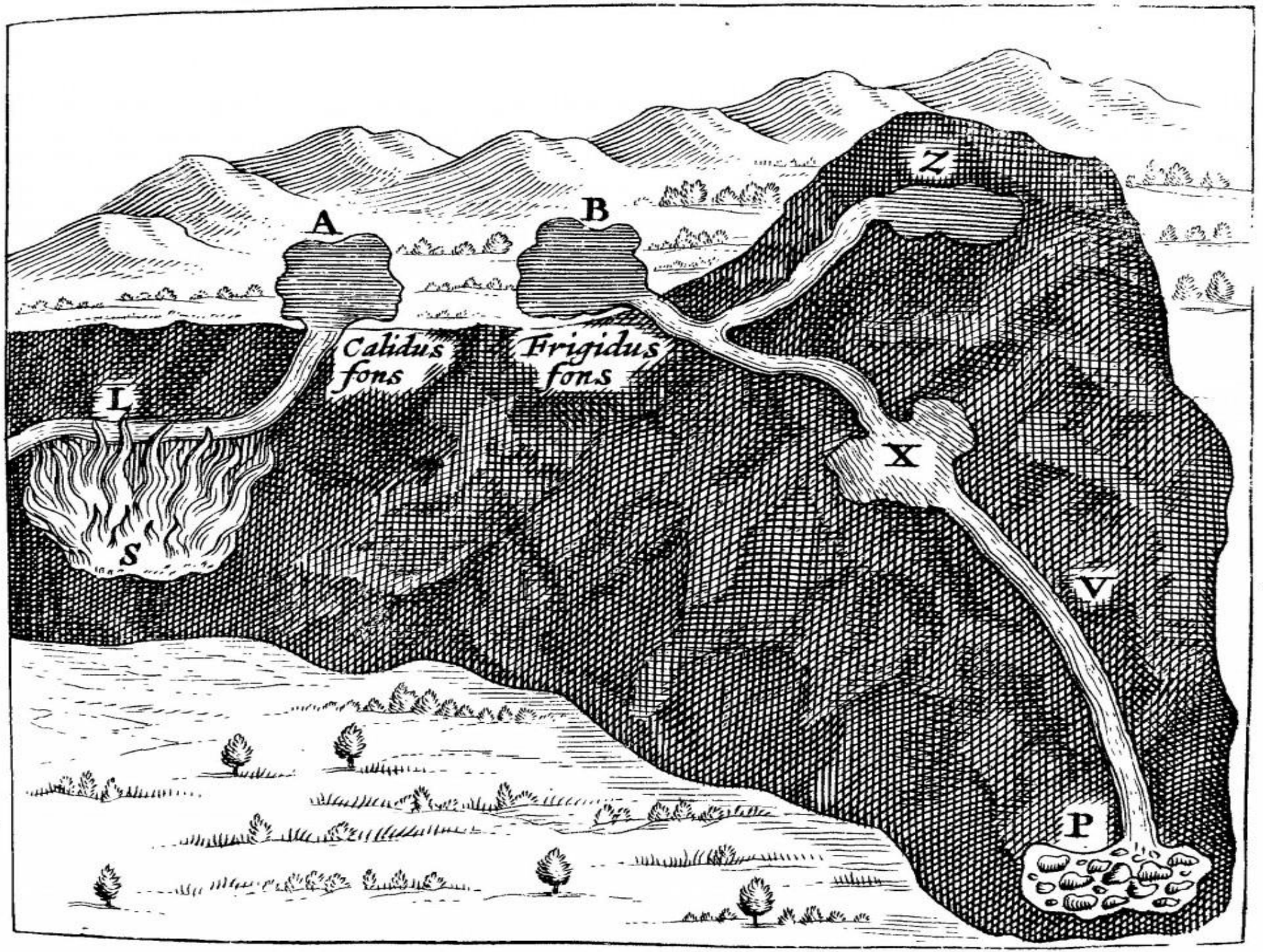
ANNO cIↃ IↃc LXXVIII. *Cum Privilegiis.*



P. ATHANASIVS KIRCHERVS FVLDENSIS
ê Societ: Iesu Anno ætatis LIII.
Honoris et observantiæ ergò sculpsit et D.D. C. Bloemaert Romæ 2 Maij A. 1655.


Systema Ideale
PYROPHYLACIORUM
Subterraneorum, quorum montes


Systema Telluris
QVO EXPRIMITVR AQUARUM


A
B
Z
Calidus
fons
Frigidus
fons
L
X
S
V
P

CARSTE

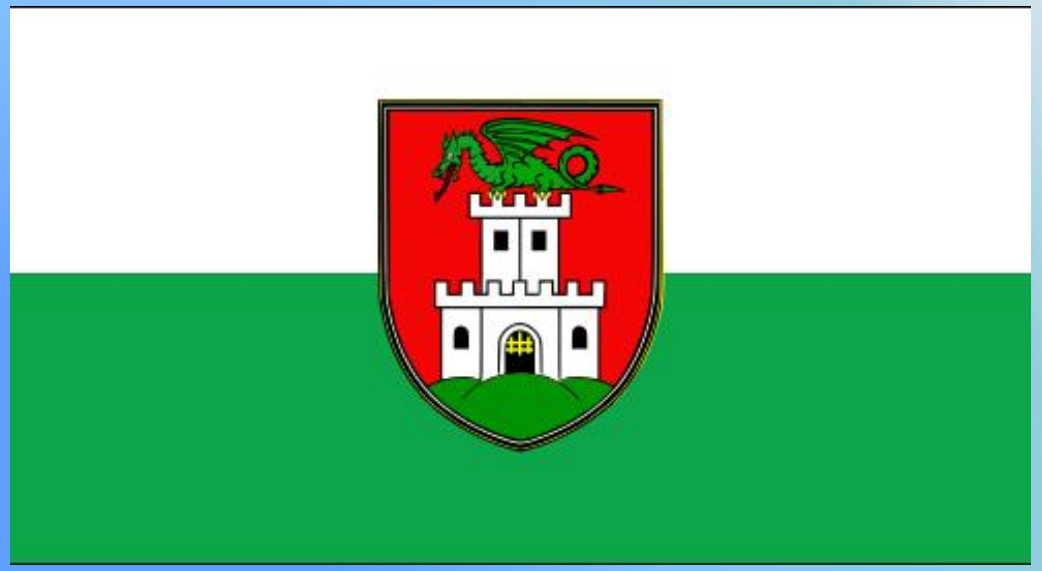
KARST

CARSO

KRAS



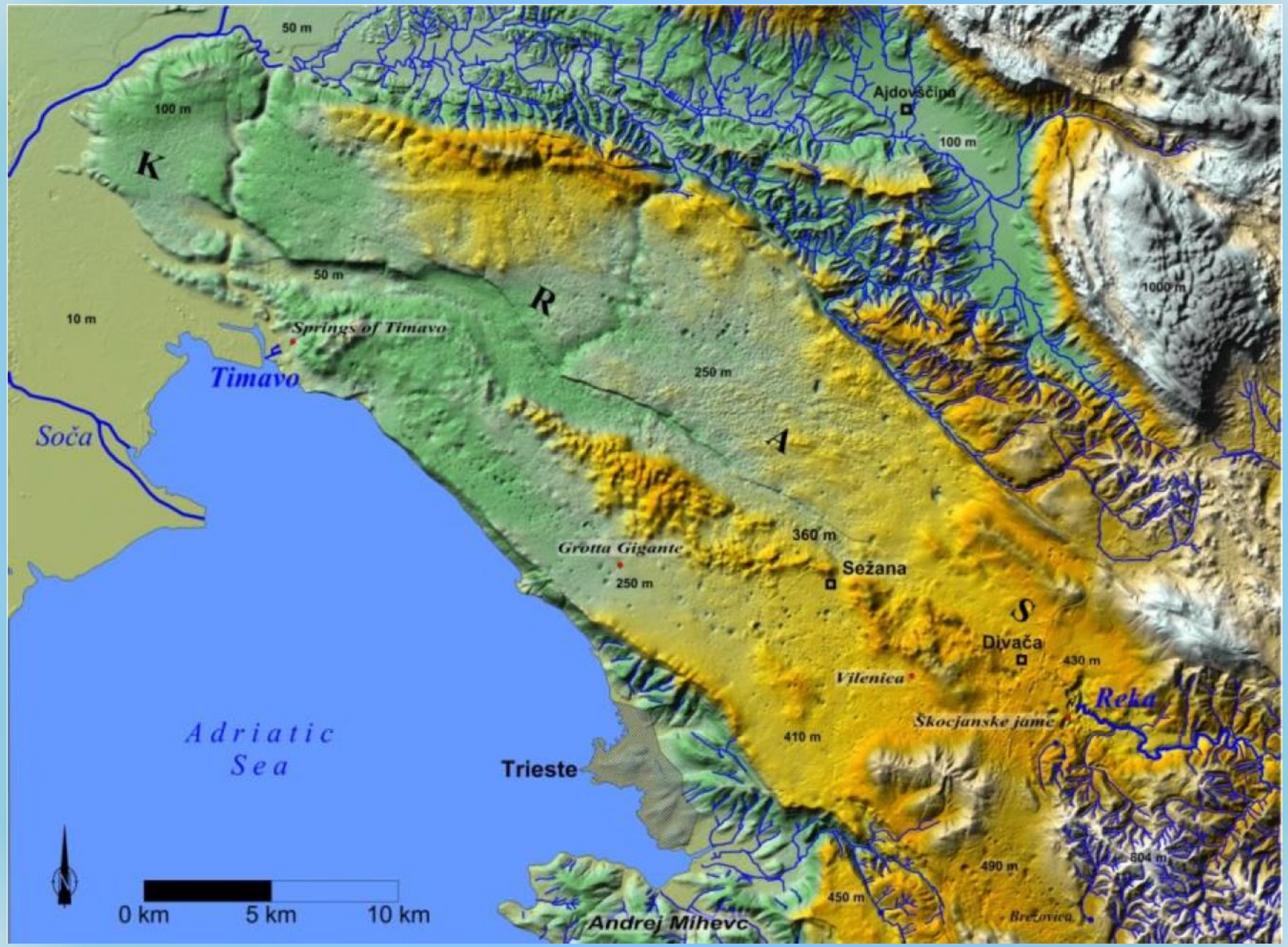




https://iks.zrc-sazu.si/en/






50 m
100 m
Ajdovščina
100 m
K
50 m
R
1000 m
10 m
Springs of Timavo
Timavo
250 m
Soča
A
360 m
Grotta Gigante
Sežana
250 m
S
Divača
430 m
Vilenica
Reka
Škocjanske jame
Adriatic
Sea
410 m
Trieste
490 m
504 m
450 m
Brežovica
Andrej Mihevc
0 km
5 km
10 km

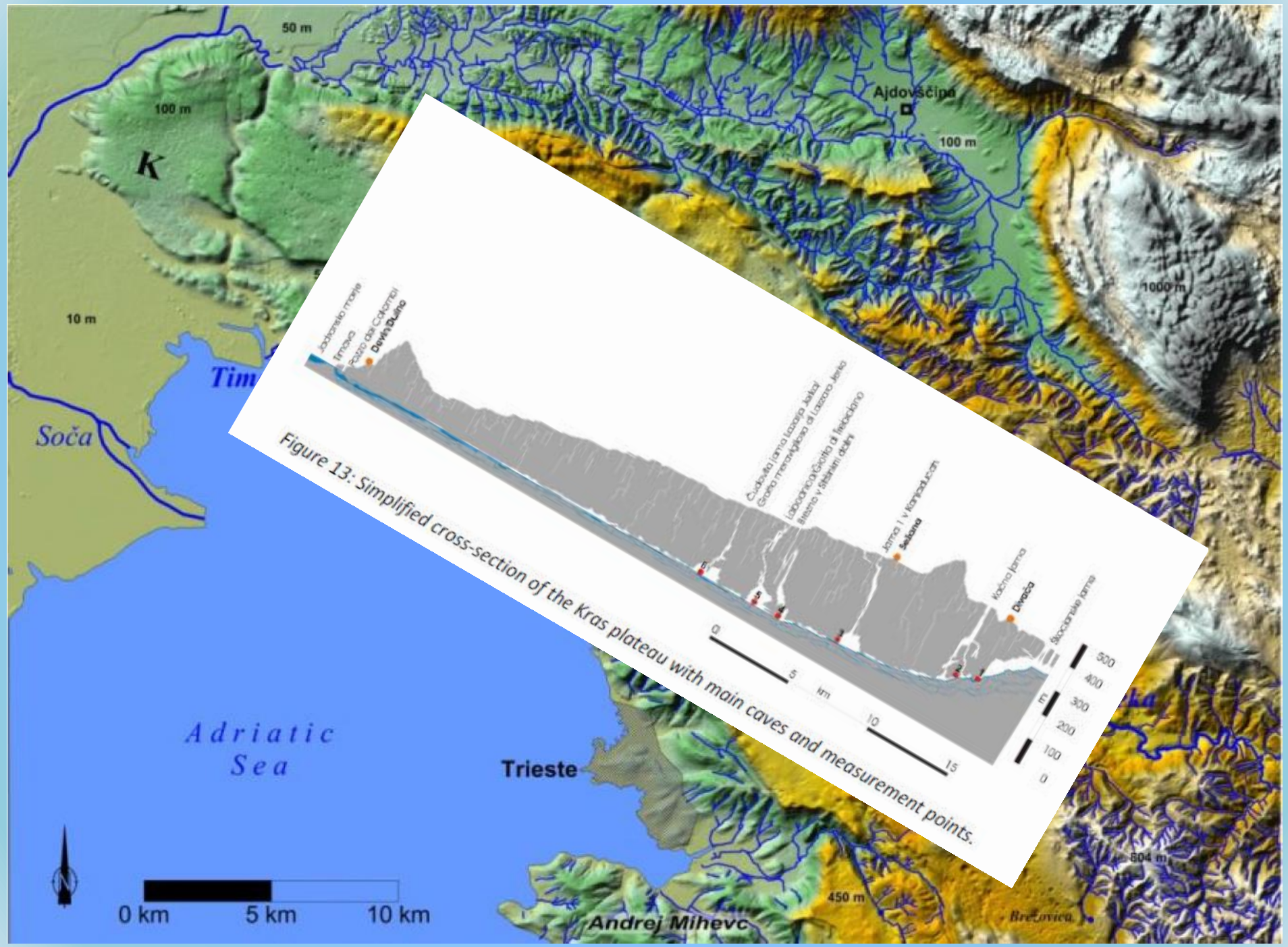
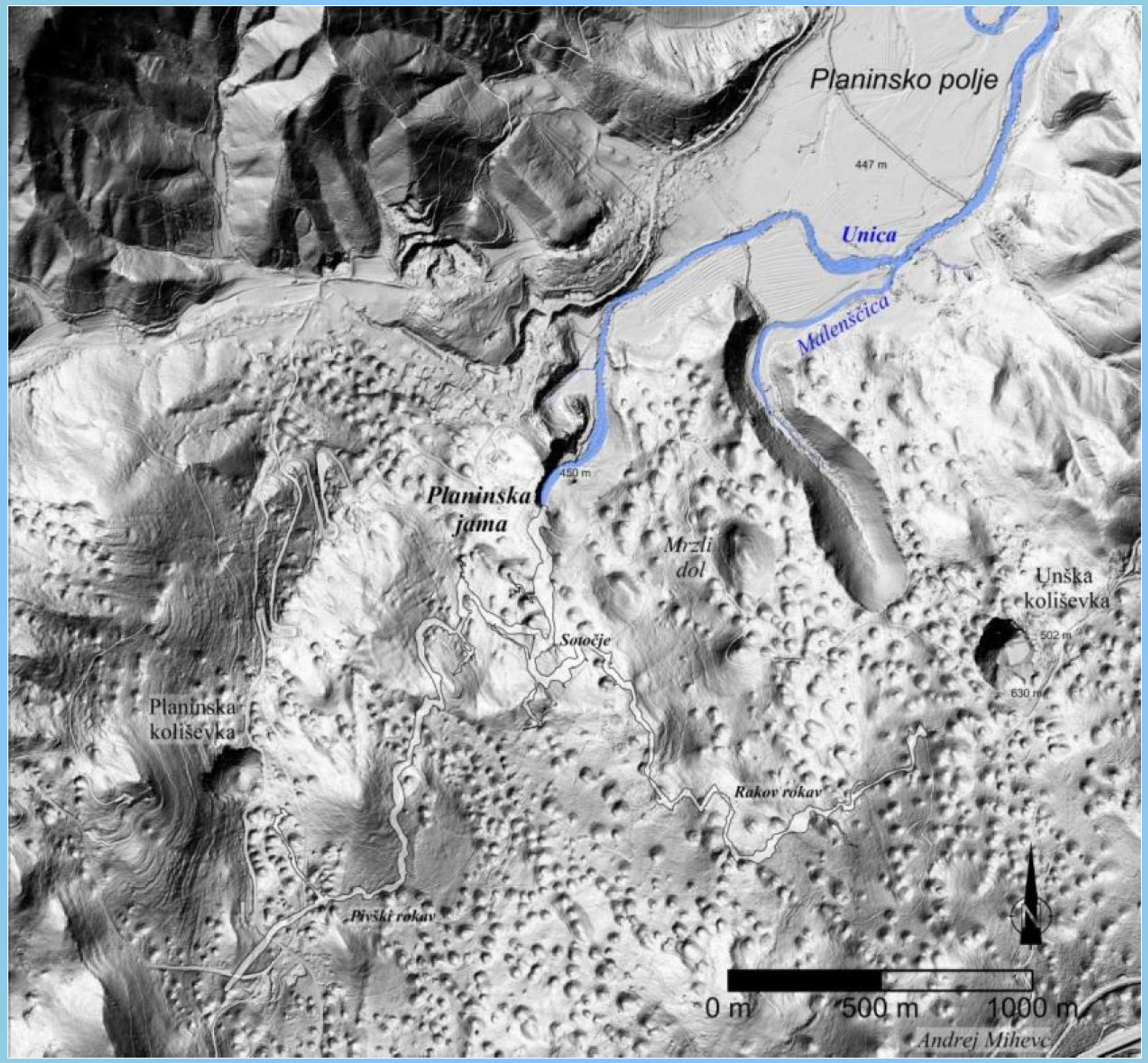


Figure 13: Simplified cross-section of the Kras plateau with main caves and measurement points.


Planinsko polje
447 m
Unica
Malenščica
450 m
Planinska jama
Mrzli dol
Unška koliševka
502 m
630 m
Sotočje
Planinska koliševka
Rakov rokav
Pivški rokav
0 m
500 m
1000 m
Andrej Mihevc

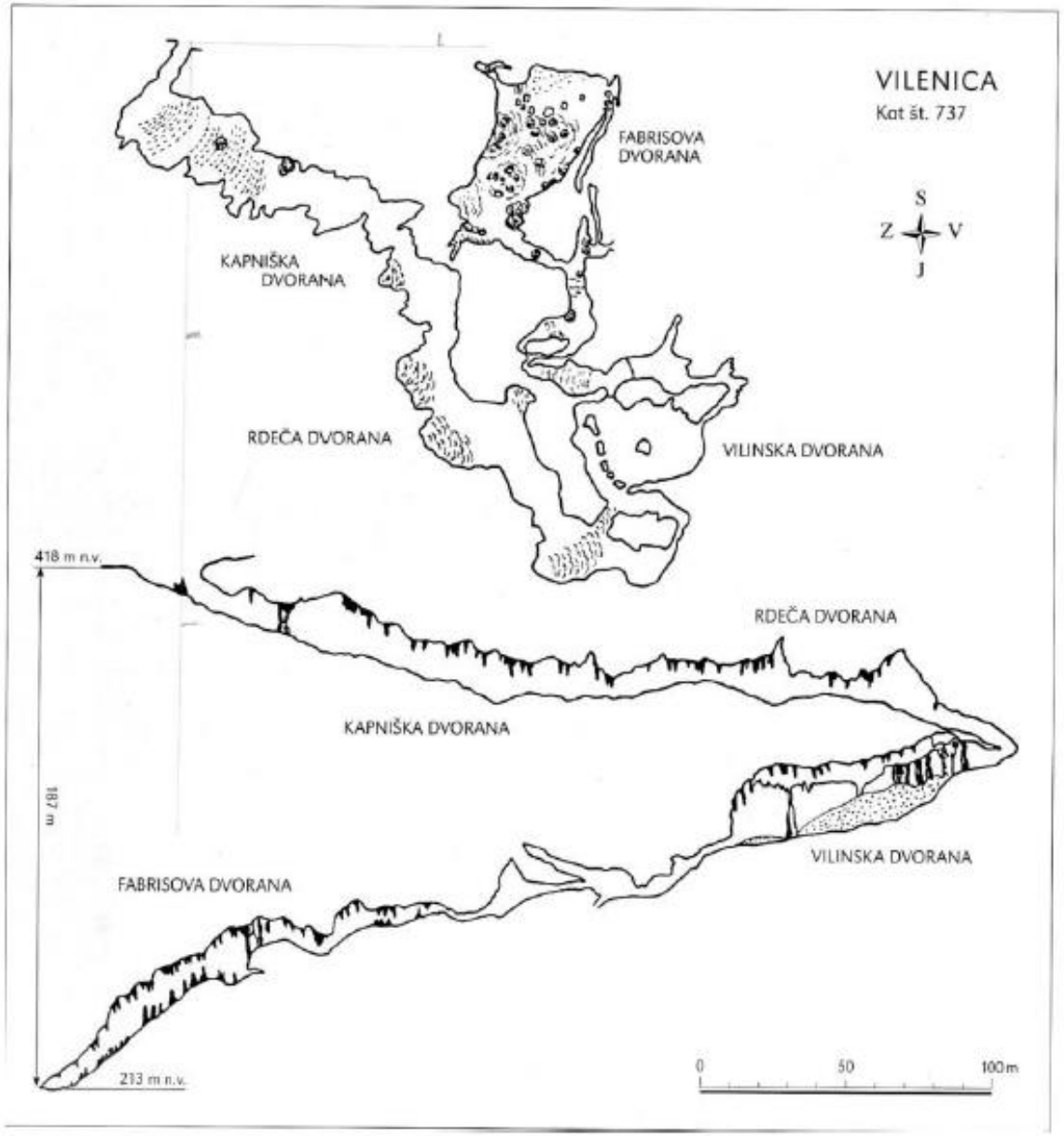


Figure 7: Ground plan and profile of Vilenica cave (after Gams 2004).

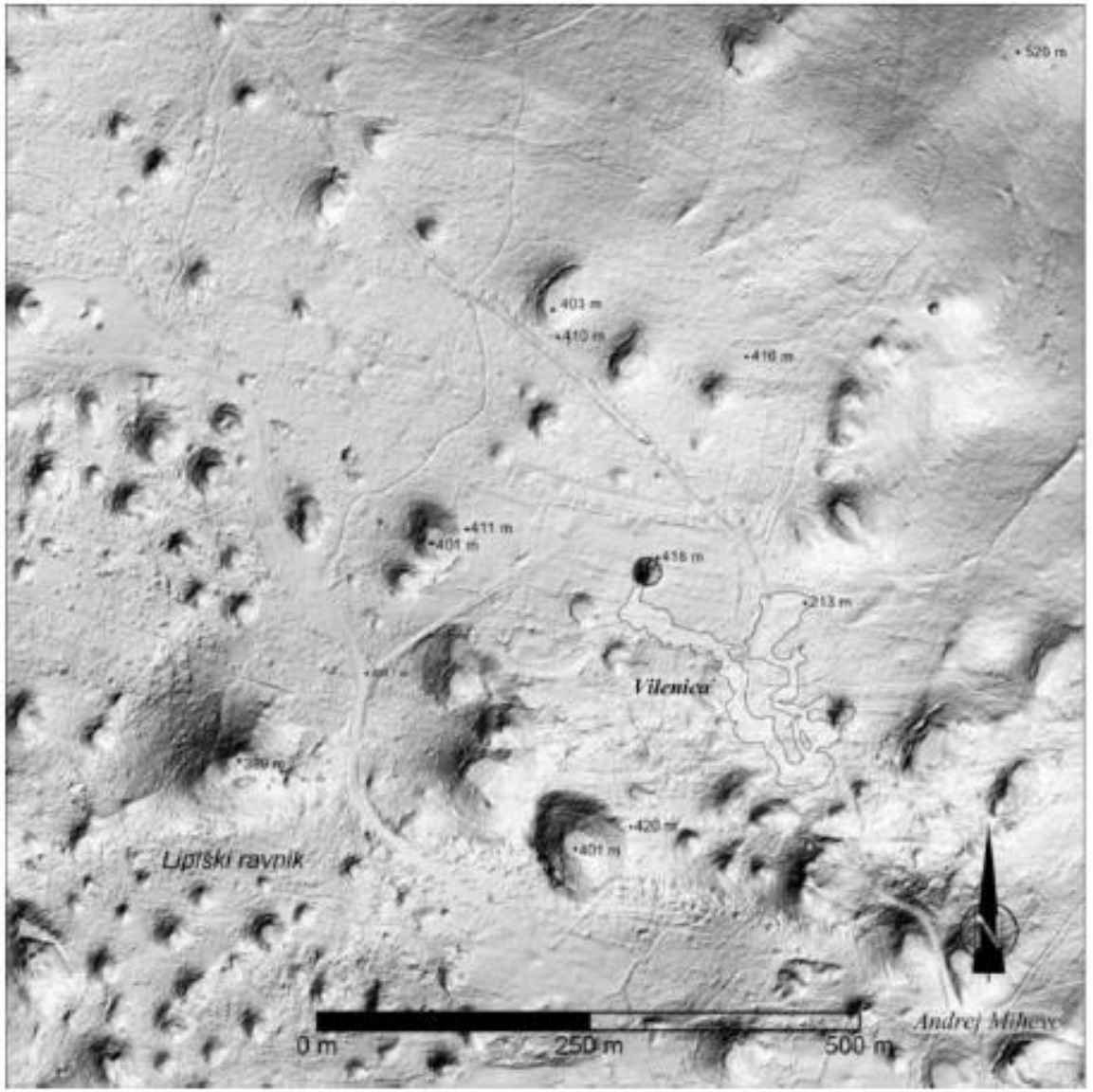


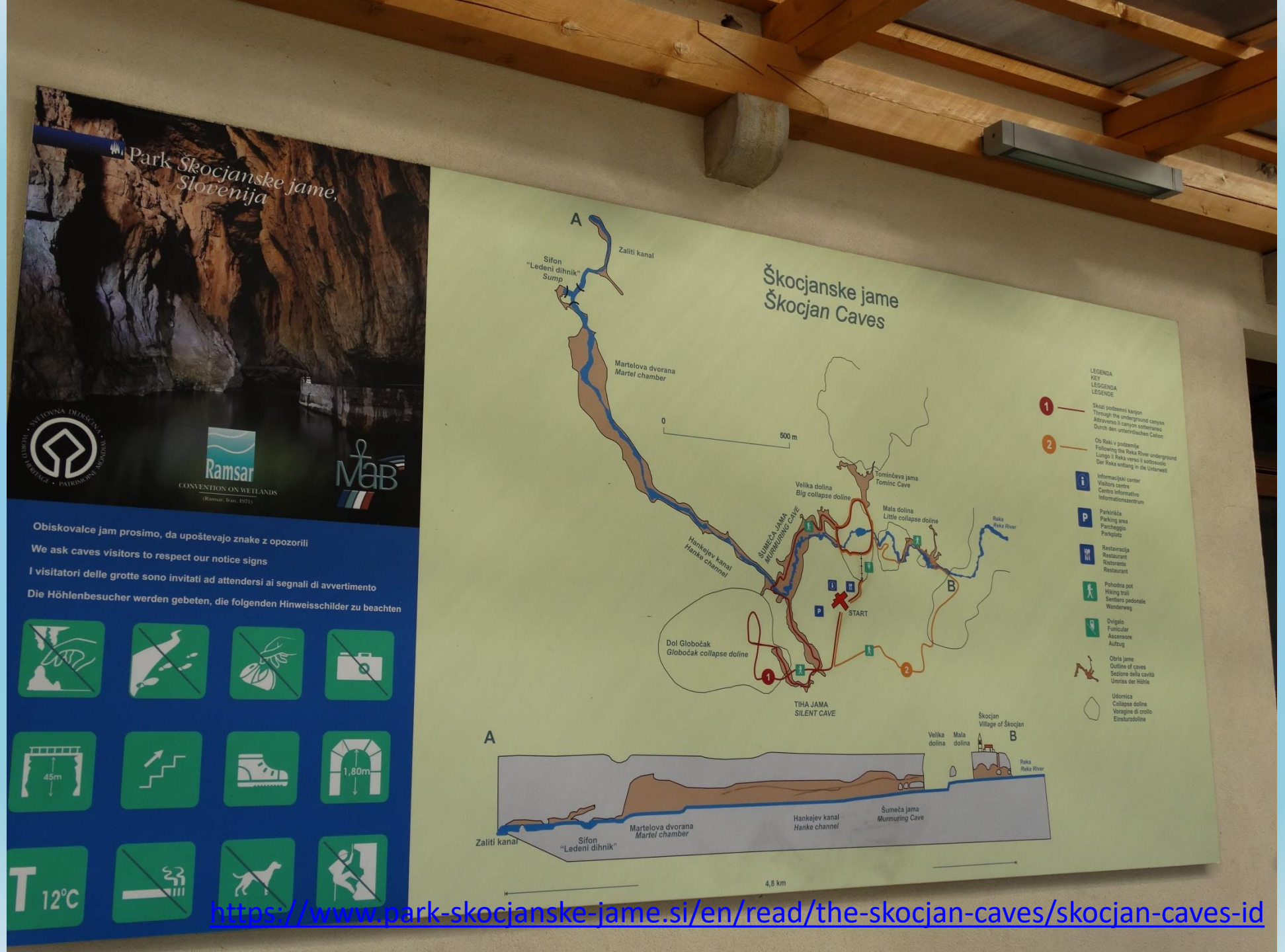
Figure 6: Levelled surface of Lipiški ravnik above Vilenica cave (LiDAR data, Geodetski oddelek ARSO).

https://www.vilenica.com/en/





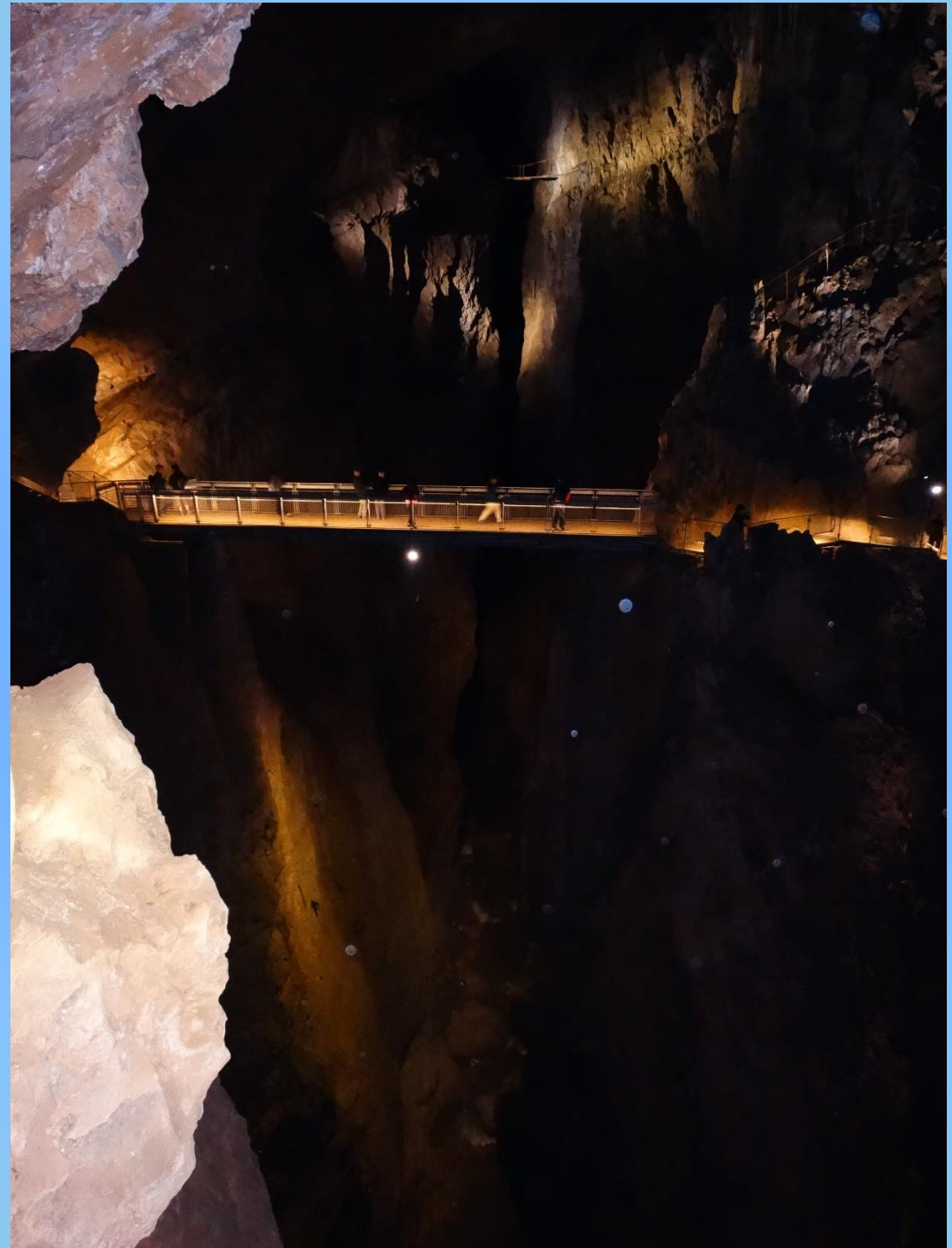




https://www.park-skocjanske-jame.si/en/read/the-skocjan-caves/skocjan-caves-id









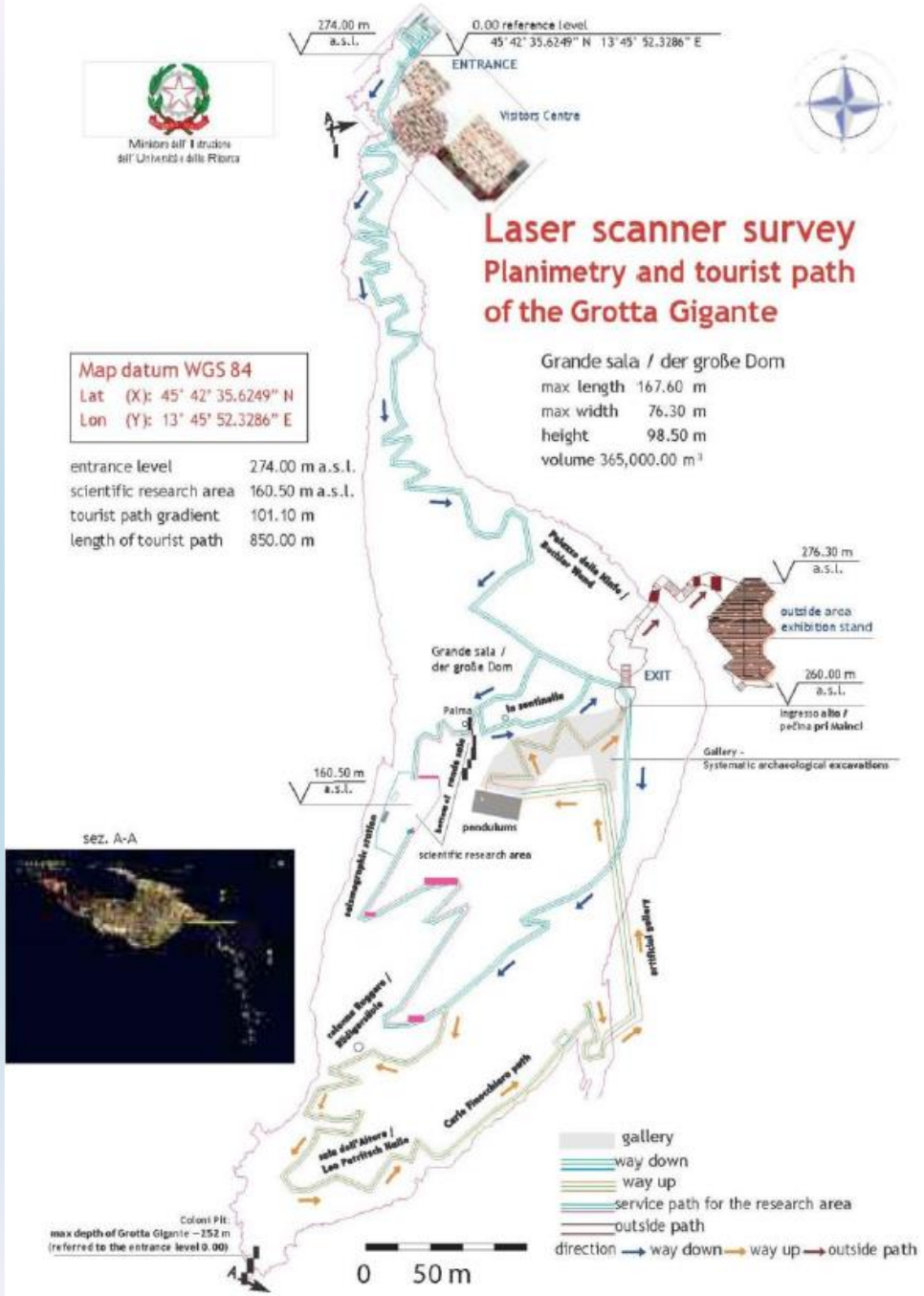


Figure 29: Laser scanner survey. Planimetry and tourist path (23. 8. 2012).



Figure 22: Laser scanning image from the botton of colonna Ruggero/Rüdigersäule to Sala dell'Altare/Leo Petritsch Halle.

https://www.grottagigante.it/







Carstosfera*: *camada descontínua de rochas "carstificáveis", cobertura de rochas solúveis (Maruashvili, 1970); parte da litosfera que serve de "arena" para os processos cársticos (Maksimovich, 1979).

Exocarstosfera: sistema aberto, feições superficiais, intensa remoção de material.

Mesocarstosfera: zona de catagênese, baixa circulação de água.

Hipocarstosfera: zona de catagênese, baixissíma circulação de água.

- Maksimovich (1975) classificou o processo de acordo com a rocha dissolvida:

BRADIKARST: (bradus=devagar) processo de carstificação em rochas siliciclásticas.

TACHIKARST: (tachus=rápido) processo de carstificação em halita e sulfatos.

KARST: processo de carstificação em carbonatos.





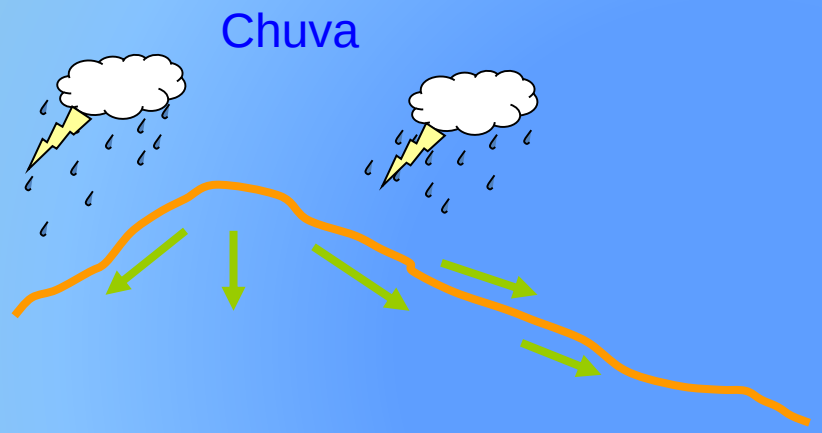
Epigênico X Hipogênico

http://www.speleogenesis.info/index.php

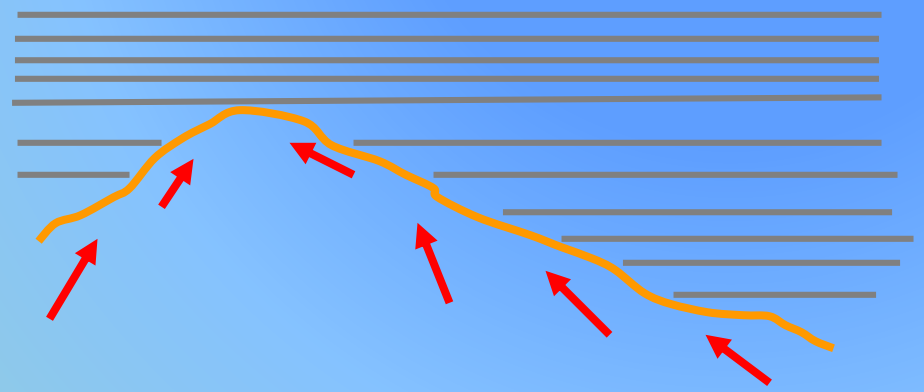
http://digital.lib.usf.edu/karst



Processos de carstificação
- Criação de Porosidade -

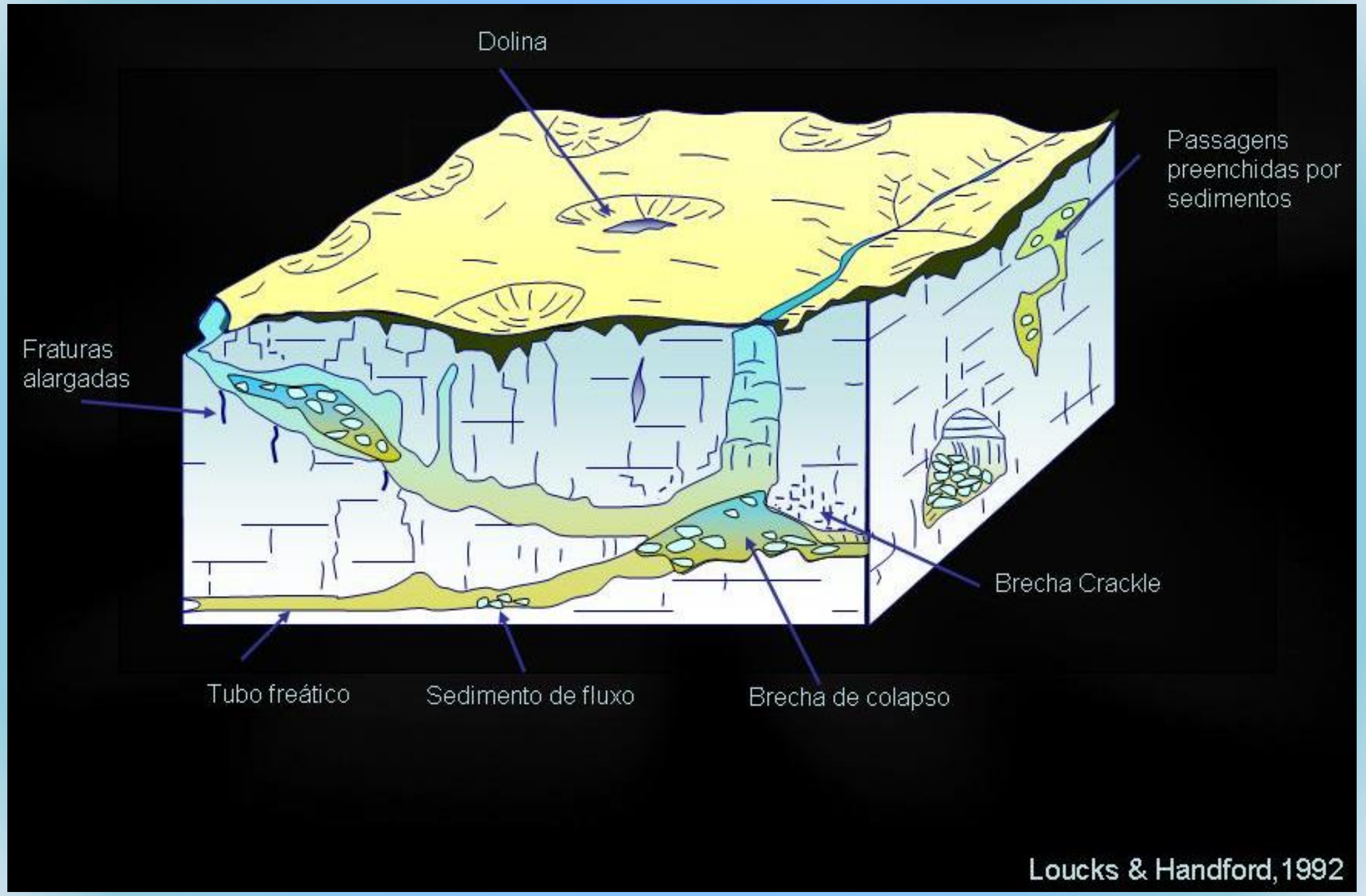


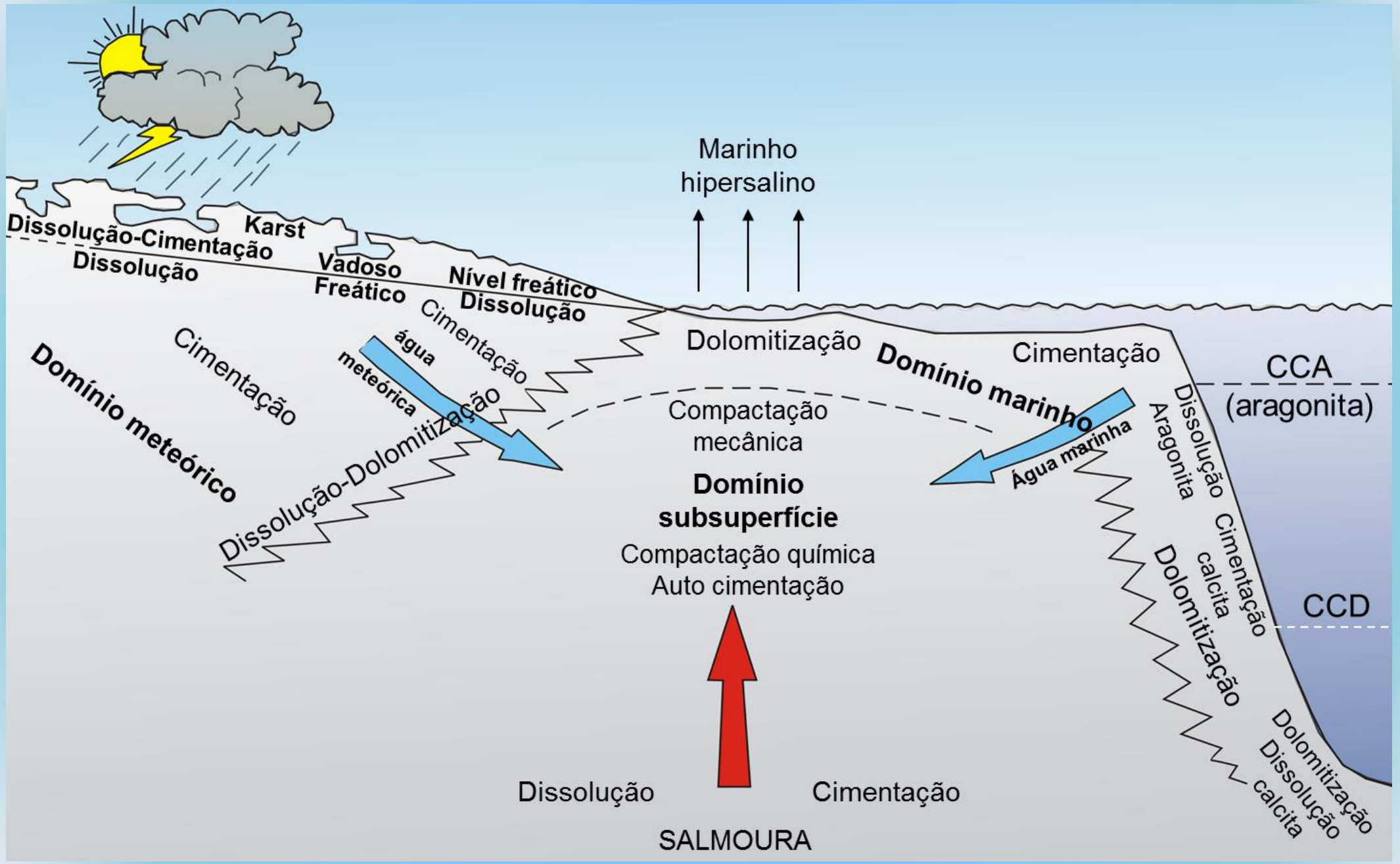
Meteórico (epigênico)



Soterramento (hipogênico)

(Esteban, 2004)


Dolina
Passagens preenchidas por sedimentos
Fraturas alargadas
Brecha Crackle
Tubo freático
Sedimento de fluxo
Brecha de colapso
Loucks & Handford, 1992

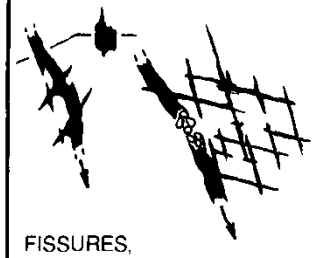
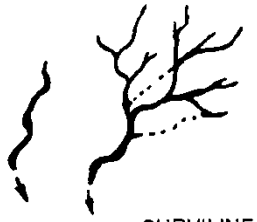
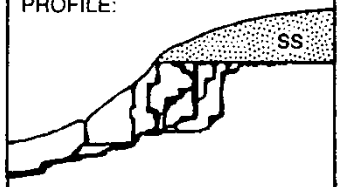
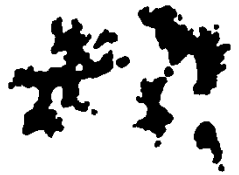
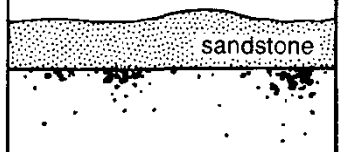

Marinho
hipersalino
Karst
Dissolução-Cimentação
Dissolução
Vadoso
Freático
Nível freático
Dissolução
Cimentação
Dolomitização
Cimentação
Domínio marinho
Domínio meteórico
Cimentação
água
meteórica
Dissolução-Dolomitização
Compactação
mecânica
Domínio
subsuperfície
Compactação química
Auto cimentação
Água marinha
CCA
(aragonita)
Dissolução
Aragonita
Cimentação
calcita
Dolomitização
CCD
Dolomitização
Dissolução
calcita
Dissolução
Cimentação
SALMOURA

erosional truncation, dismantling
PHASE 3
PHASE 2
PHASE 1
MEGAKARST (open system)
MICROKARST and/or BURIAL CORROSION
THERMAL WATERS
COLD WATERS
VADOSE ZONE
MIXED, SHALLOW PHREATIC ZONE
CONFINED, DEEP PHREATIC ZONE

Soil, regolith
COMMON DEPTHS -TEMPERATURES
0m
15°C
incasion
flowstones, cave sediments
conduit flow
water table

botryoidal cements
cones of floating rafts, sediment
cupolas
Lacy-work zone
400m
40°C
oscillation zone
thermal convection
800m 60°C

nodular zone
powder zone
mineralization
silicification
1200m 80°C
diffuse (local conduits ?)
caves? 120°C

DOMINANT TYPE OF POROSITY	TYPE OF RECHARGE				
	VIA KARST DEPRESSIONS		DIFFUSE		HYPOGENIC
	SINKHOLES (LIMITED DISCHARGE FLUCTUATION)	SINKING STREAMS (GREAT DISCHARGE FLUCTUATION)	THROUGH SANDSTONE	INTO POROUS SOLUBLE ROCK	DISSOLUTION BY ACIDS OF DEEP-SEATED SOURCE OR BY COOLING OF THERMAL WATER
	BRANCHWORKS (USUALLY SEVERAL LEVELS) & SINGLE PASSAGES	SINGLE PASSAGES AND CRUDE BRANCHWORKS, USUALLY WITH THE FOLLOWING FEATURES SUPERIMPOSED:	MOST CAVES ENLARGED FURTHER BY RECHARGE FROM OTHER SOURCES	MOST CAVES FORMED BY MIXING AT DEPTH	
FRACTURES	 ANGULAR PASSAGES	 FISSURES, IRREGULAR NETWORKS	 FISSURES, NETWORKS	 ISOLATED FISSURES AND RUDIMENTARY NETWORKS	 NETWORKS, SINGLE PASSAGES, FISSURES
BEDDING PARTINGS	 CURVILINEAR PASSAGES	 ANASTOMOSES, ANASTOMOTIC MAZES	PROFILE:  SHAFT AND CANYON COMPLEXES, INTERSTRATAL SOLUTION	 SPONGEWORK	 RAMIFORM CAVES, RARE SINGLE-PASSAGE AND ANASTOMOTIC CAVES
INTERGRANULAR	 RUDIMENTARY BRANCHWORKS	 SPONGEWORK	PROFILE:  RUDIMENTARY SPONGEWORK	 SPONGEWORK	 RAMIFORM & SPONGEWORK CAVES

Palmer, 1991

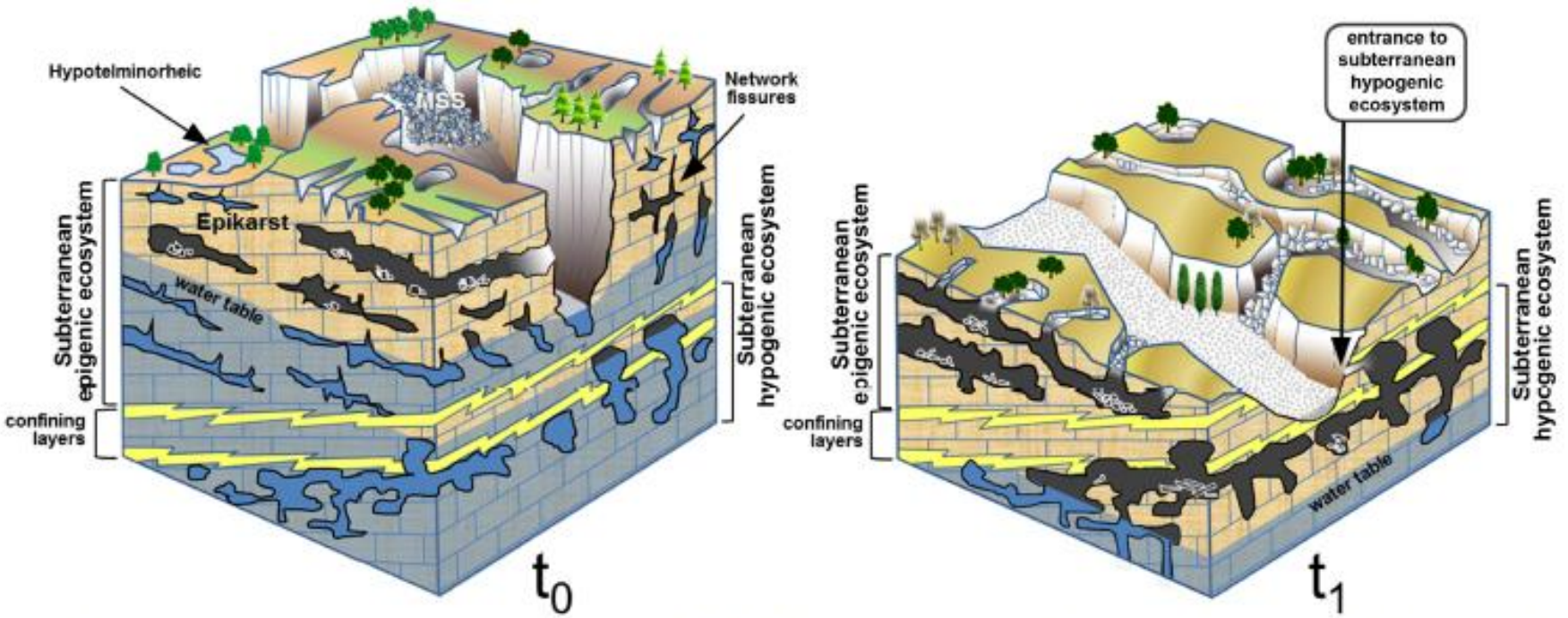


Fig. 1. Diagram of subterranean epigenic and hypogenic ecosystems: t_0 active phase and t_1 inactive phase with connection of epigenic and hypogenic ecosystems. SSH, Shallow Subterranean Habitats.

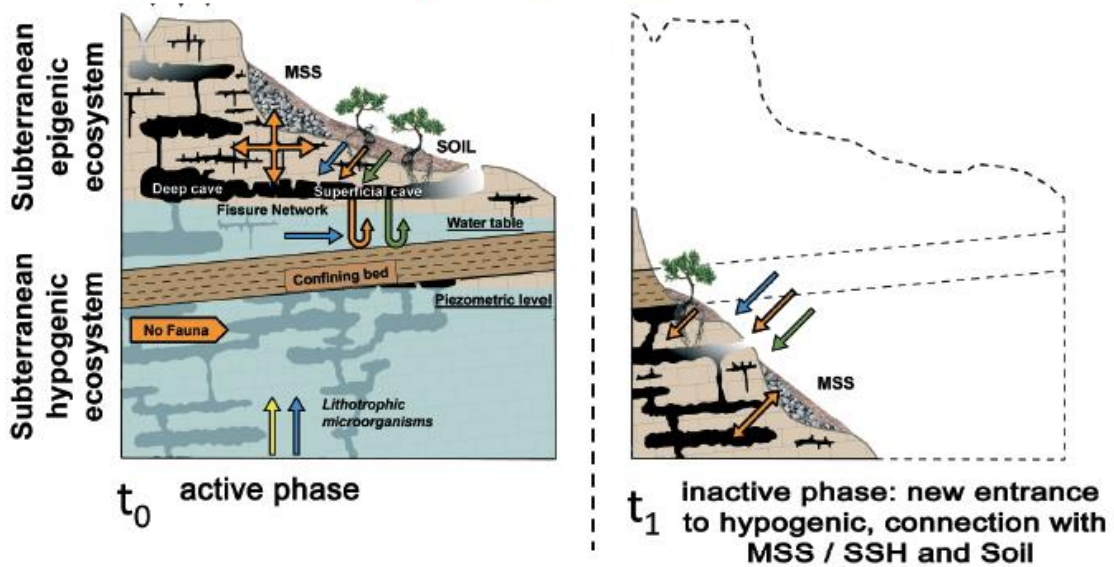
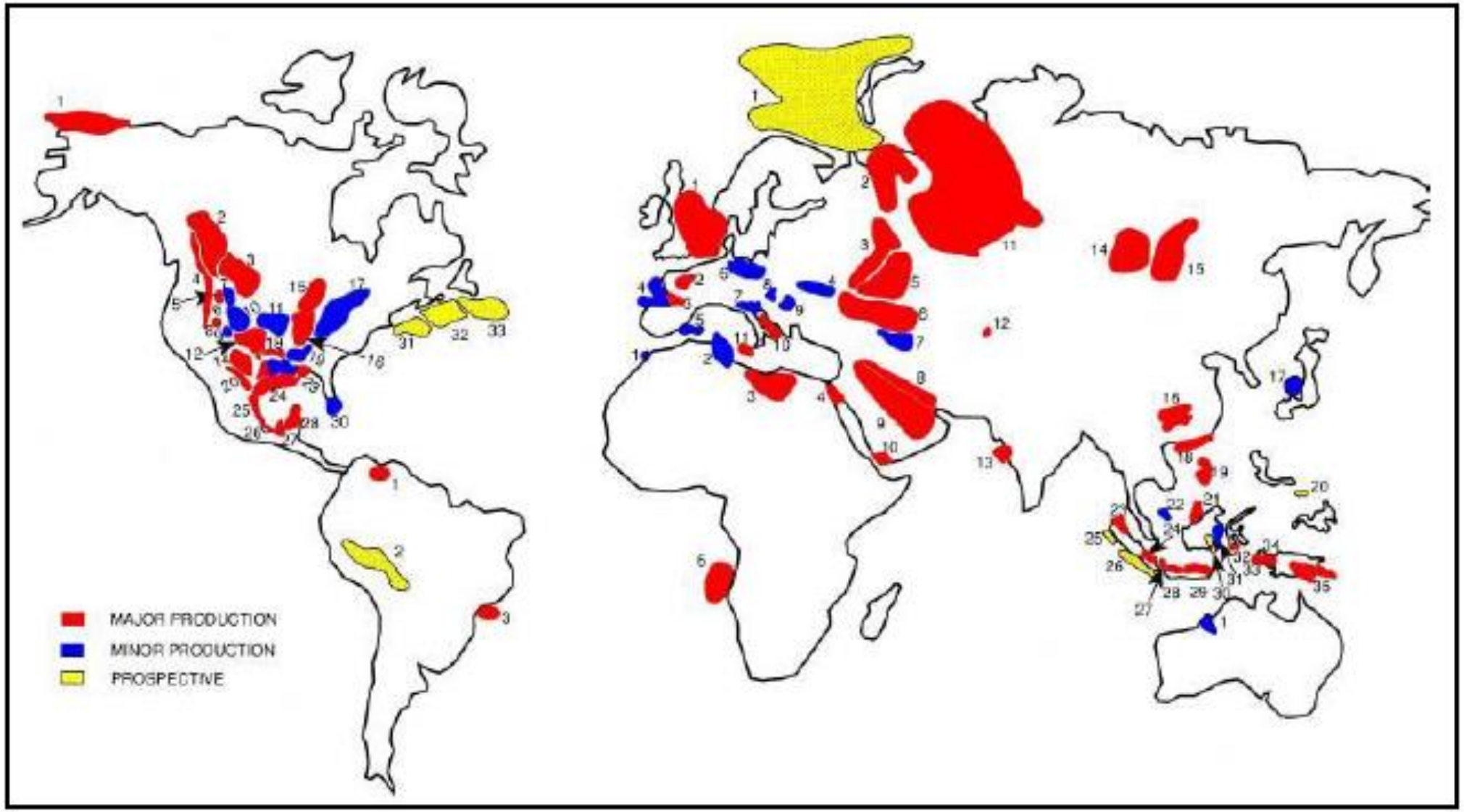


Fig. 8. Diagram of the flow of fauna, water and energy (in form of organic nutrients, or inorganic chemical compounds) in both epigenic and hypogenic subterranean ecosystems. t_0 active phase; t_1 inactive phase with the connection of hypogenic ecosystem with the surface, SSH and soil.

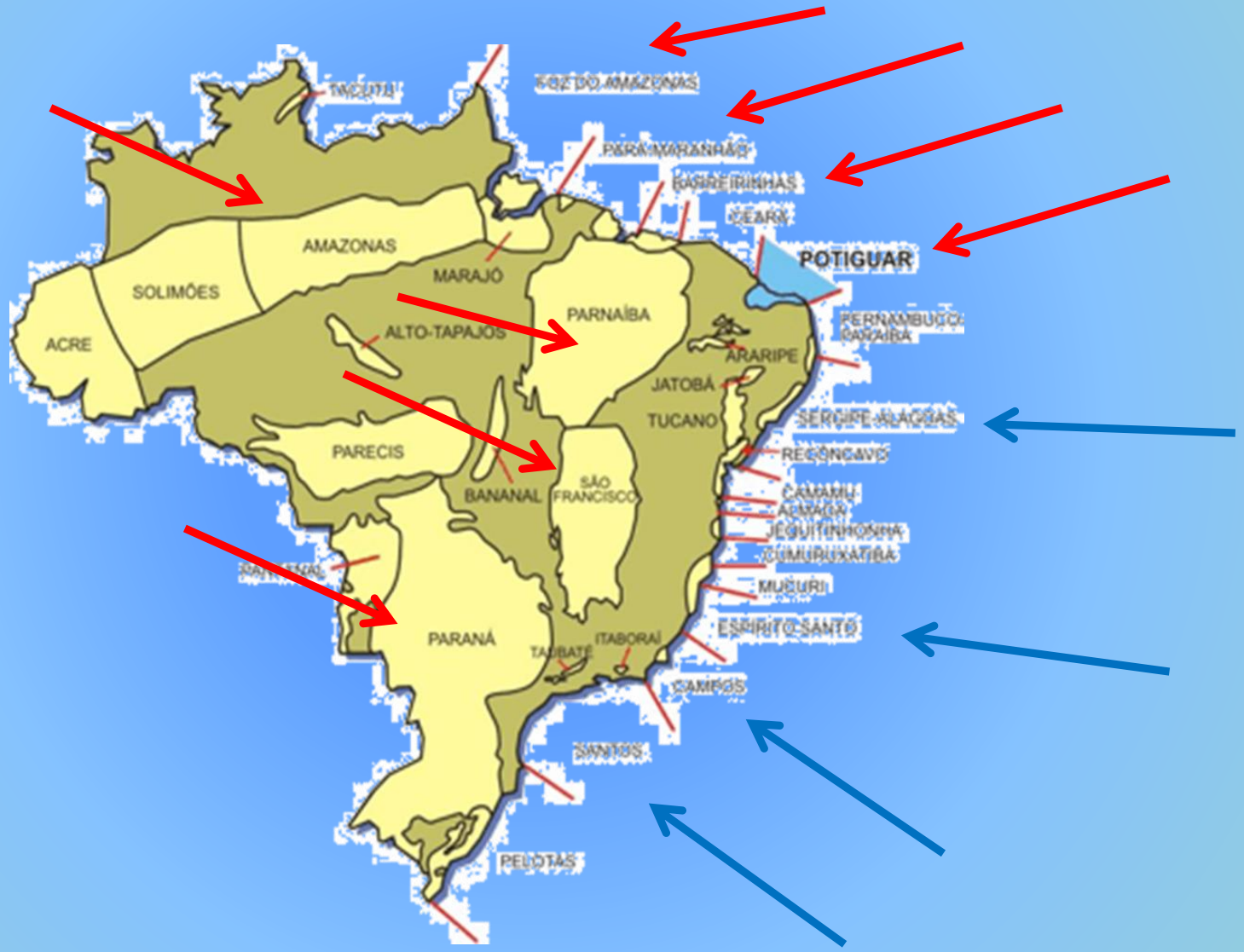
Sendra et al, 2014

Petroleum Basins with Carbonate Reservoirs



Jordan & Wilson, 1994

Reservatórios carbonáticos no Brasil



Lagoa Feia – Pré-sal





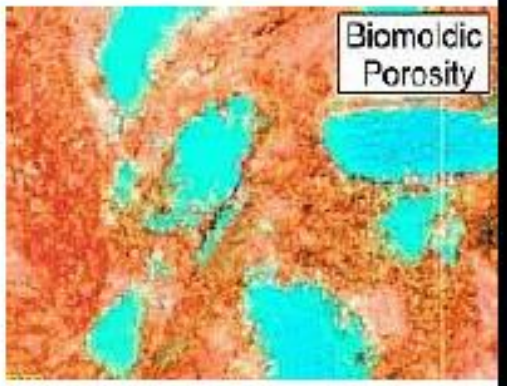
Campos Basin lacustrine coquina facies (from John Warme)

Albiano

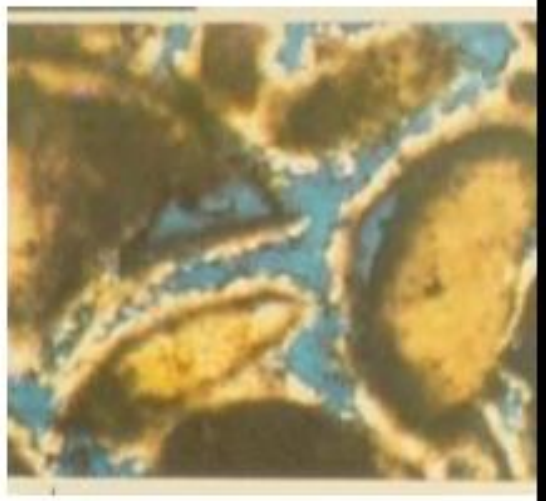
Campos Basin Albian cyclic carbonate reservoirs

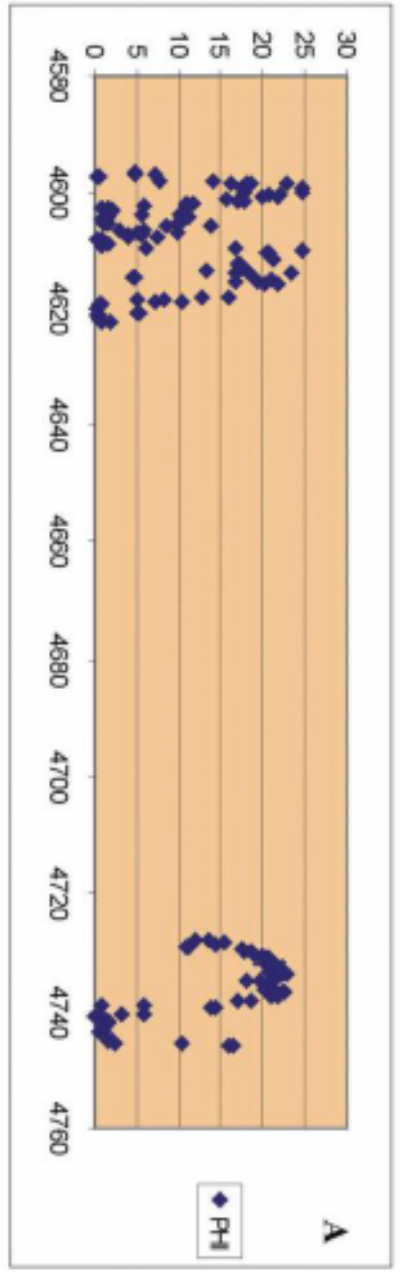
Reservoirs occur at the top of coarsening up, shallowing up cycles, but facies and diagenesis important:

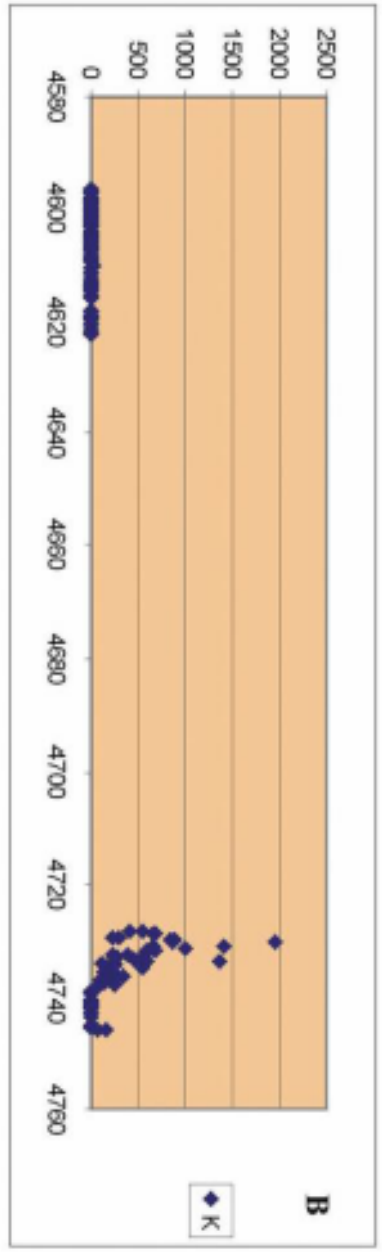
Upper unit with biomoldic porosity has high porosity but little permeability;



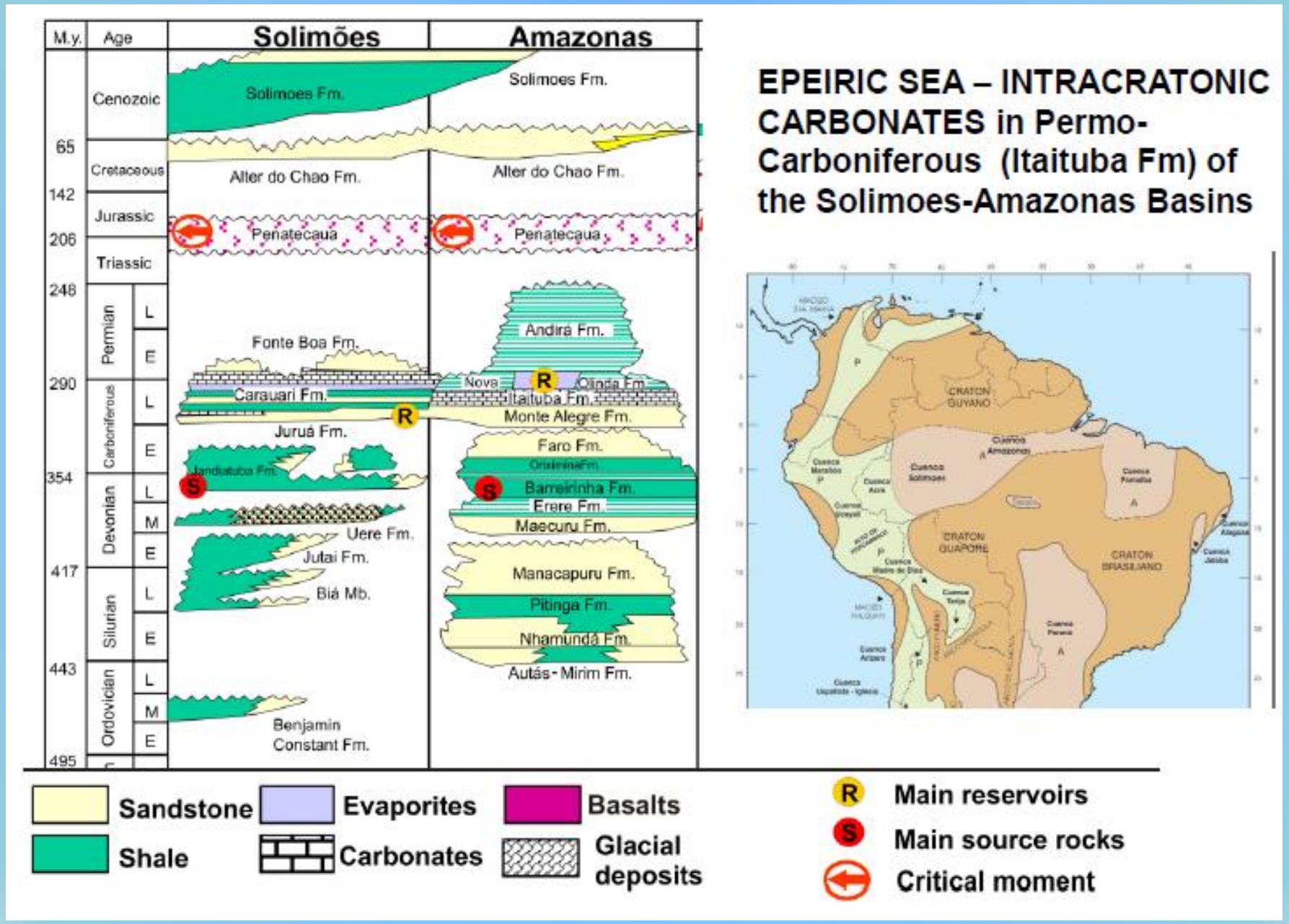
Lower unit is an oolitic grain-stone with intergranular porosity – so high porosity and good permeability.



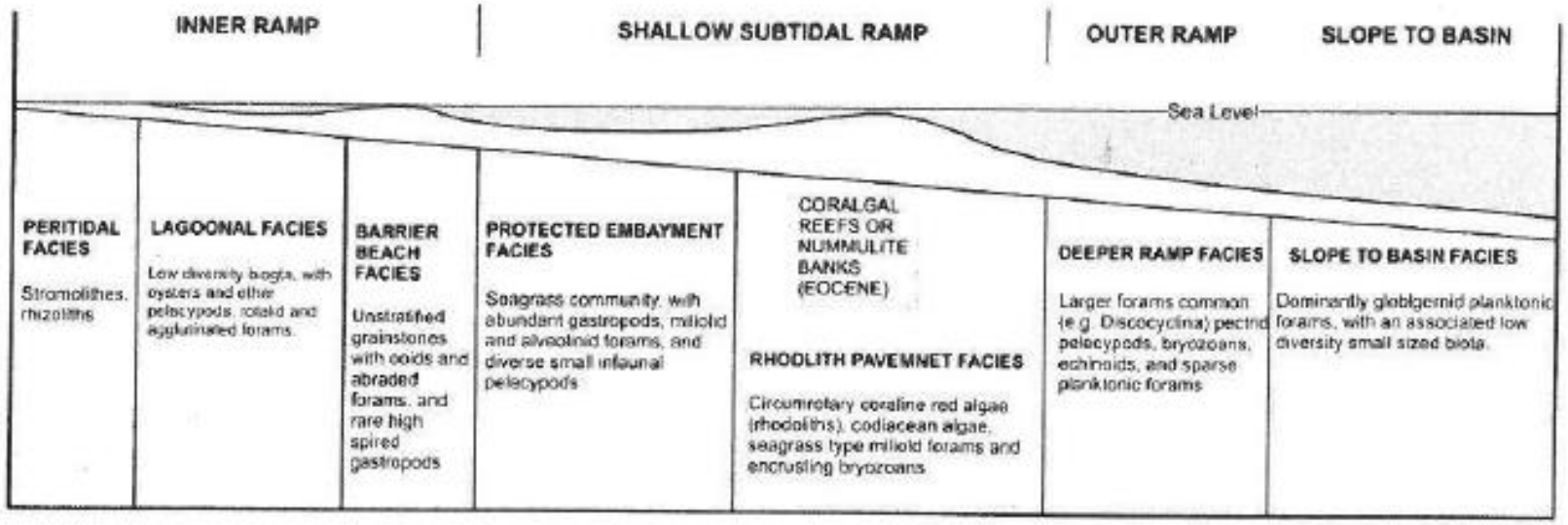




Fm Itaituba


M.y.
Age
Solimões
Amazonas
Cenozoic
Cretaceous
Jurassic
Triassic
Permian
Carboniferous
Devonian
Silurian
Ordovician
65
142
206
248
290
354
417
443
495
L
E
M
Solimoes Fm.
Alter do Chao Fm.
Penatecaua
Fonte Boa Fm.
Carauari Fm.
Juruá Fm.
Jandiatuba Fm.
Uere Fm.
Jutai Fm.
Biá Mb.
Benjamin Constant Fm.
Andirá Fm.
Nova Olinda Fm.
Itaituba Fm.
Monte Alegre Fm.
Faro Fm.
Oriximiná Fm.
Barreirinha Fm.
Erere Fm.
Maecuru Fm.
Manacapuru Fm.
Pitinga Fm.
Nhamundá Fm.
Autás-Mirim Fm.
R
S
EPEIRIC SEA – INTRACRATONIC CARBONATES in Permo-Carboniferous (Itaituba Fm) of the Solimoes-Amazonas Basins
CRATON GUYANO
CRATON GUAPORE
CRATON BRASILIANO
Sandstone
Shale
Evaporites
Carbonates
Basalts
Glacial deposits
Main reservoirs
Main source rocks
Critical moment

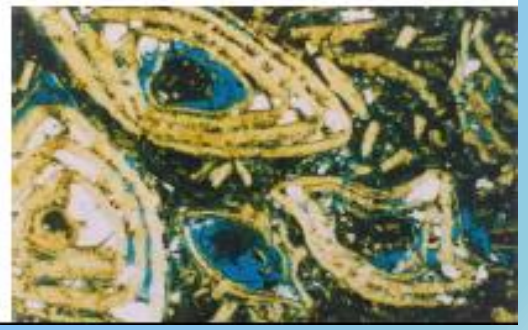
Foz do Amazonas



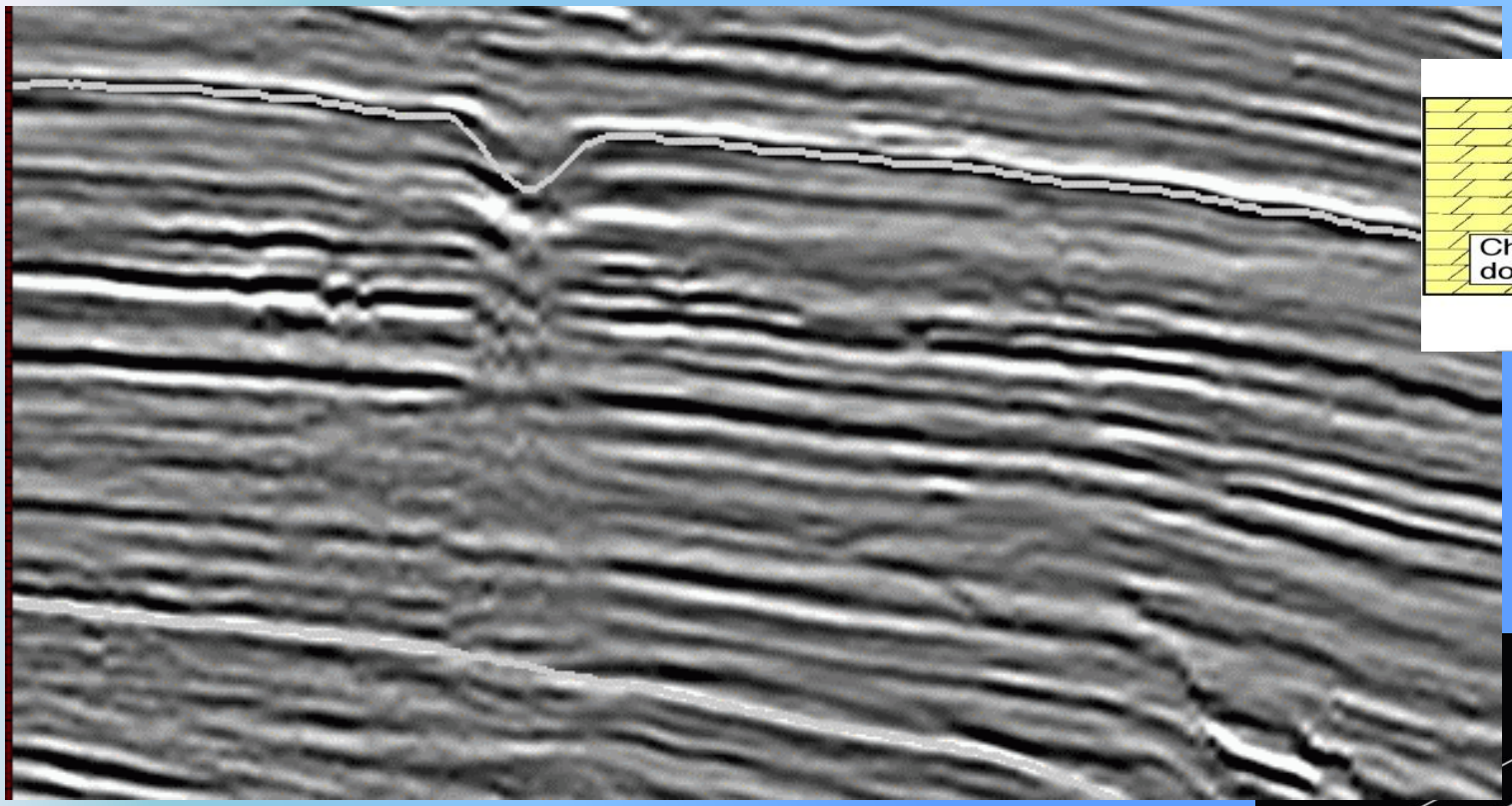
Generalized model for a Tertiary carbonate ramp – common in the Mediterranean area (Buxton & Pedley, 1989) and offshore South America – e.g. Foz de Amazonas basin, typically dominated by larger benthic foraminifera

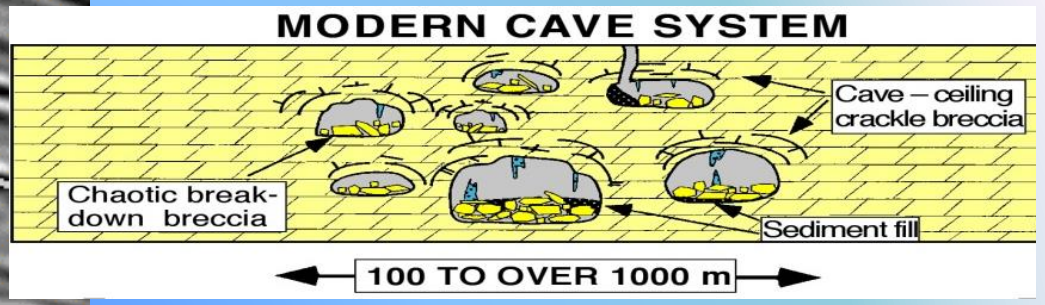


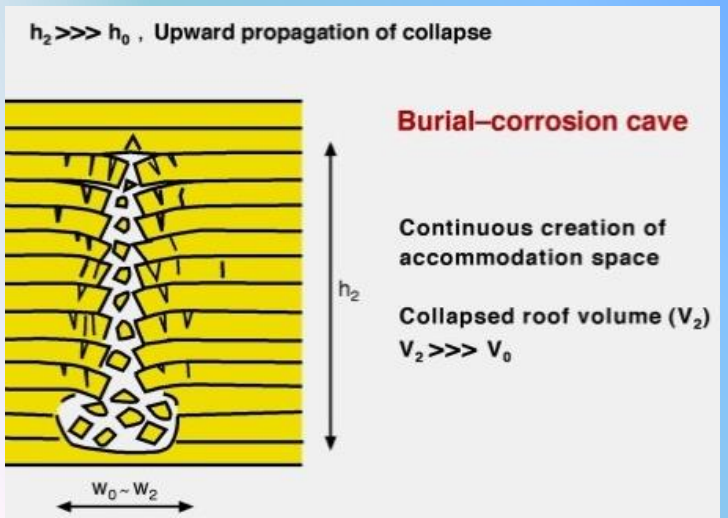
Carbonate ramps in the Eocene of North Africa and elsewhere dominated by larger benthic foraminifera

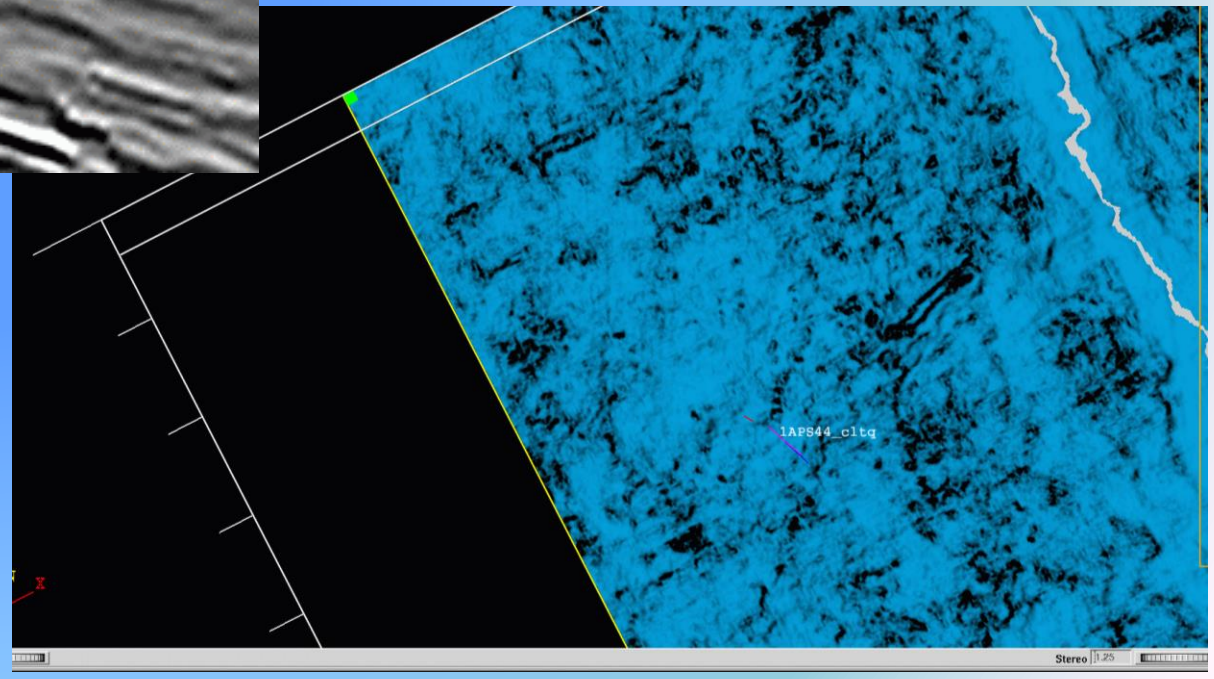


Foz do Amazonas

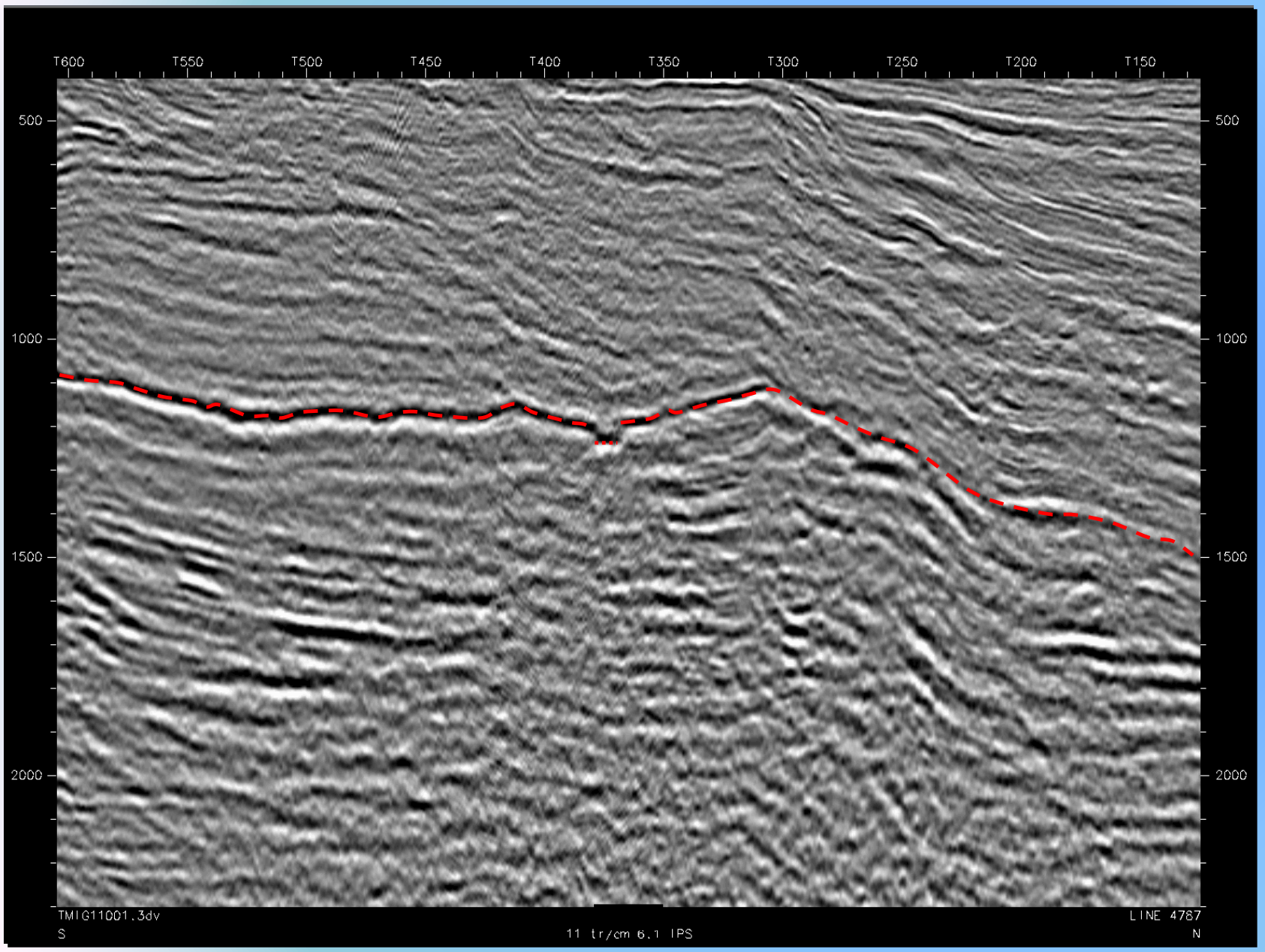






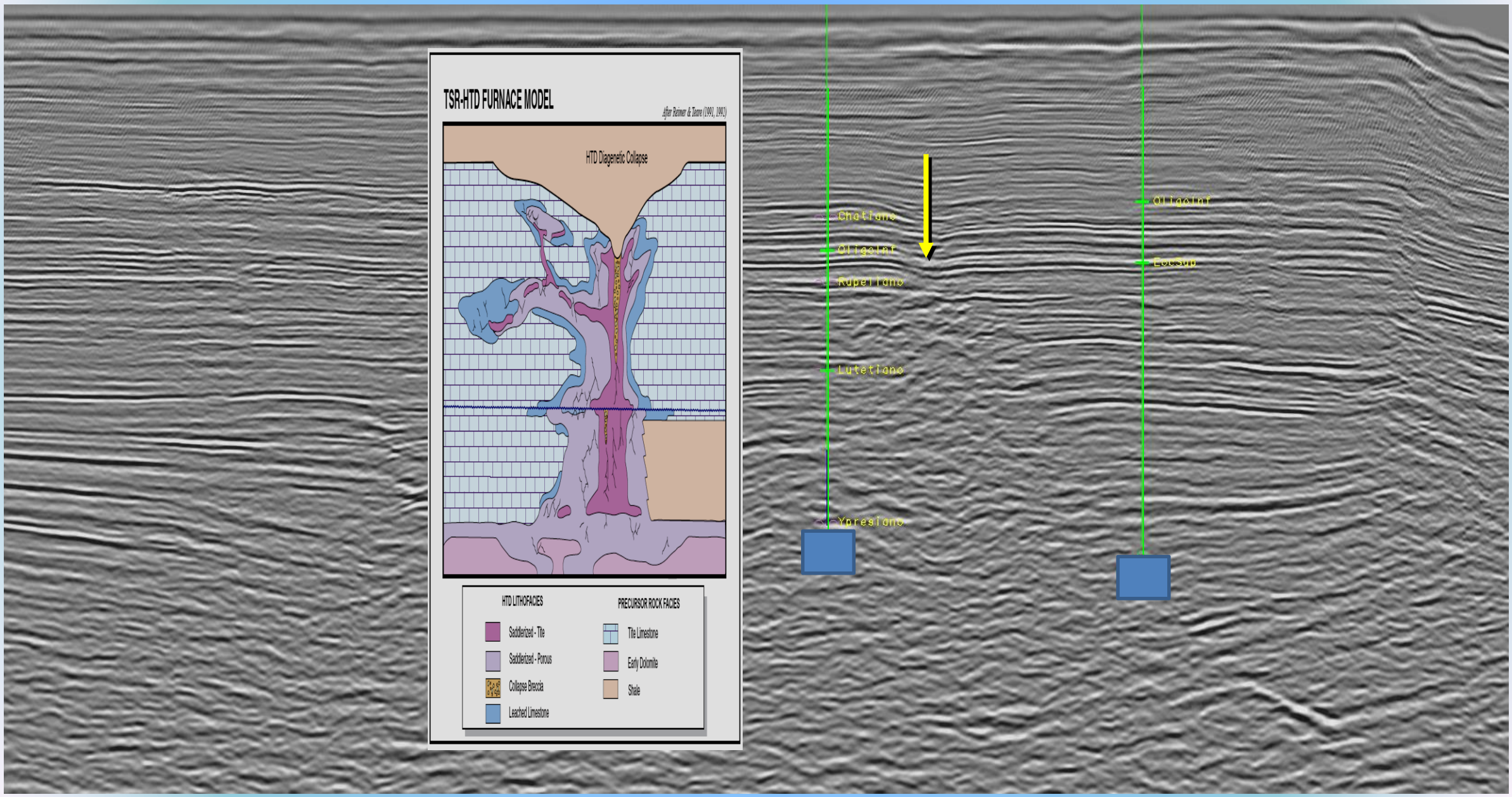


Bacia Potiguar

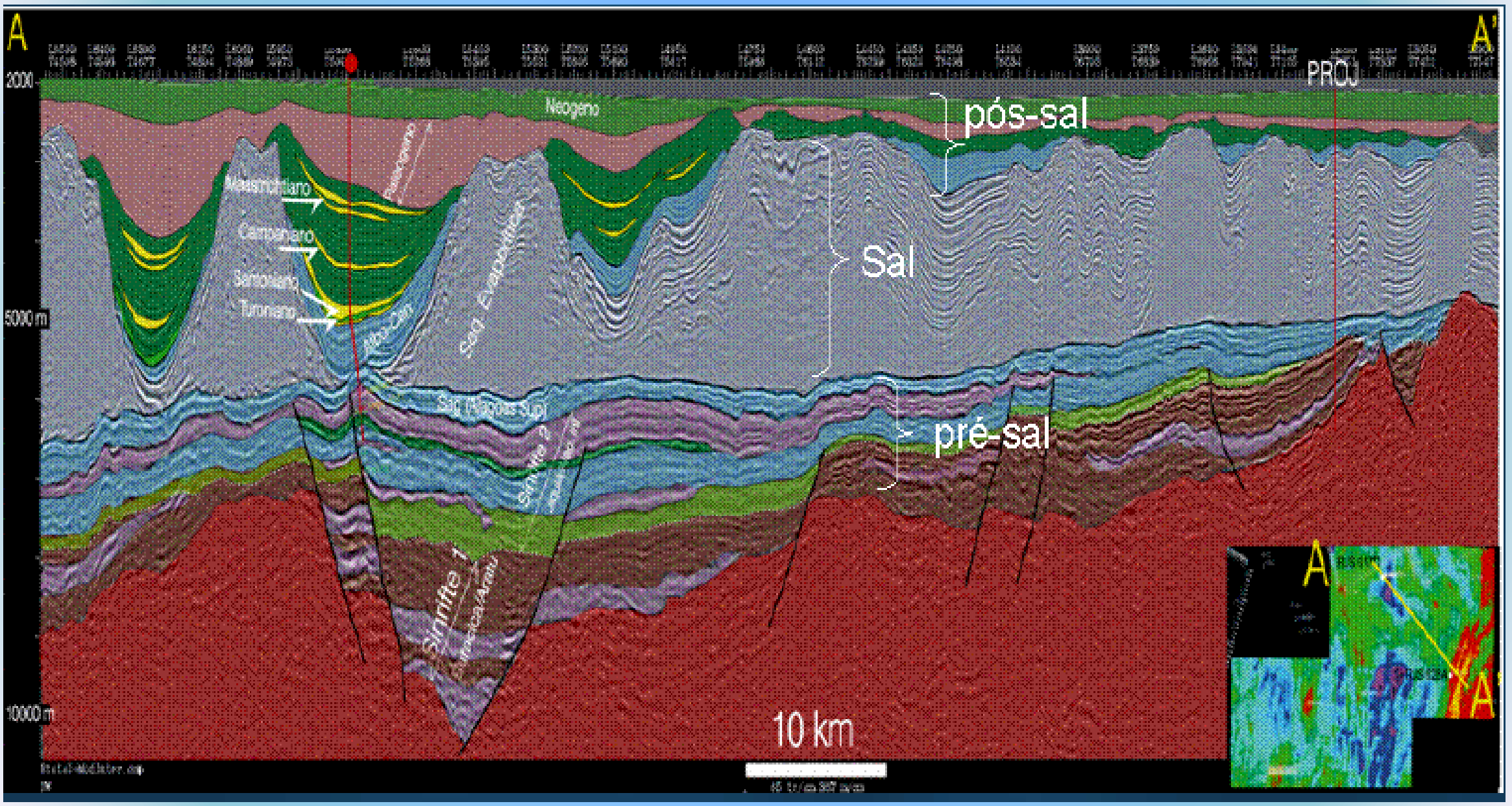




Pará-Maranhão



Pré-sal


A
A'
2000
5000 m
10000 m
Neogeno
pós-sal
sal
pré-sal
Maastrichtiano
Campaniano
Santoniano
Turoniano
Sinrifte 1
10 km
A
A'

O desafio – investigação de feições de escala sísmica à subsísmica



Geologia – Geoquímica – Petrofísica

Geofísica Rasa

Micro | Macro | **metros** | Mega | Giga

0.00001 0.0001 0.001 0.01 0.1 1 10 100 1k 10K





Projetos de P&D - Análogos

A identificação de reservatórios ou afloramentos análogos é importante, principalmente, para o desenvolvimento de um novo campo.

Normalmente, as informações disponíveis sobre a nova área é limitada ou não existem.

Tradicionalmente, a busca por reservatórios ou afloramentos análogos é realizada por geocientistas e engenheiros de produção.




UFRN


UnB


UNISINOS
UNIVERSIDADE DO VALE DO RIO DOS SINOS


UFRGS
UNIVERSIDADE FEDERAL
DO RIO GRANDE DO SUL


UFG
UNIVERSIDADE
FEDERAL DE GOIÁS


PUC
RIO


UFCG
Universidade Federal
de Campina Grande


UNIVERSIDADE
FEDERAL DO CEARÁ


UPE
UNIVERSIDADE
DE PERNAMBUCO


UDESC
UNIVERSIDADE
DO ESTADO DE
SANTA CATARINA


Instituto do Carste


Laboratório
Nacional de
Computação
Científica
UNIDADE DE PESQUISA DO MCTIC

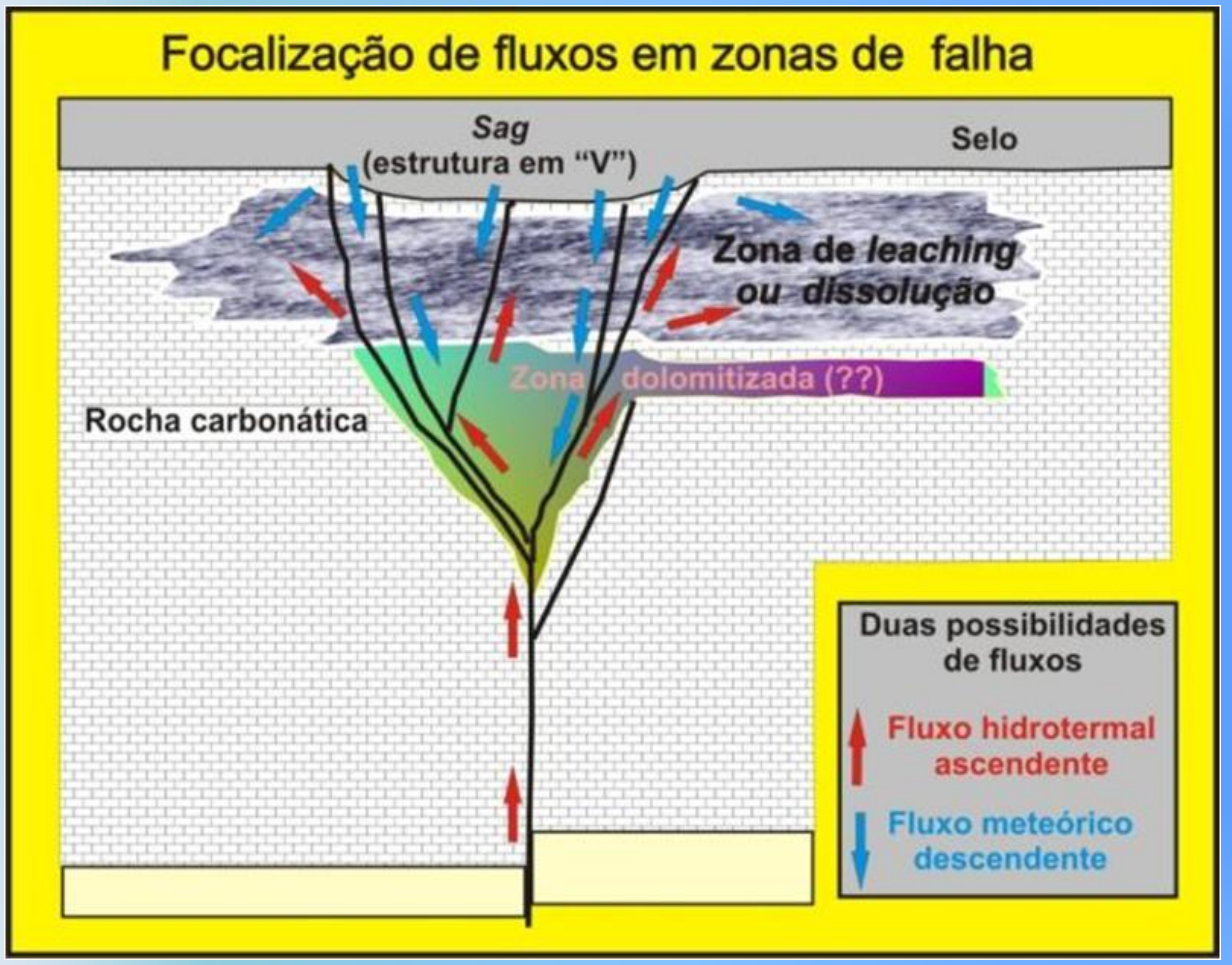

UNIVERSIDADE FEDERAL
DE SANTA CATARINA


UNIVERSIDADE
FEDERAL
DE PERNAMBUCO


unipampa
Universidade Federal do Pampa


UNICAMP

Caracterização da arquitetura e cinemática de falhas e fraturas e seu papel na distribuição da permeabilidade e da porosidade secundária em rochas carbonáticas carstificadas.



Sibson (1990)



Análogo Epigênico



Análogo Hipogênico

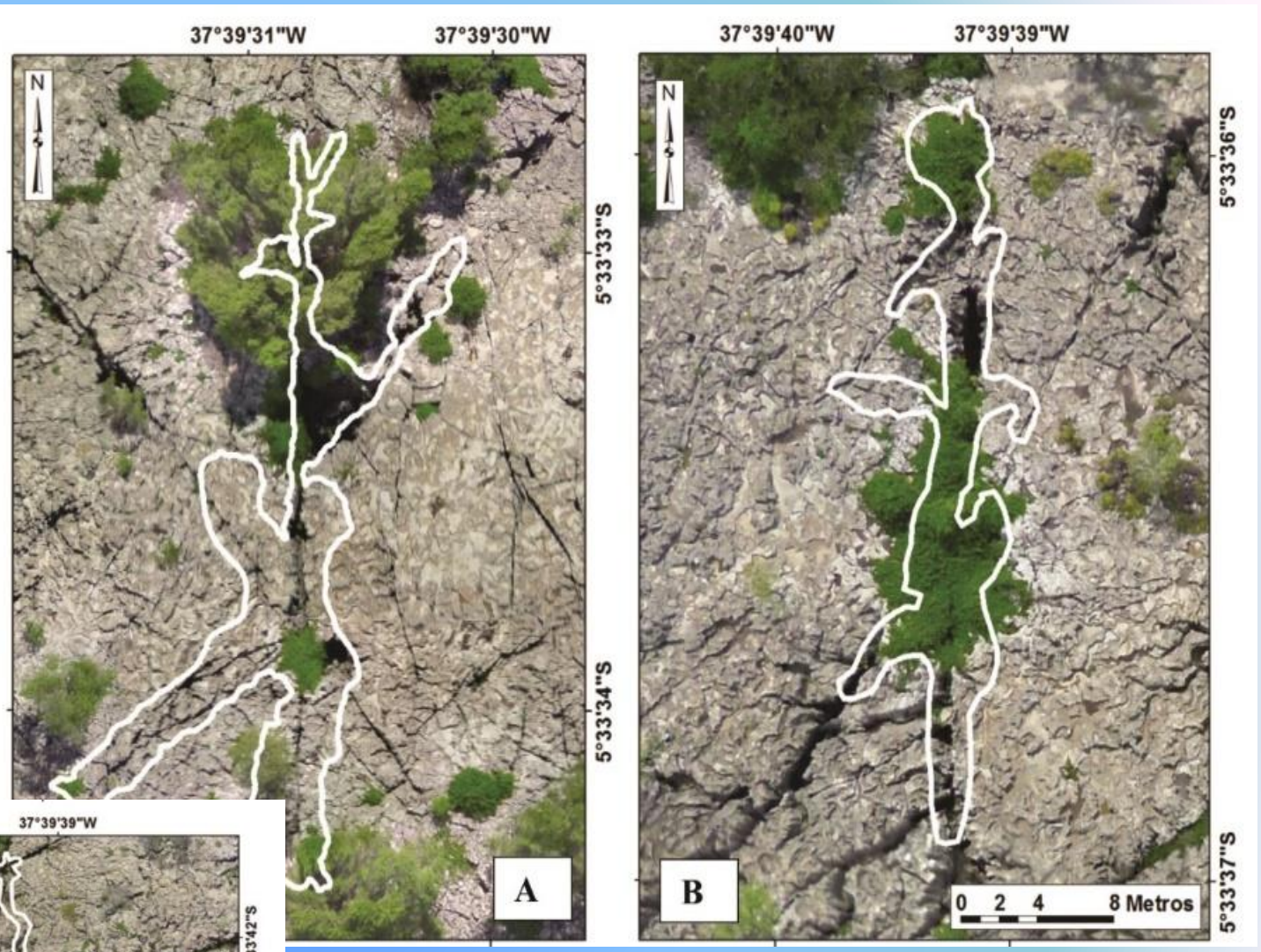
Utilização de imagens captadas por VANT para estudo de fraturas subsísmicas e processos cársticos no análogo epigênico.

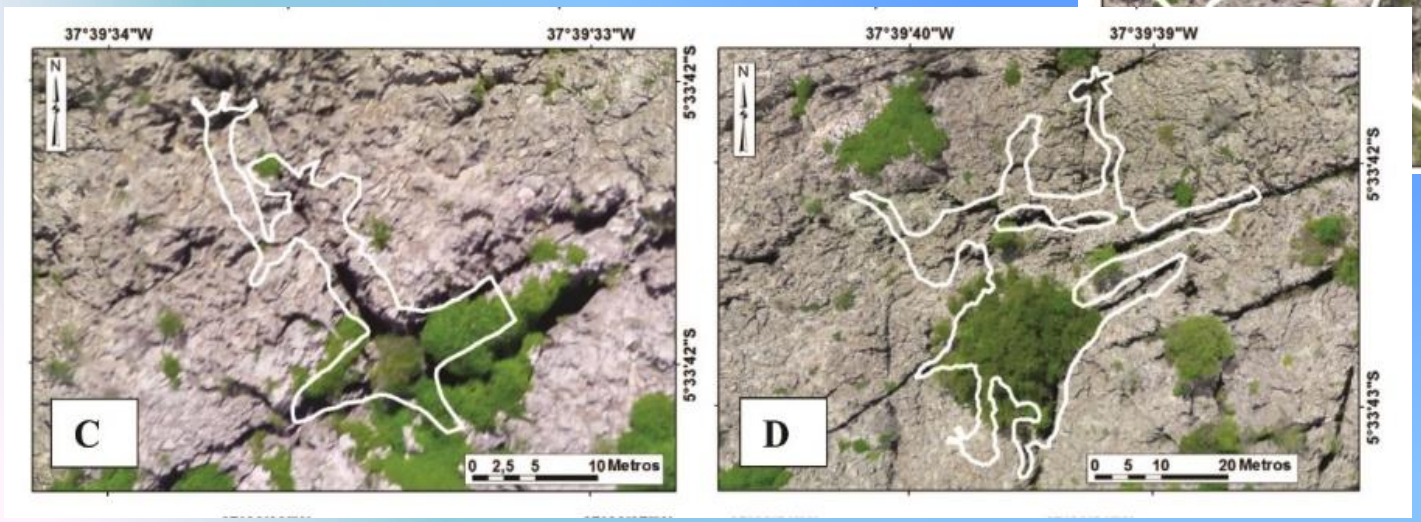


Informações importantes são “omitidas” na sísmica.



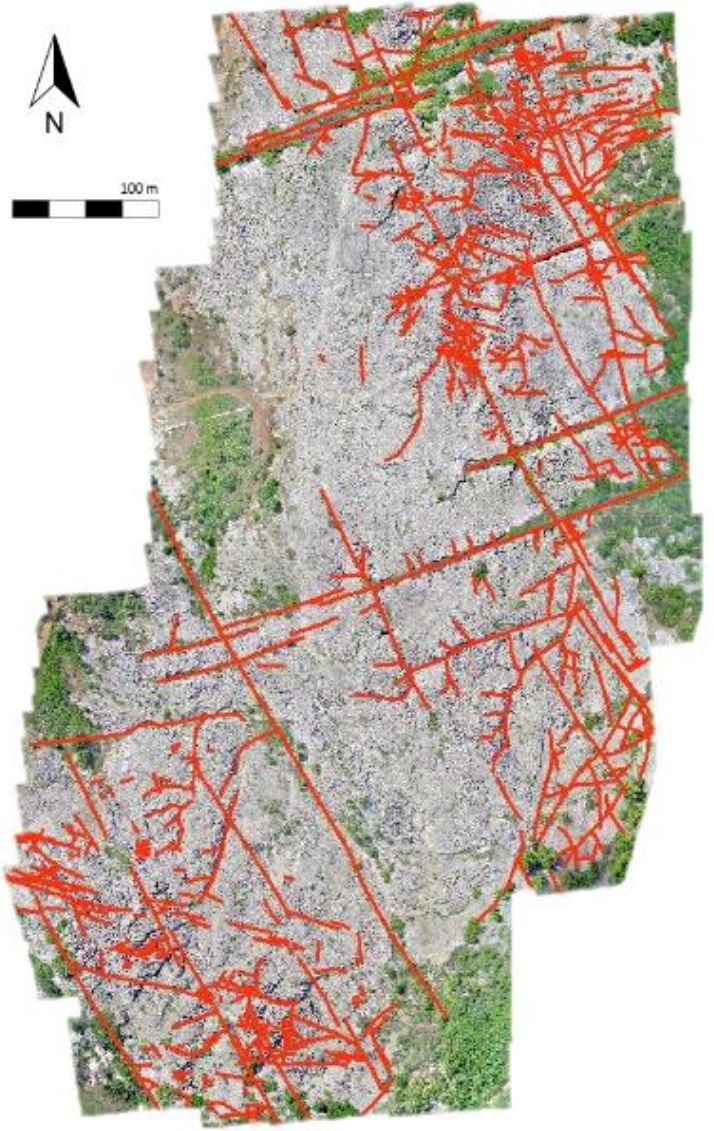
A dissolução (carste) ocorre, preferencialmente, ao longo dos cruzamentos de fraturas que podem ser usadas como guias para a ocorrência de carste.

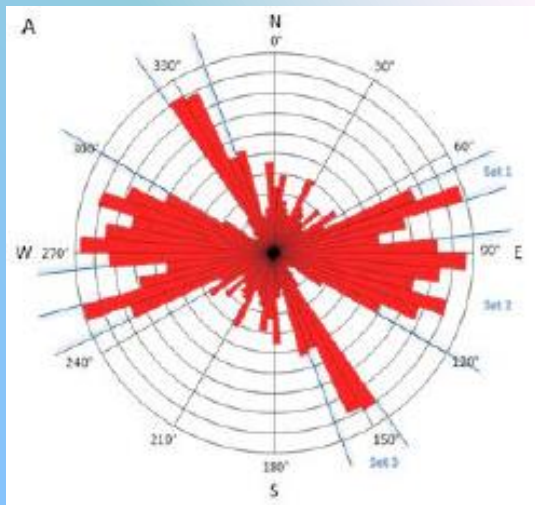


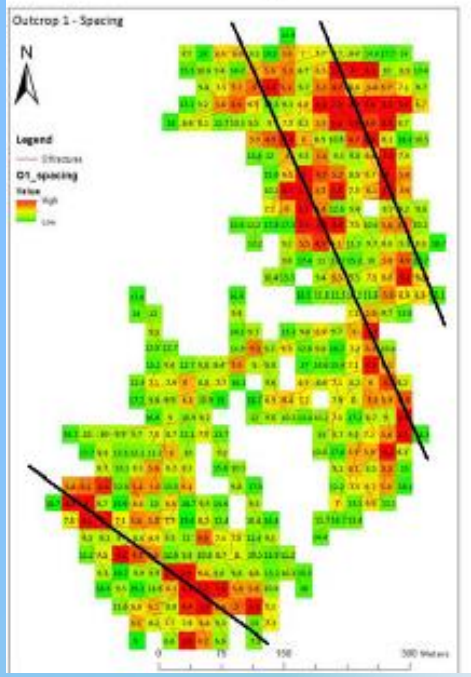


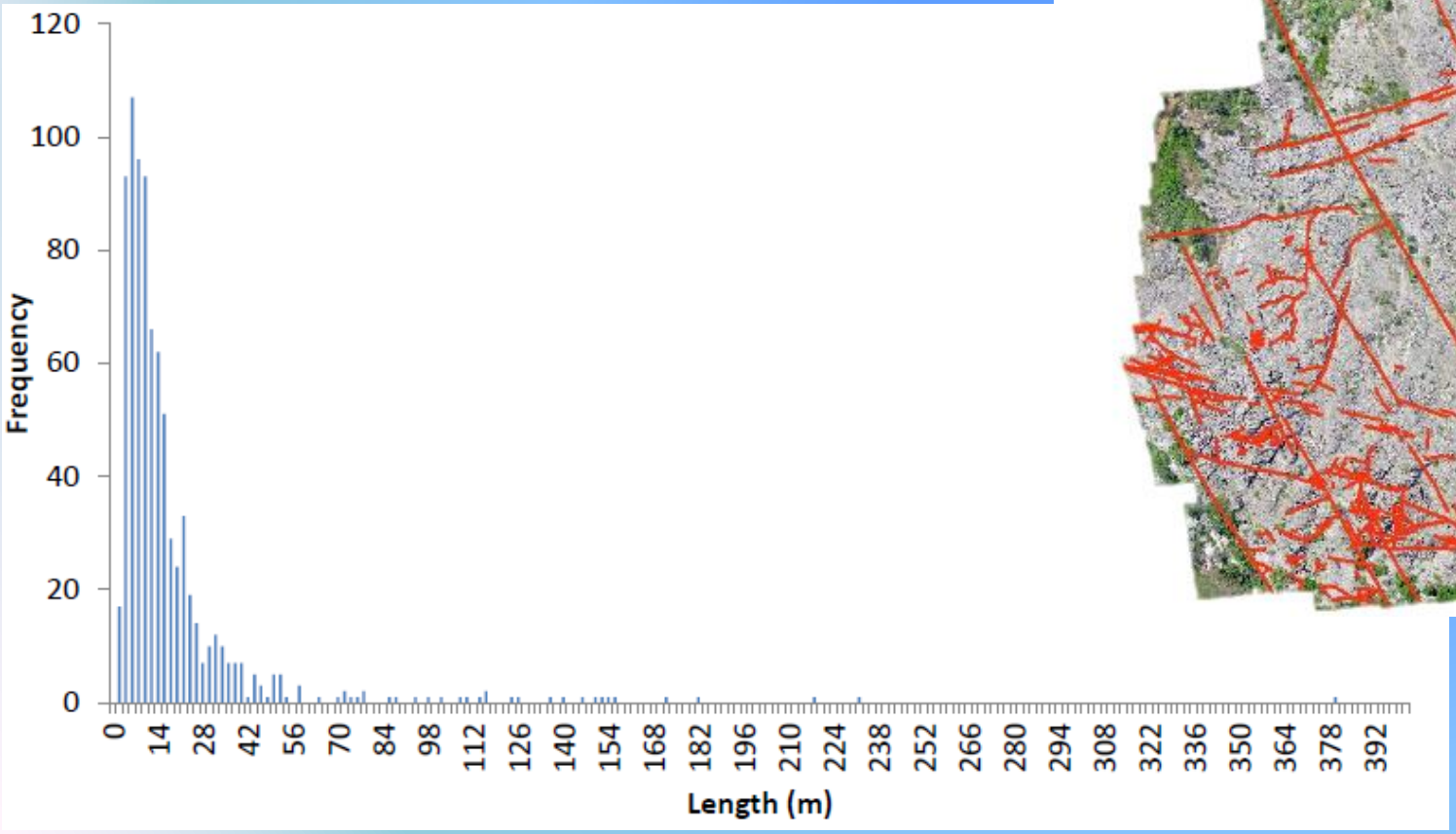
Carneiro *et al.*
Geoc. Unesp, 2015

Conjuntos de fraturas mostram correlação com padrões regionais e formam corredores de maior permeabilidade. A maioria destes conjuntos são de escala subsísmica.



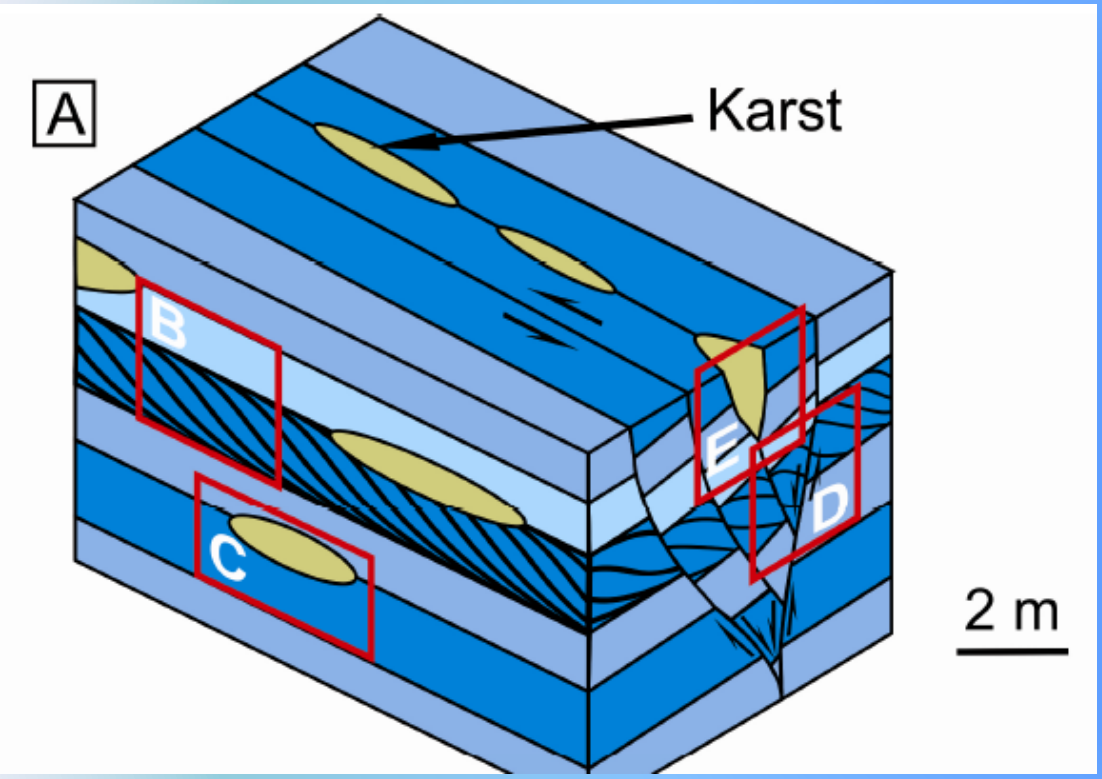


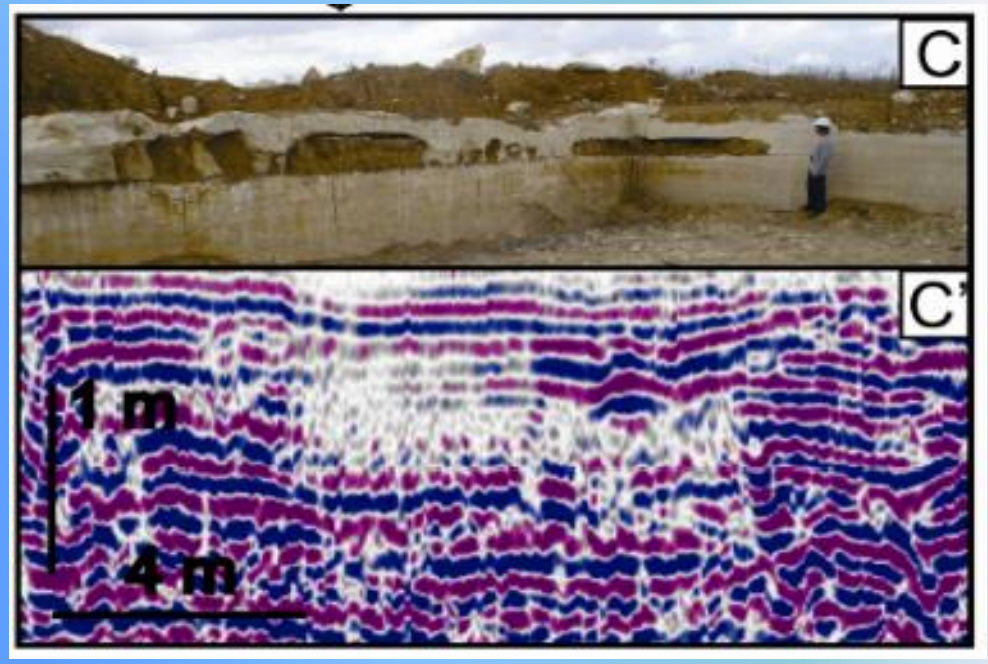




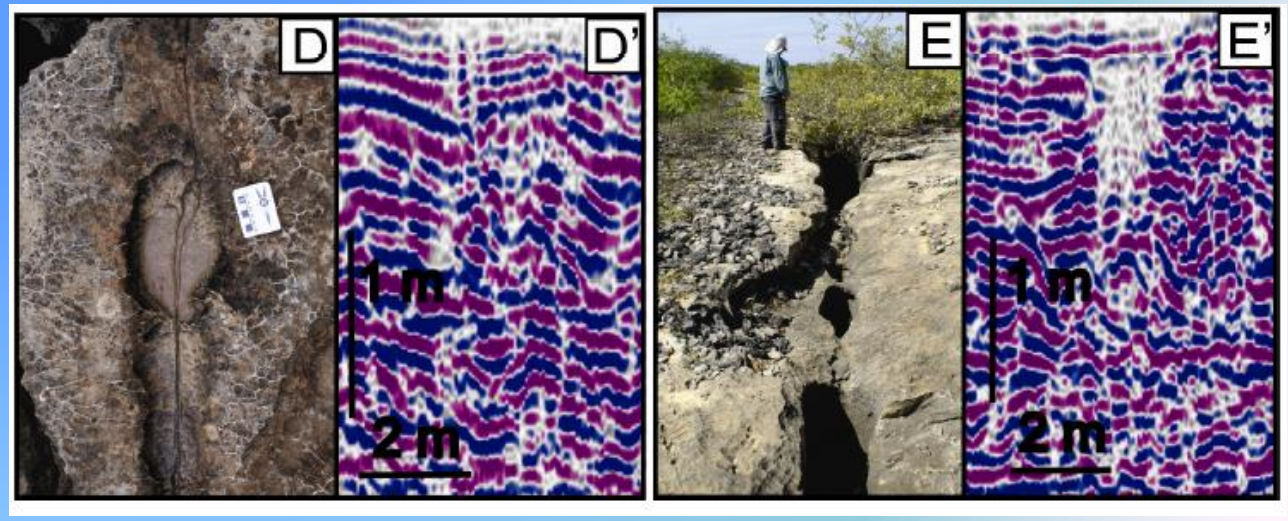
Bisdom, 2016
PhD Thesis

Dados de GPR indicam que o processo de dissolução cria “vazios” ao longo do acamamento sedimentar e de fraturas que são identificados, em radargramas, por zonas de sombras.





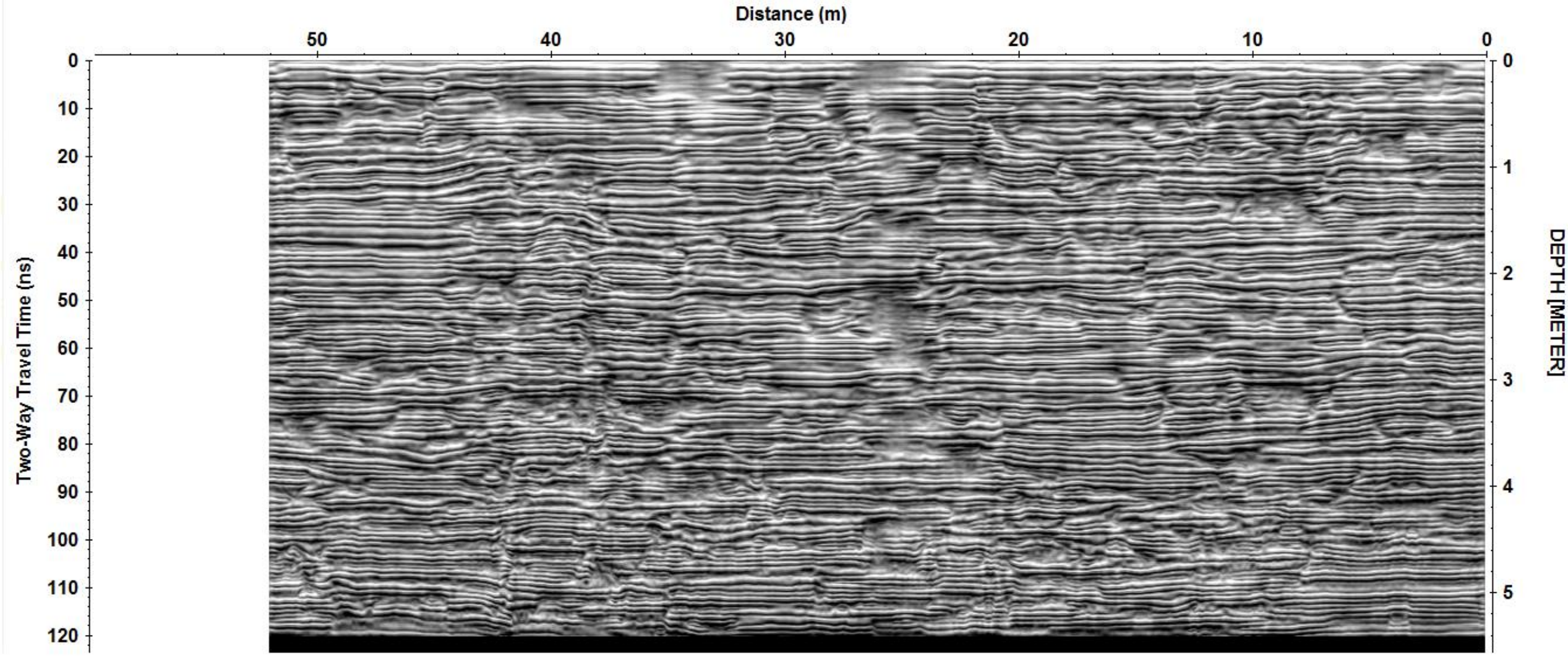
Acamamento sedimentar



Fraturas

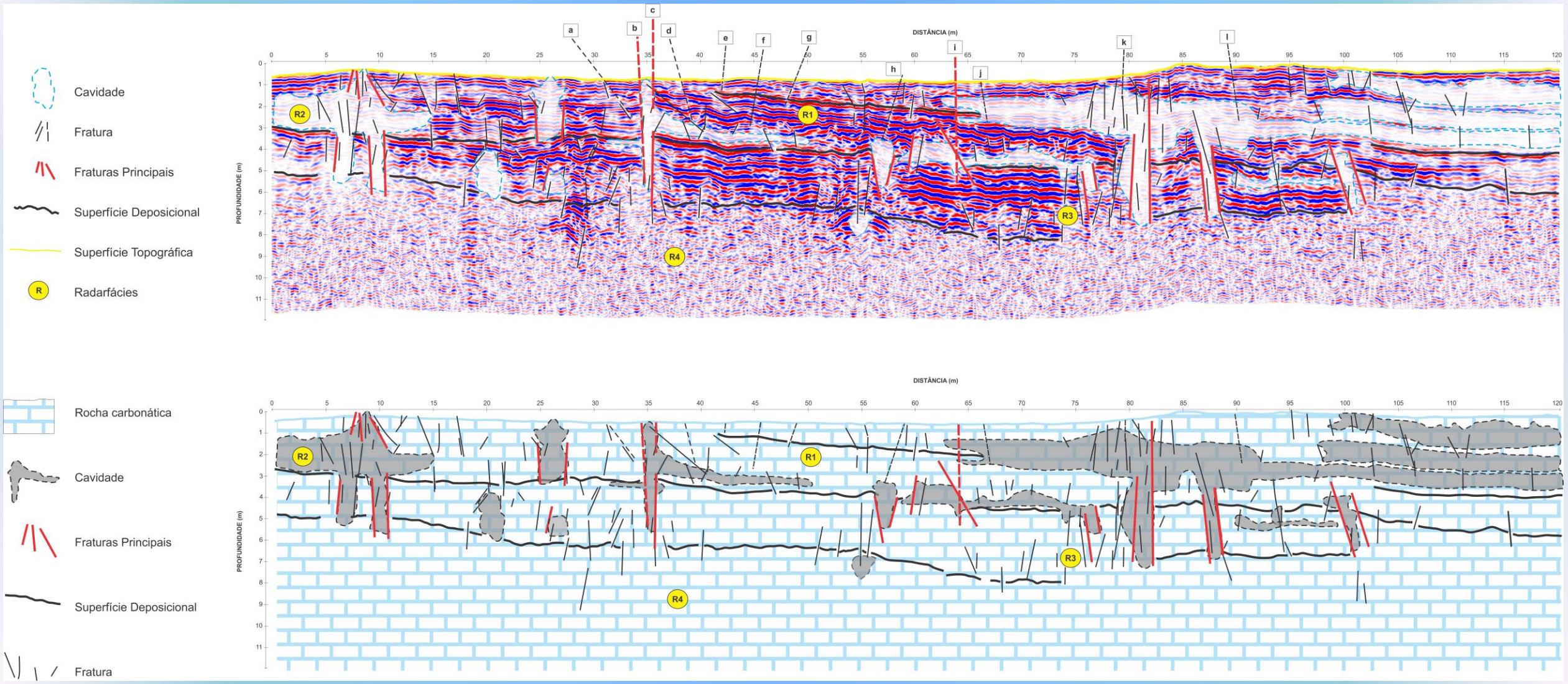
Fernandes *et al.*
J Applied Geophysics, 2015


CASE



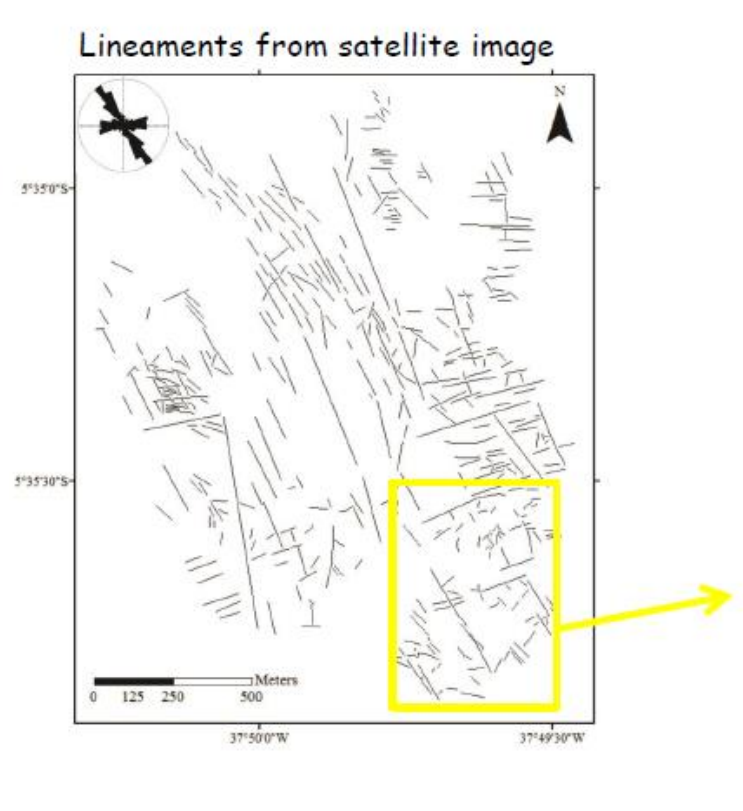
Oliveira *et al.*
Near Surf Geophysics 2019

LAJEDO ARAPUÁ-RN (Fraturas)



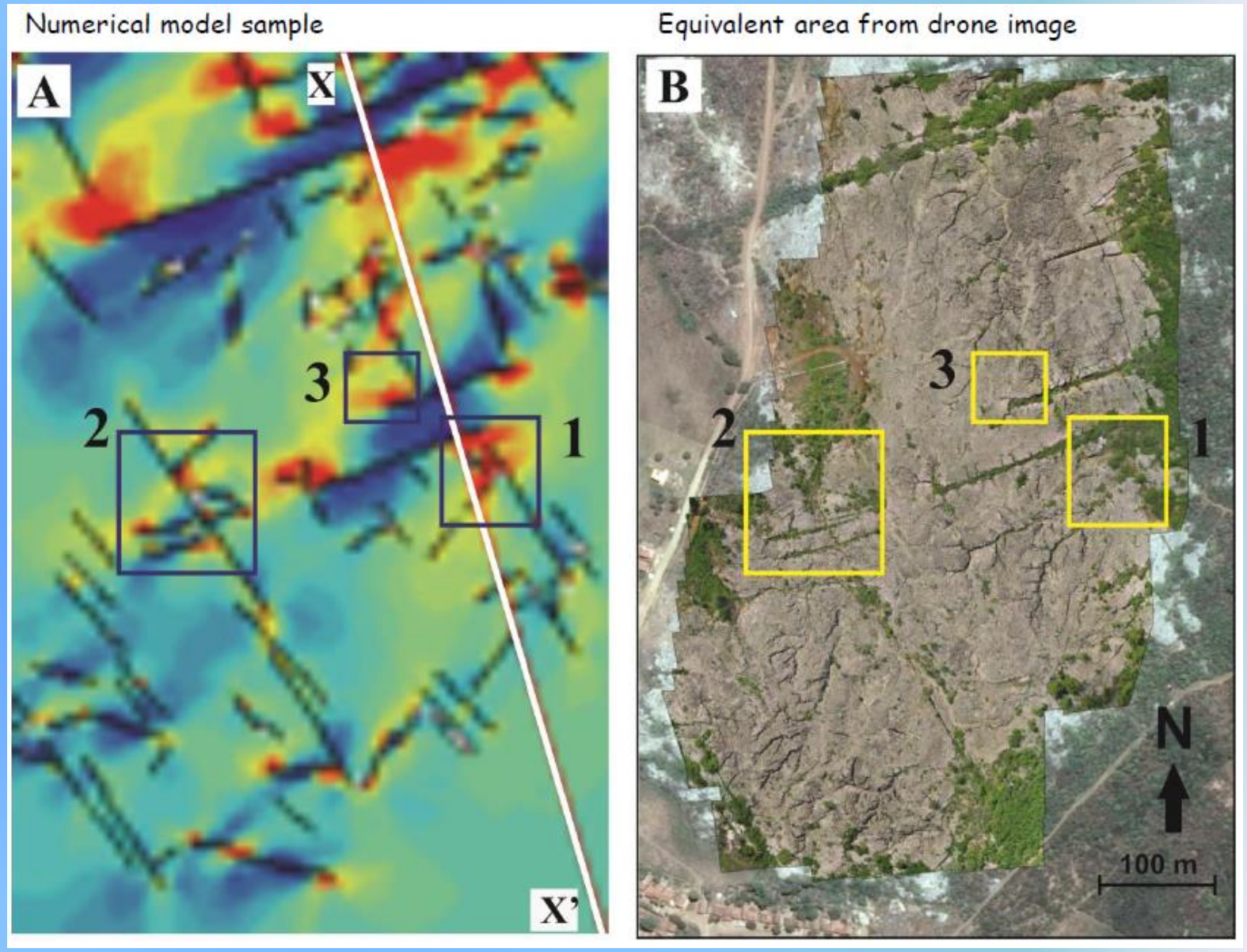
Modelagem numérica dos efeitos das tensões atuais e das paleo-tensões sobre as estruturas identificadas.

(TECTOS)

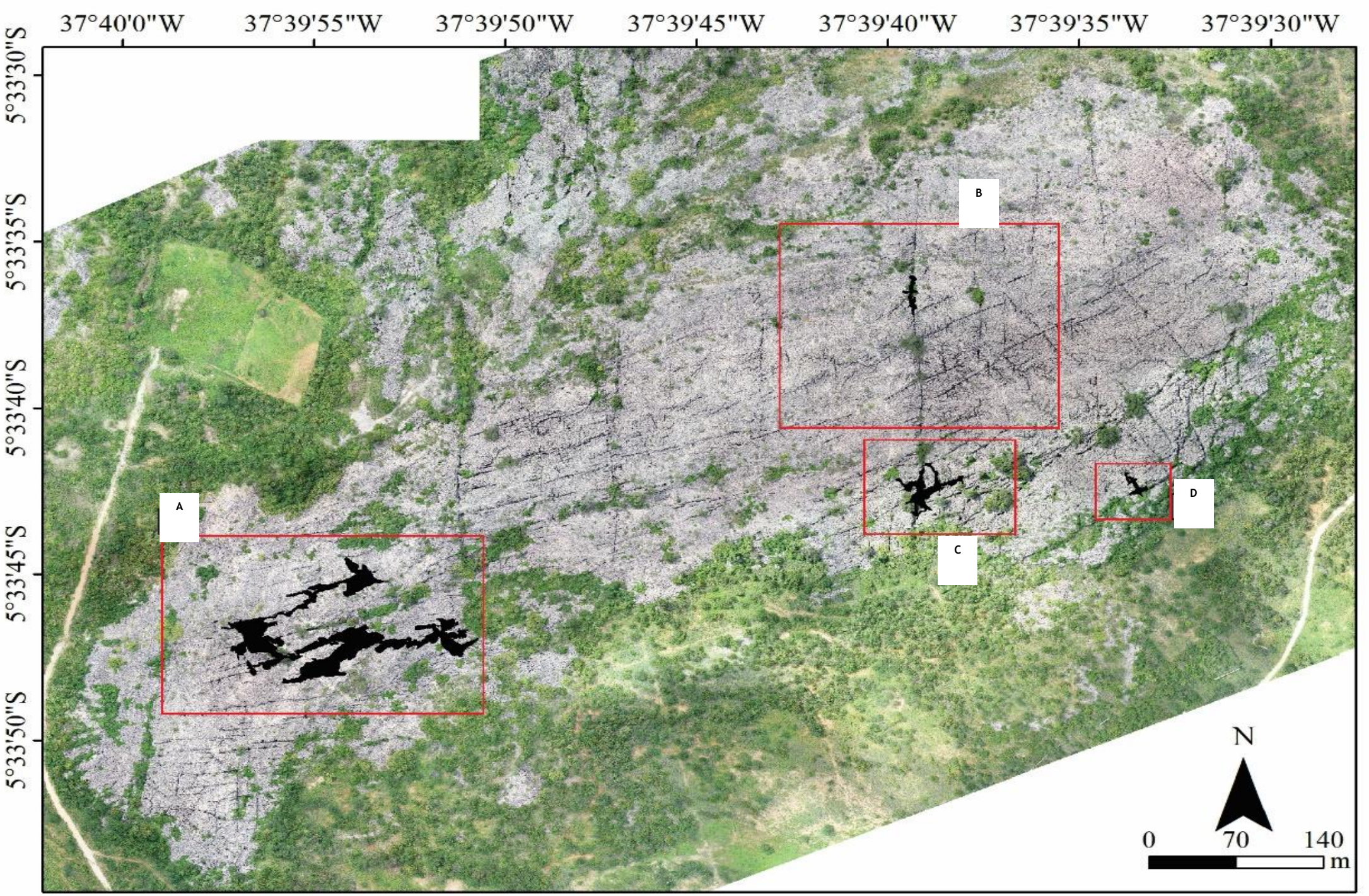


Áreas críticas:

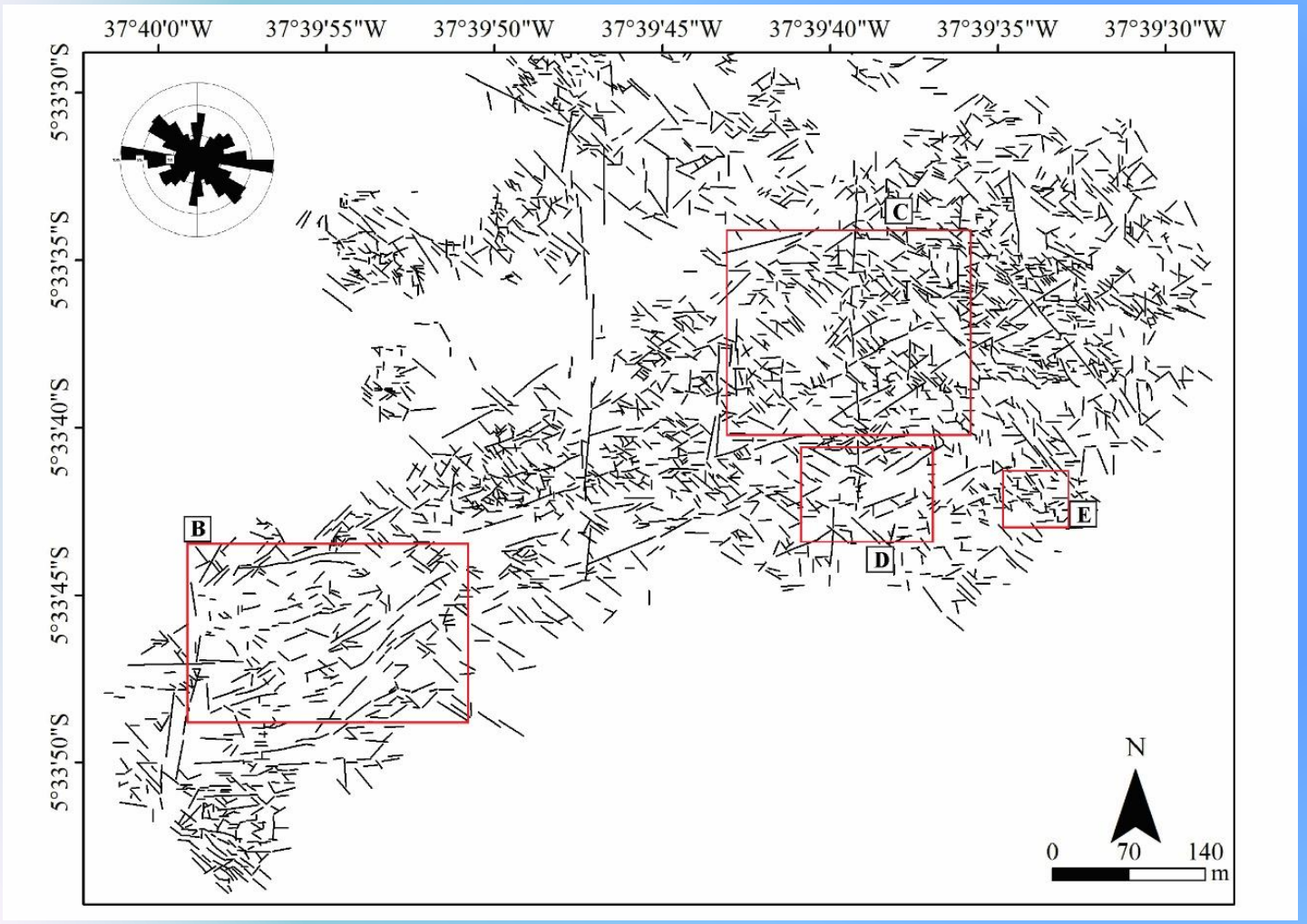
- Final das fraturas
- intersecção de fraturas
- *Relay ramps*

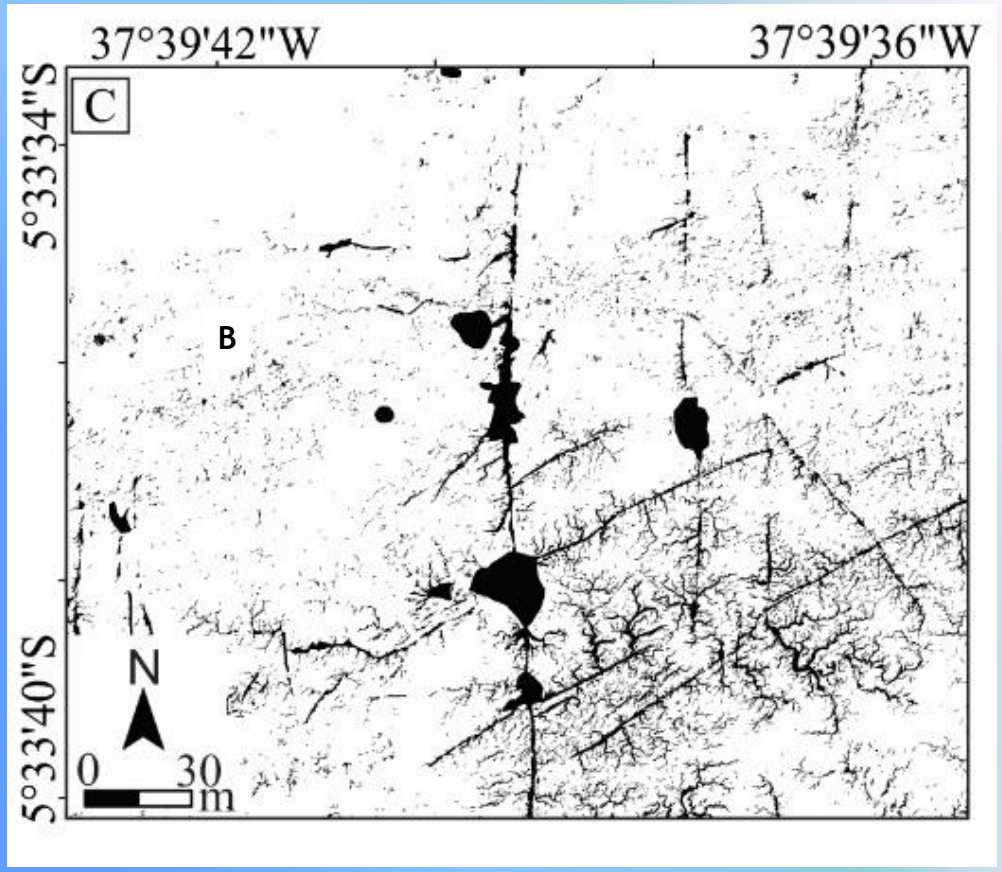


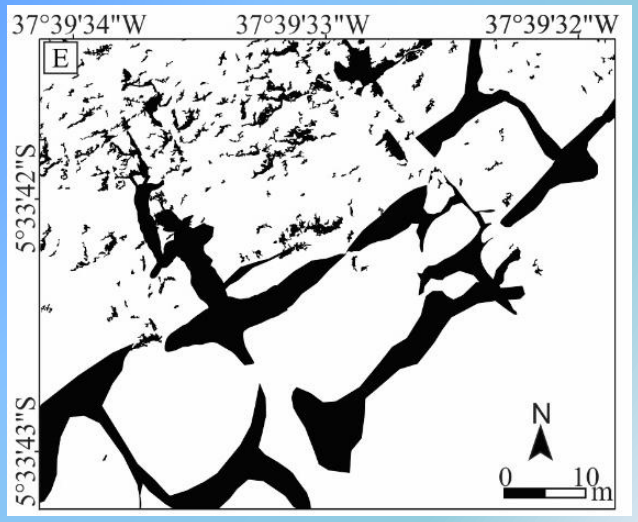
Rabelo *et al.* *Geol. USP*, 2015

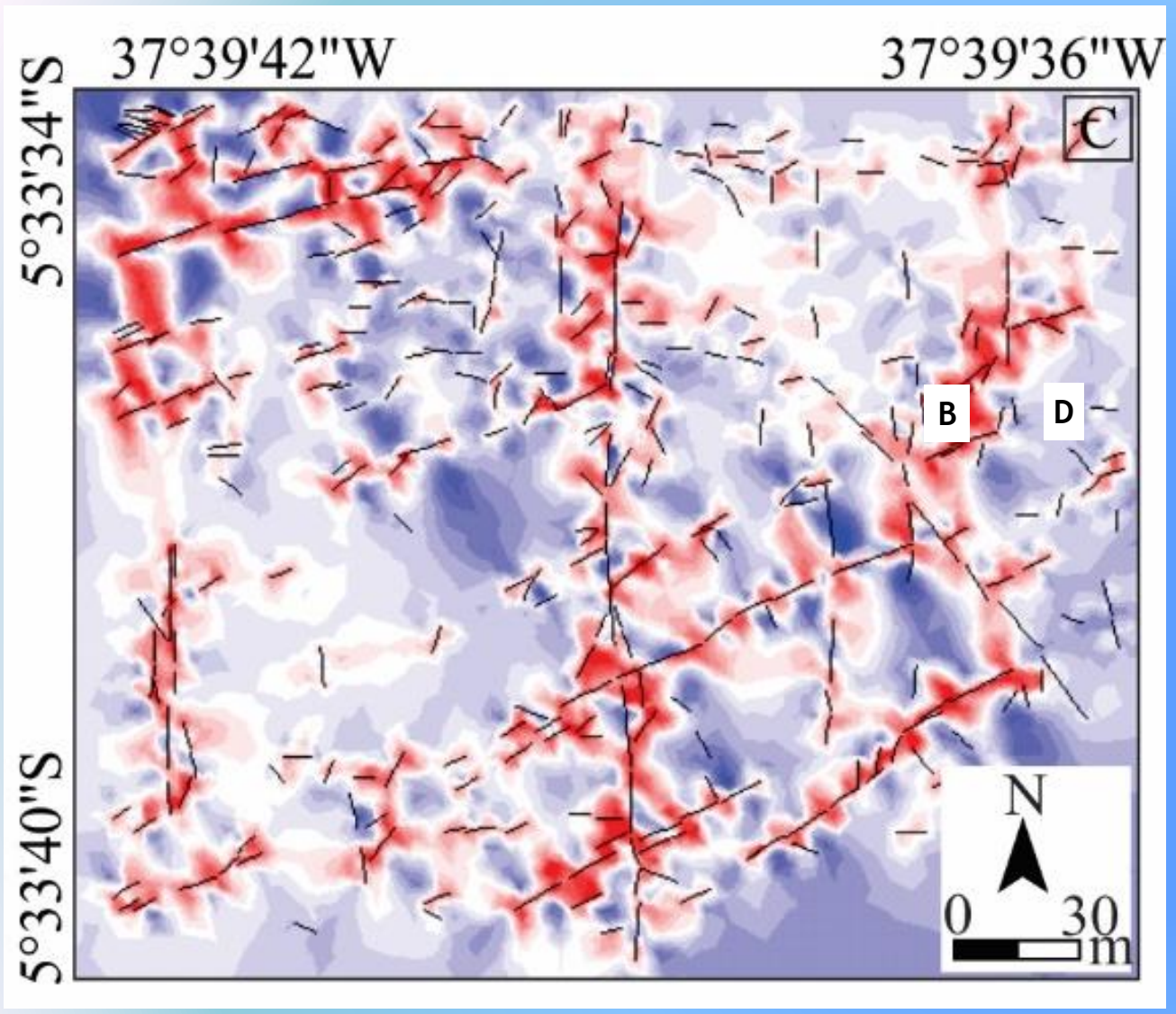

37°40'0"W
37°39'55"W
37°39'50"W
37°39'45"W
37°39'40"W
37°39'35"W
37°39'30"W
5°33'30"S
5°33'35"S
5°33'40"S
5°33'45"S
5°33'50"S
A
B
C
D
N
0
70
140
m

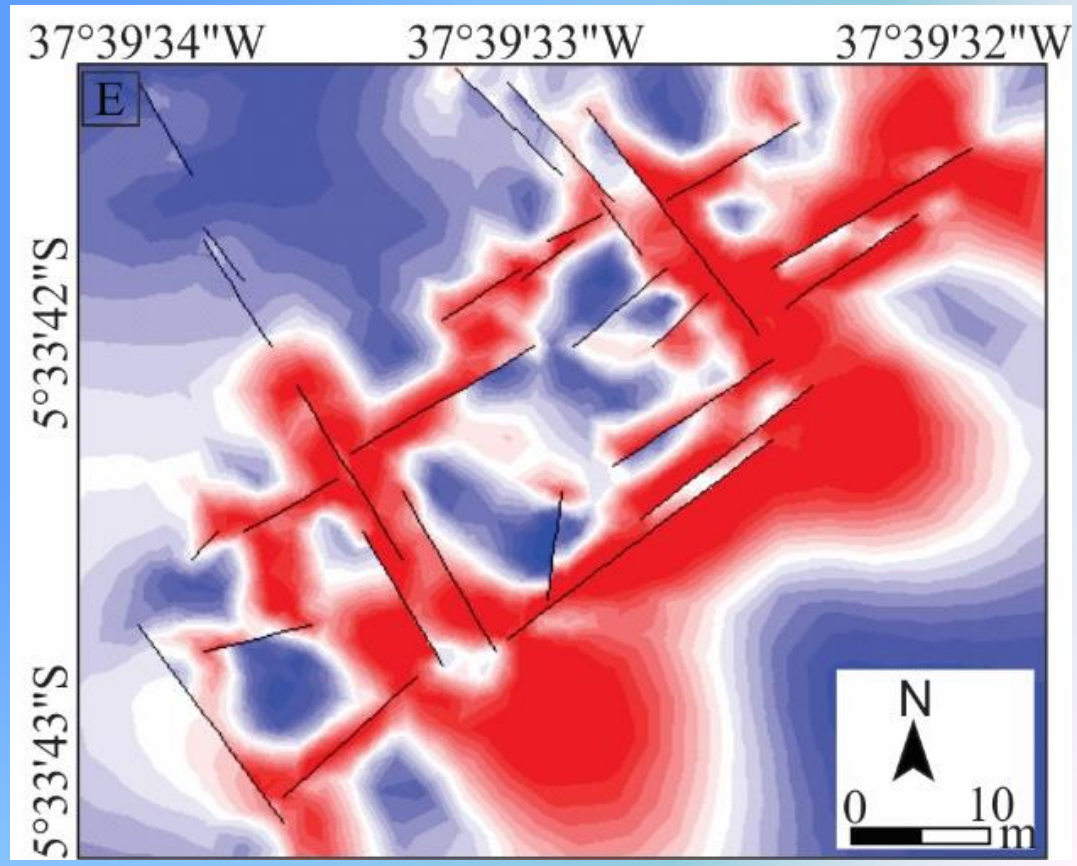
Mapeamento das fraturas e carste epigênico associado





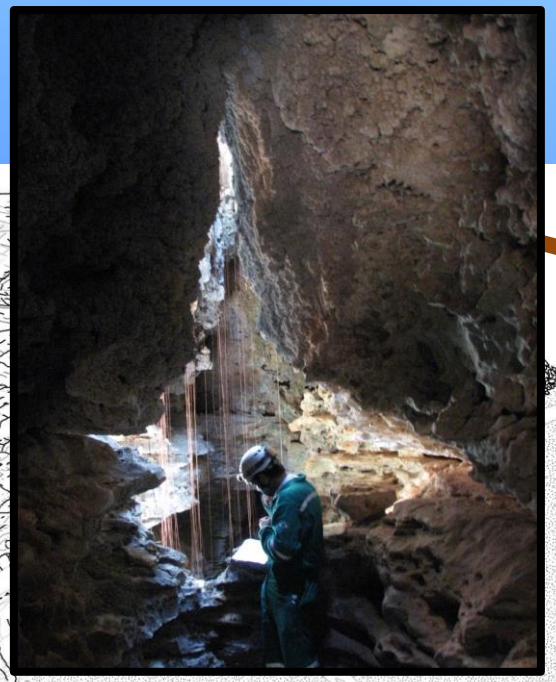



37°39'42"W
37°39'36"W
5°33'34"S
5°33'40"S
C
B
D
N
0
30
m


37°39'34"W
37°39'33"W
37°39'32"W
5°33'42"S
5°33'43"S
E
N
0
10
m

Inversão de relevo – Vale cárstico do Rio Apodi

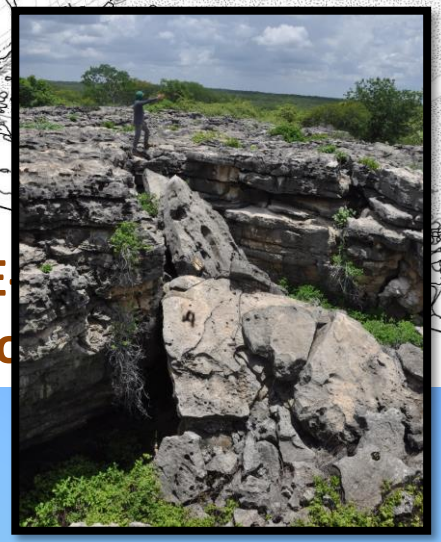


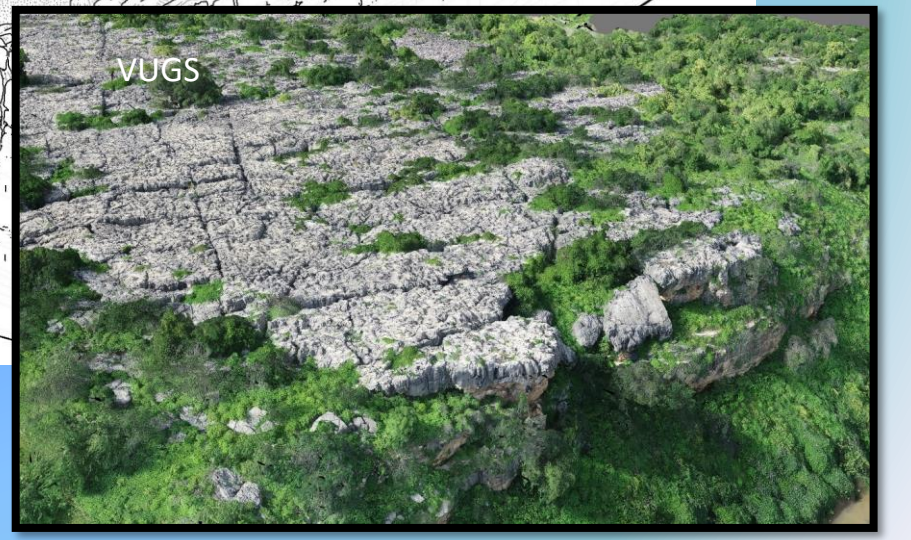




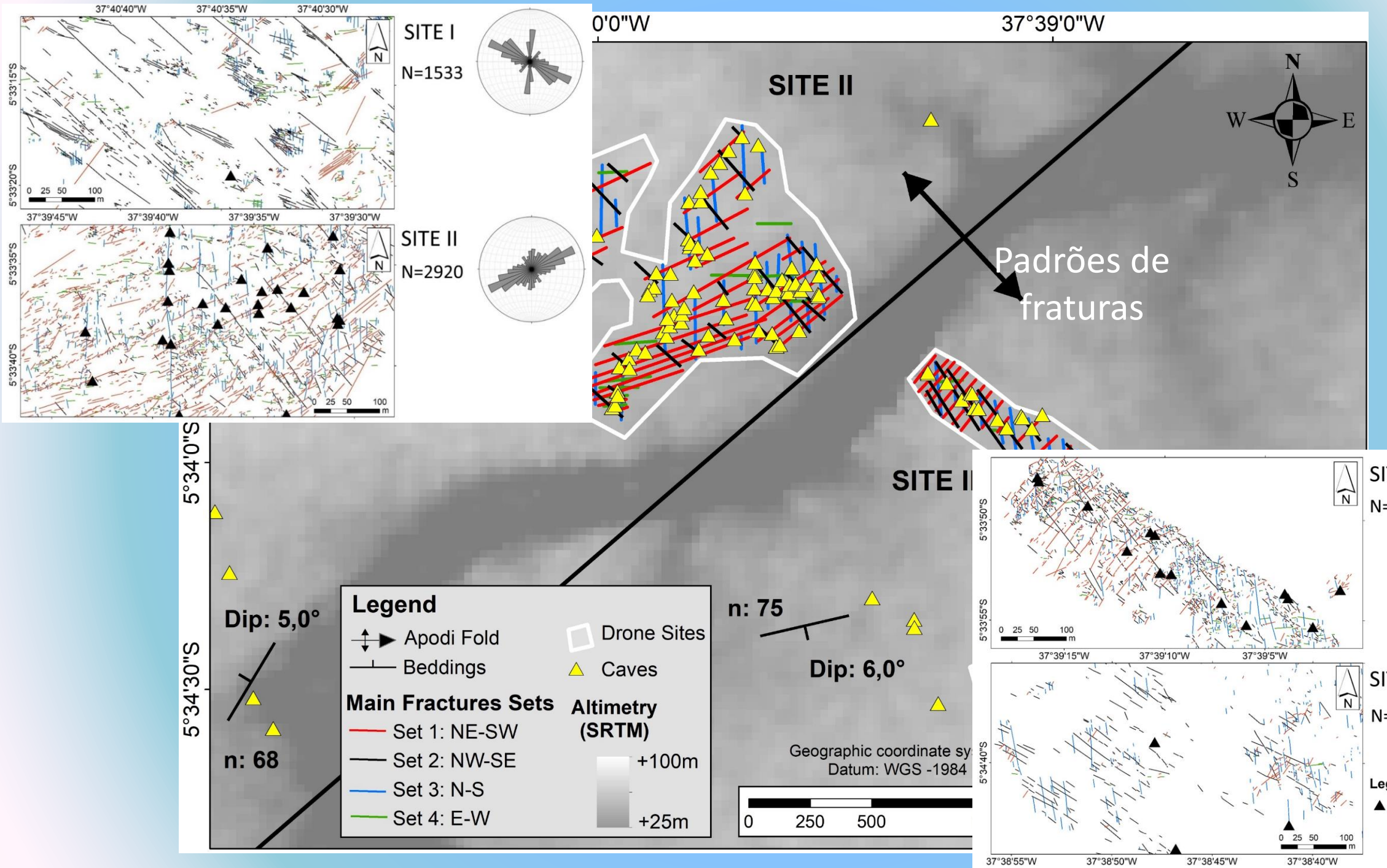


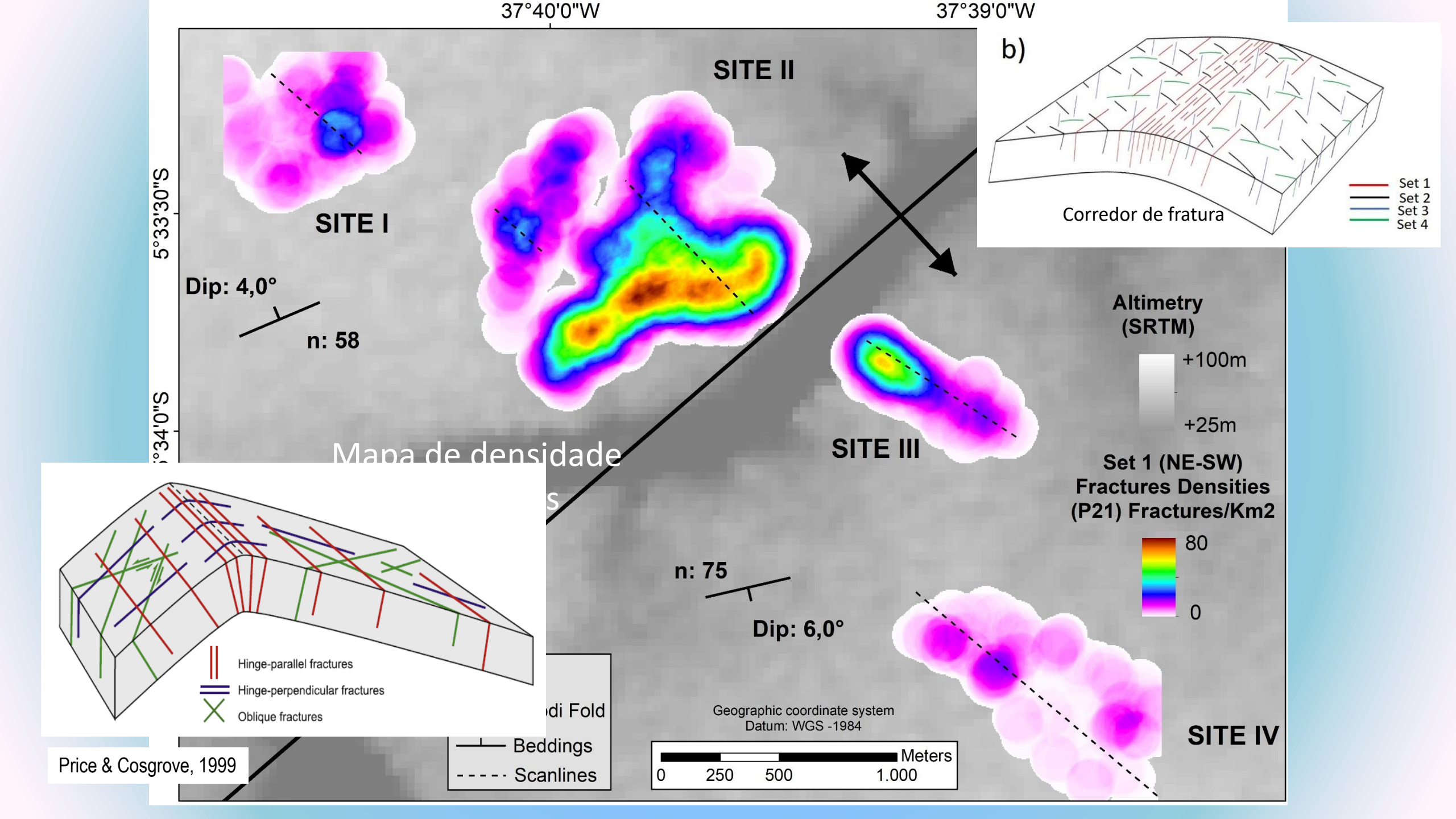




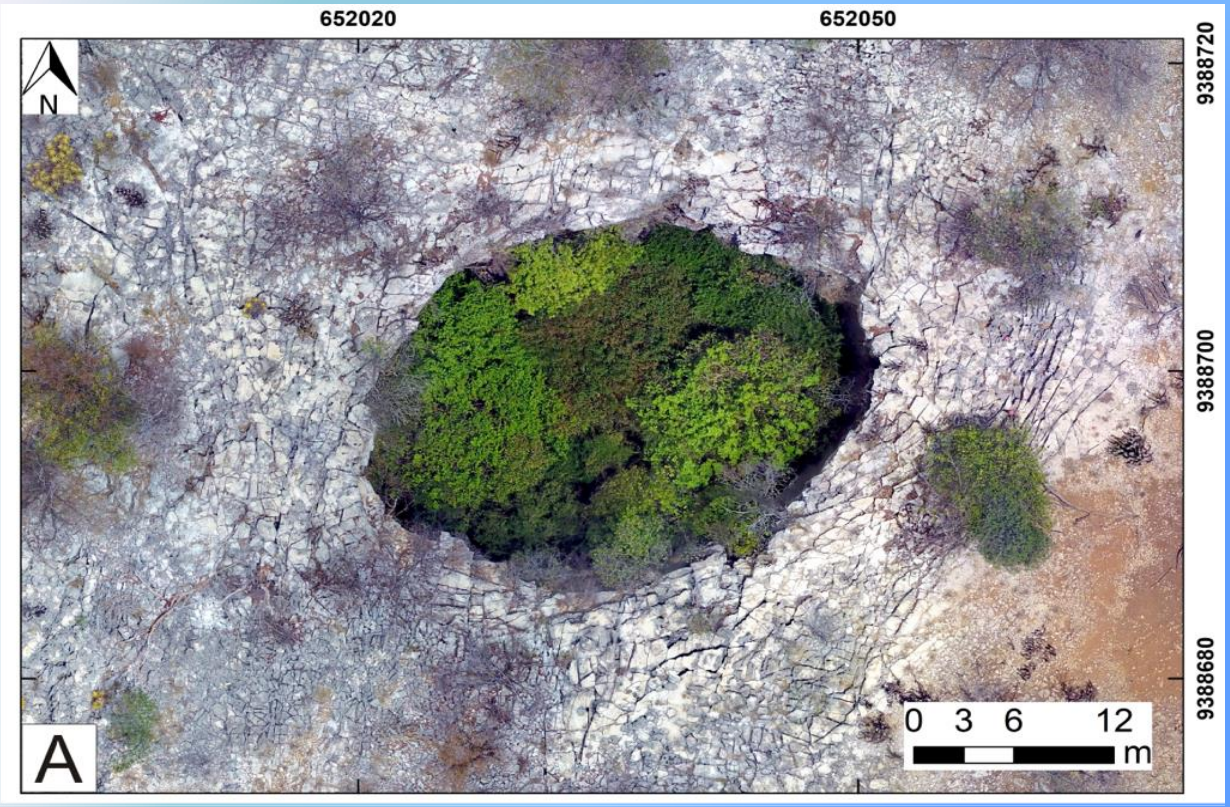


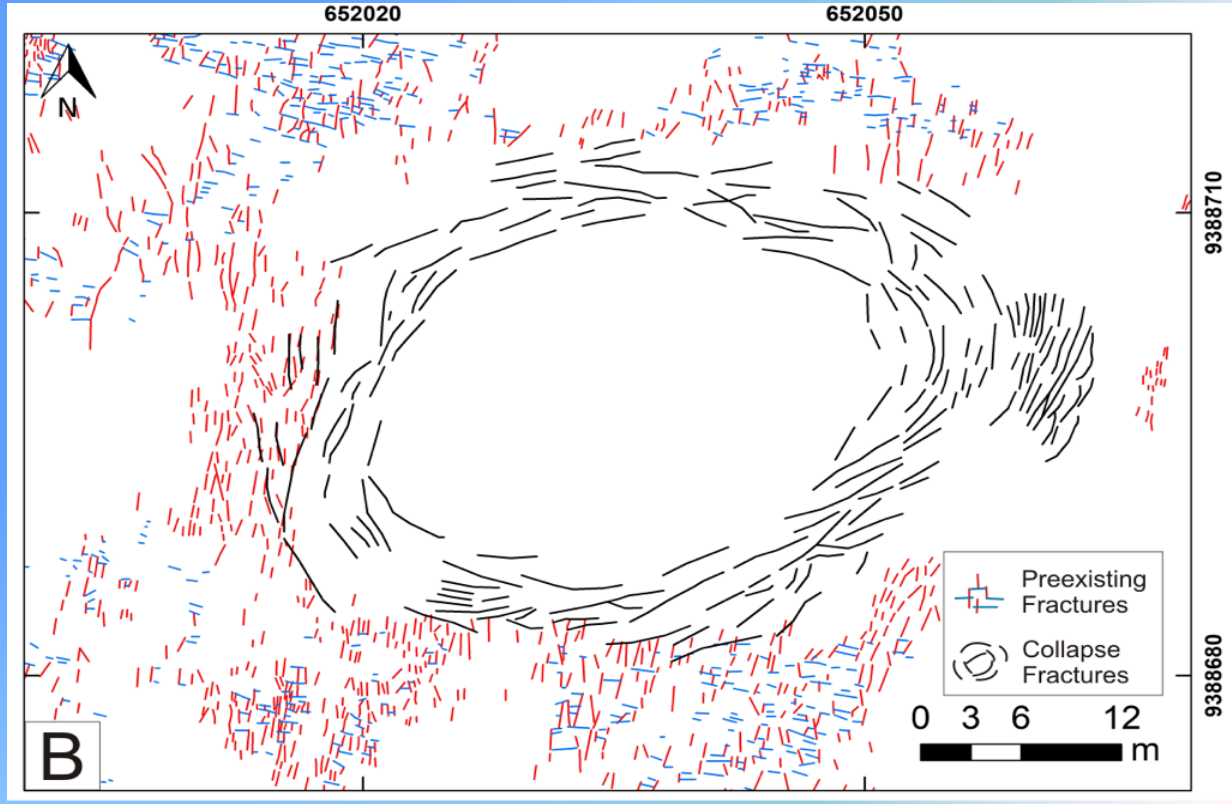
Bagni *et al.*
M&P Geology, 2020


SITE I
N=1533
SITE II
N=2920
SITE II
Padrões de fraturas
SITE III
N=2045
SITE IV
N=611
Dip: 5,0°
n: 68
n: 75
Dip: 6,0°
Legend
Apodi Fold
Beddings
Drone Sites
Caves
Main Fractures Sets
Set 1: NE-SW
Set 2: NW-SE
Set 3: N-S
Set 4: E-W
Altimetry (SRTM)
+100m
+25m
Geographic coordinate sy
Datum: WGS -1984
0 250 500
Legend
Caves
Fractures Sets
Set 1: NE-SW
Set 2: NW-SE
Set 3: N-S
Set 4: E-W


37°40'0"W
37°39'0"W
5°33'30"S
SITE I
SITE II
SITE III
SITE IV
Dip: 4,0°
n: 58
n: 75
Dip: 6,0°
Mapa de densidade
b)
Corredor de fratura
Set 1
Set 2
Set 3
Set 4
Altimetry
(SRTM)
+100m
+25m
Set 1 (NE-SW)
Fractures Densities
(P21) Fractures/Km2
80
0
Hinge-parallel fractures
Hinge-perpendicular fractures
Oblique fractures
Price & Cosgrove, 1999
Beddings
Scanlines
Geographic coordinate system
Datum: WGS -1984
Meters
0
250
500
1.000

Fraturas de Colapso

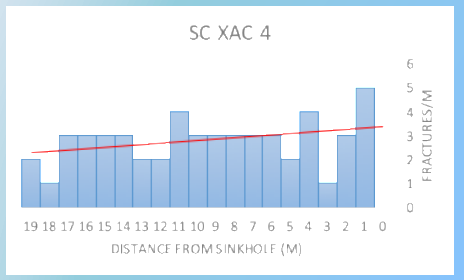


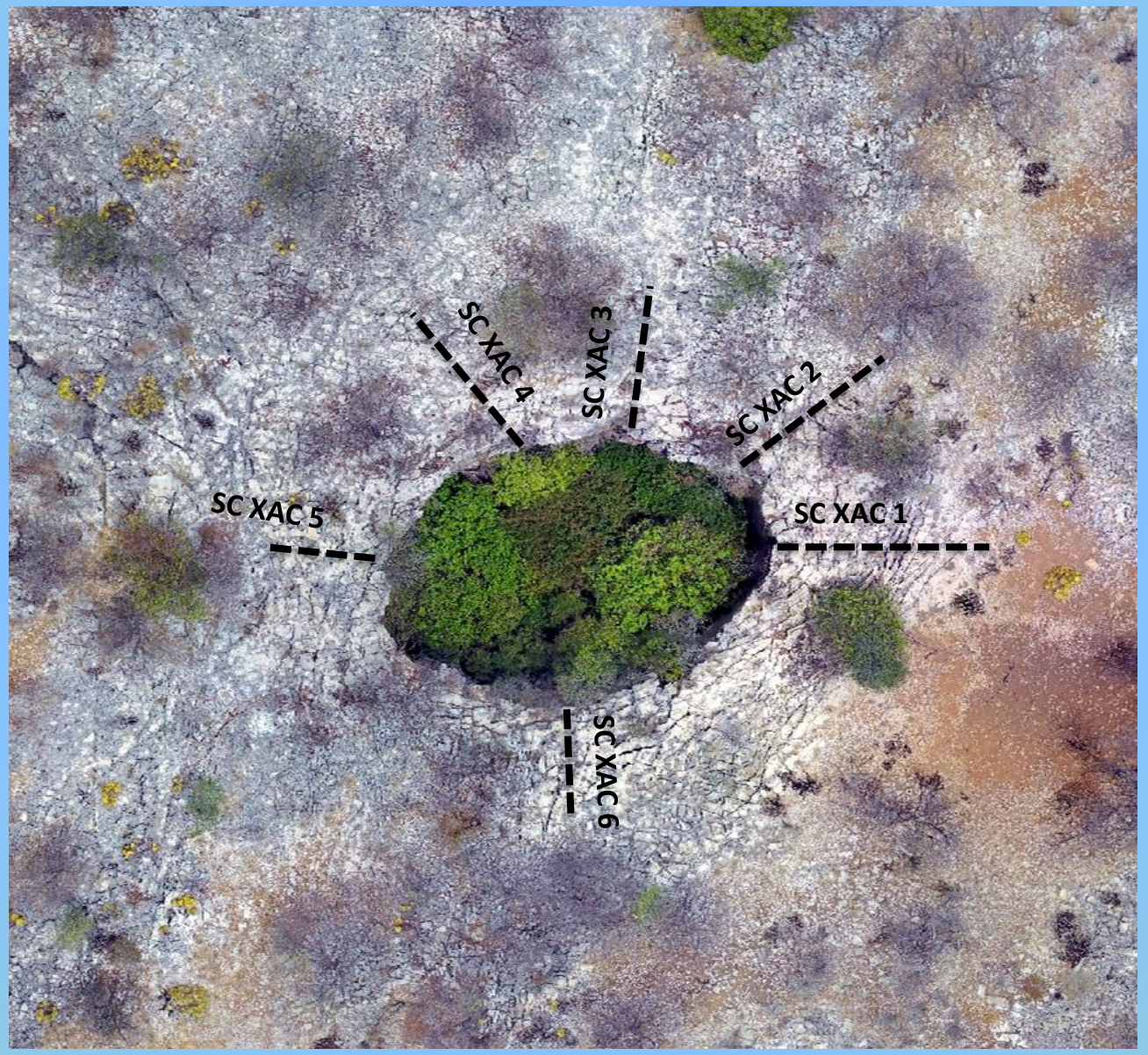


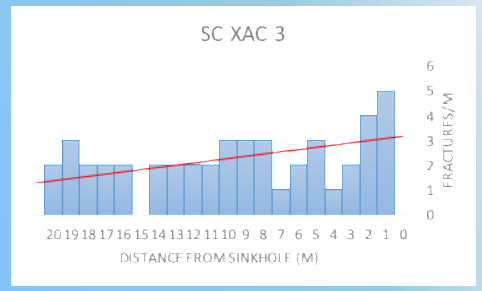
- Fraturamentos secundários gerados pelos colapsos
- Formas curvilíneas
- Aproveitam sistemas de fraturas preexistentes

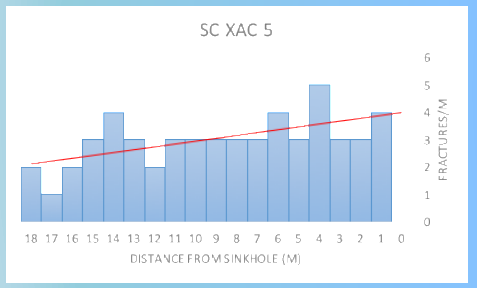
Menezes *et al.*
***M&P Geology*, 2019**

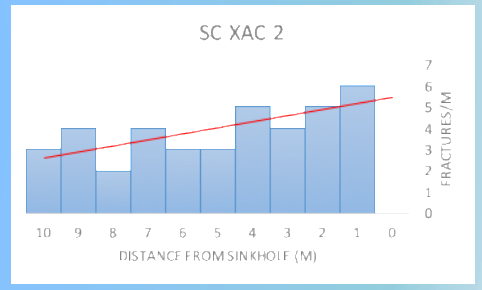
O fraturamento diminui sistematicamente com a distância da dolina.
Esta relação está sendo parametrizada.

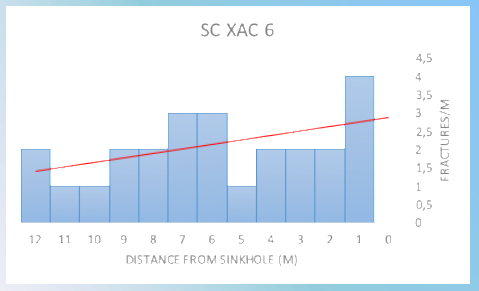


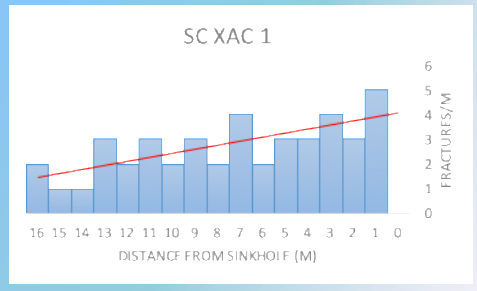




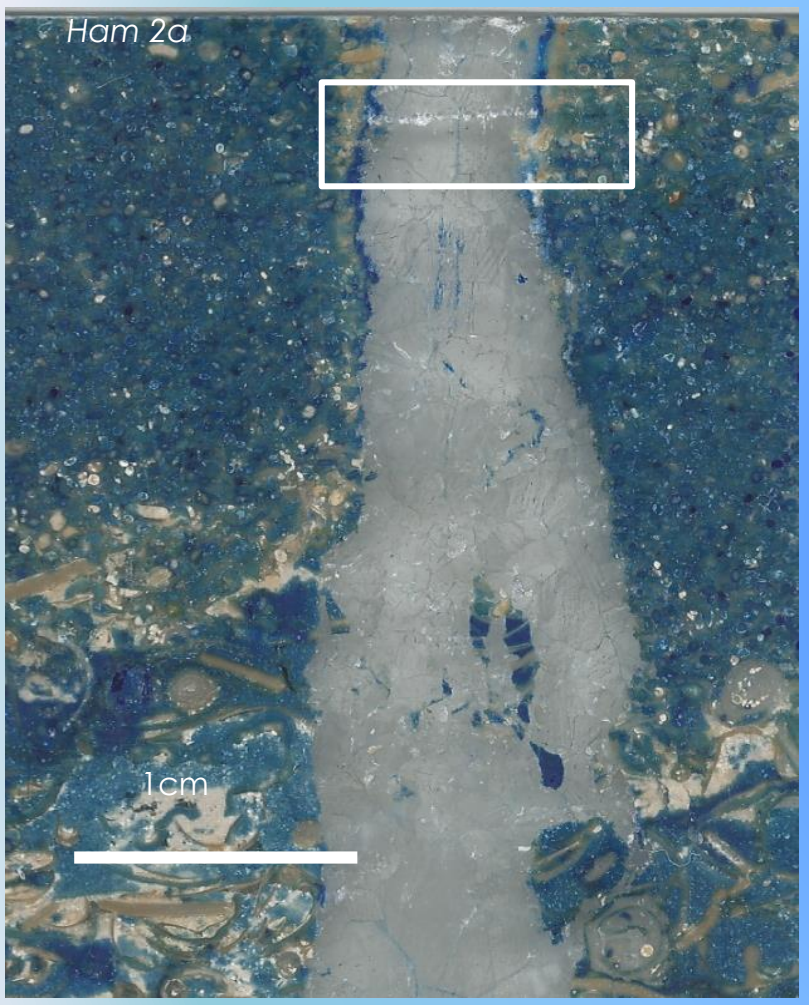


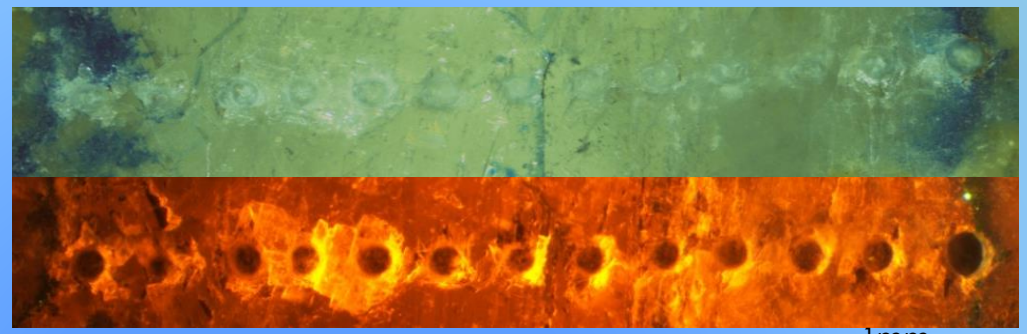


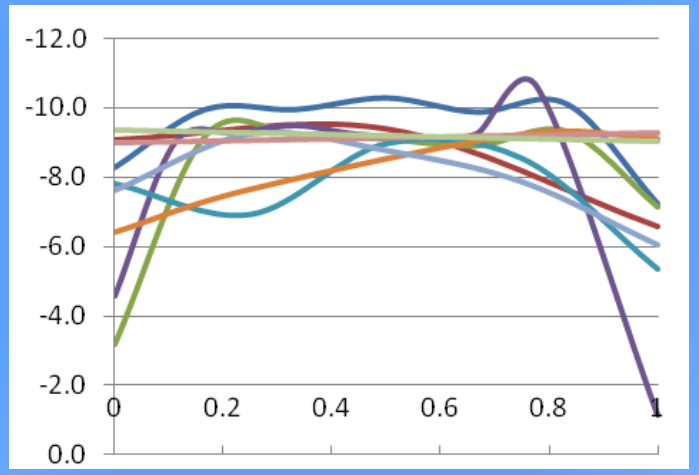


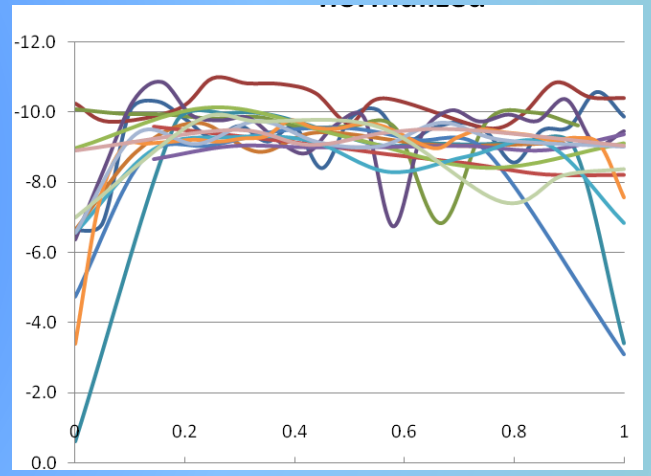


Análises isotópicas e inclusões fluidas em veios preenchidos.







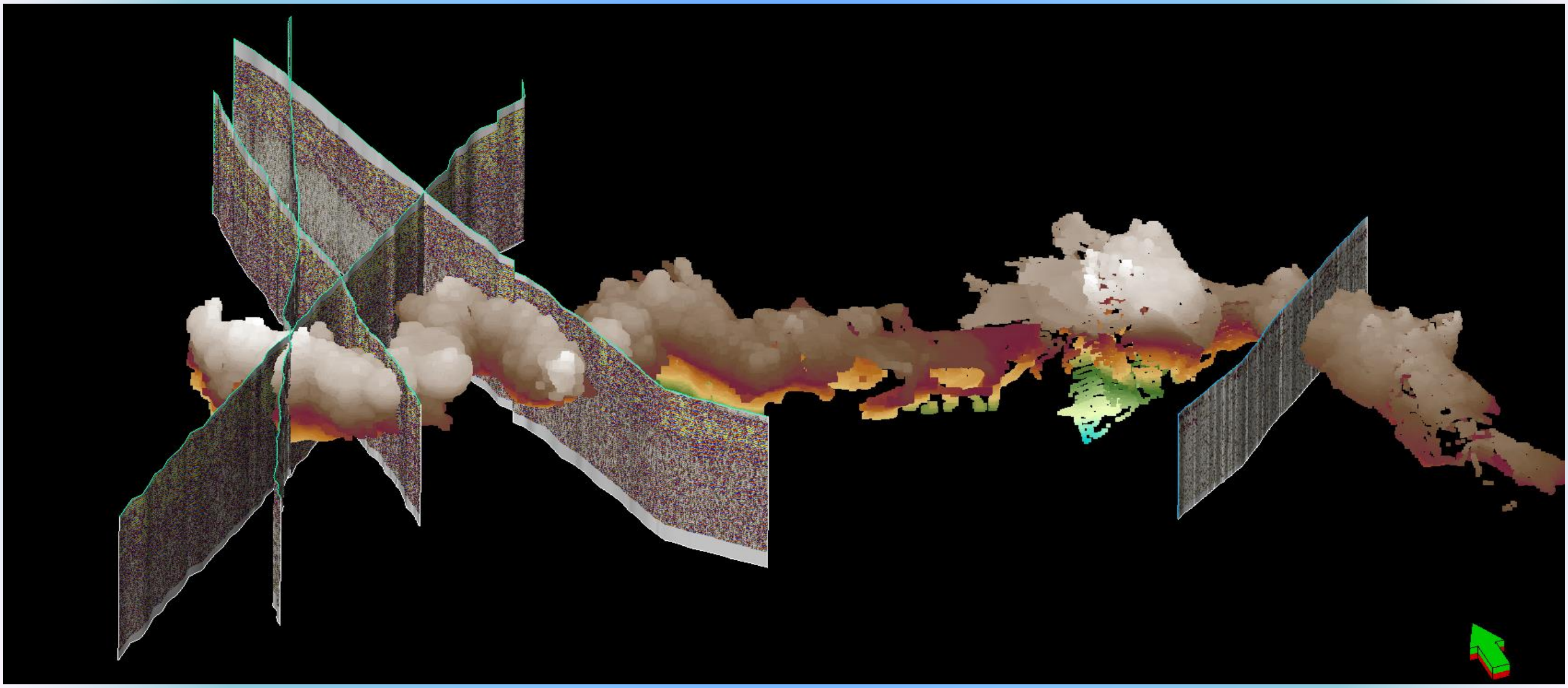


$\delta^{18}O$ matching and non-matching veins veins

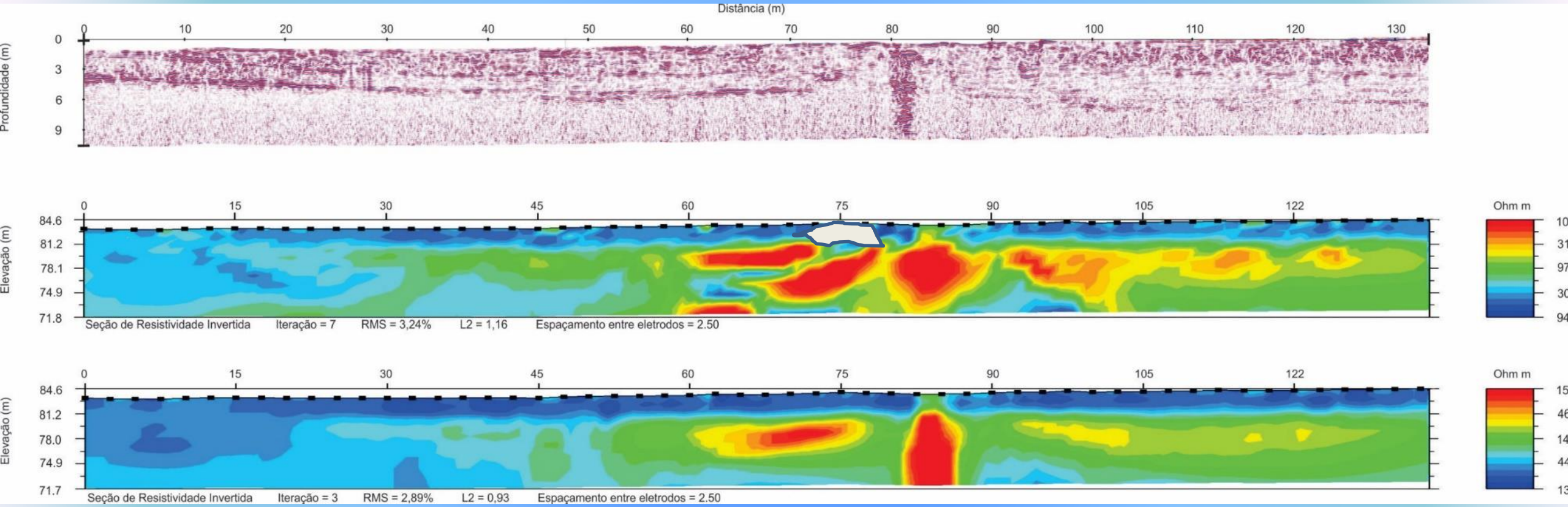
- Os cimentos analisados são originados do mesmo fluido (stable $\delta^{18}O$)
- Os fluidos são, provavelmente, salinos (positive $\delta^{13}C$)
- Os dados isotópicos (-10‰) e de inclusões fluidas (-1.4‰) sugerem T~50-60°

LASER SCANNER (LIDAR) – FURNA FEIA (RN)

INTEGRAÇÃO DE DADOS/GERAÇÃO DE MODELOS VIRTUAIS 3D



Linha 02 Furna Feia - Comparação ERT e GPR



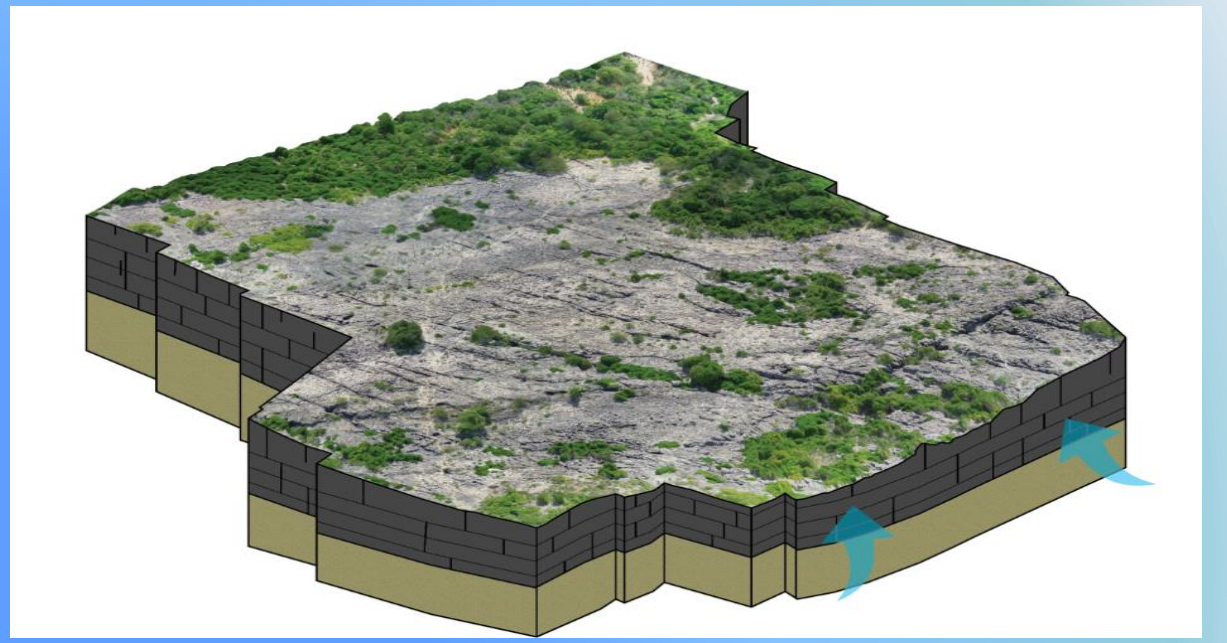
Fraturas, preenchimento de veios e processos cársticos são eventos regionais

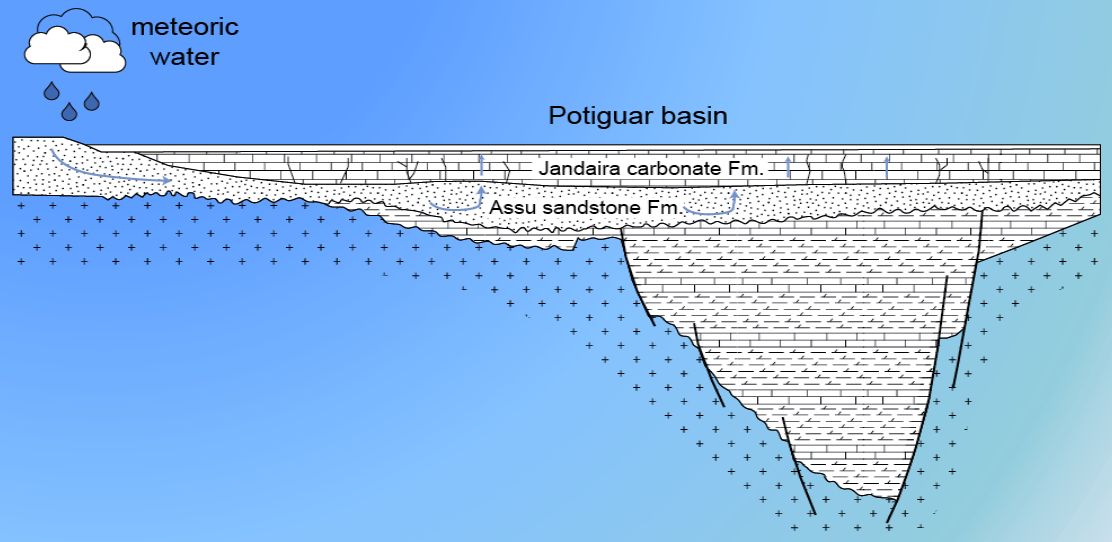
1. Forte relação entre fraturas e a circulação de fluidos.

2. A dissolução (carste e cavernas) ocorre, principalmente, ao longo de fraturas.

3. É um sistema complexo, heterogeneidades de escala e distribuição.

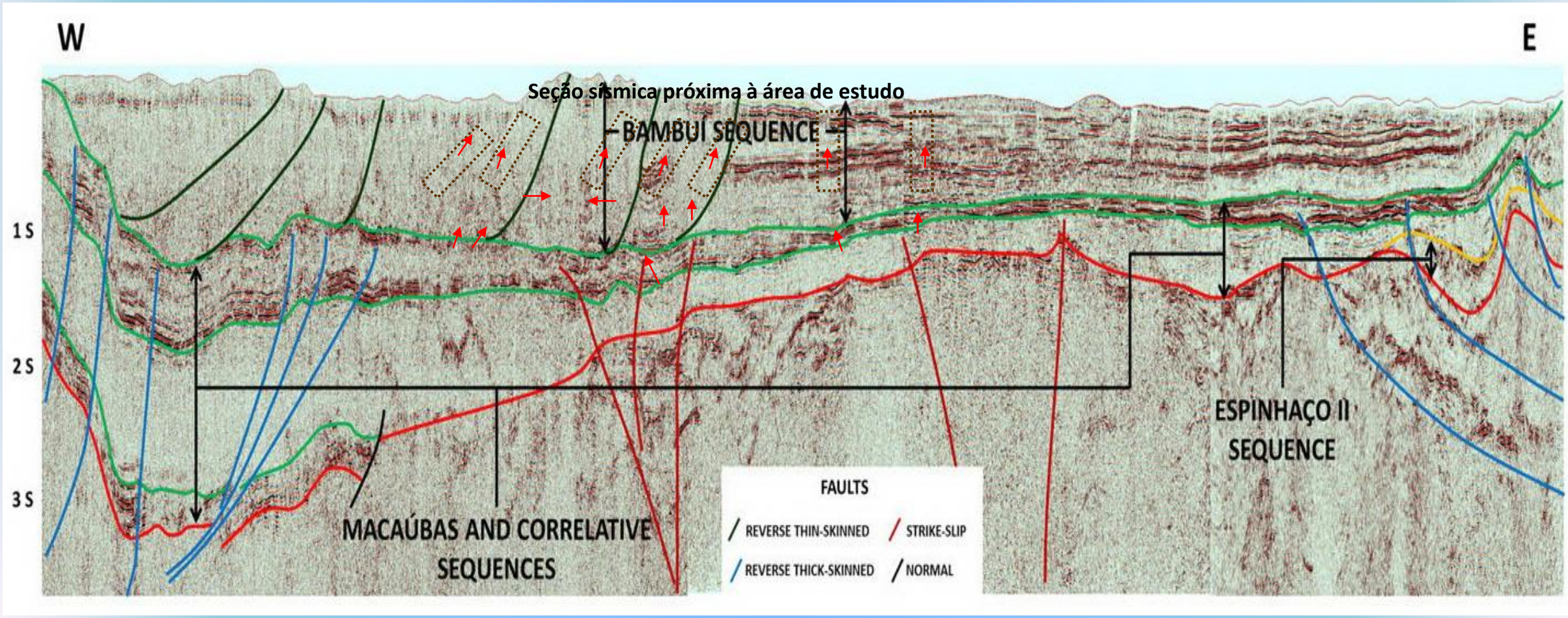
4. Alta densidade de fraturas tem forte impacto no fluxo dos fluidos, mesmo para aberturas de pequena escala.



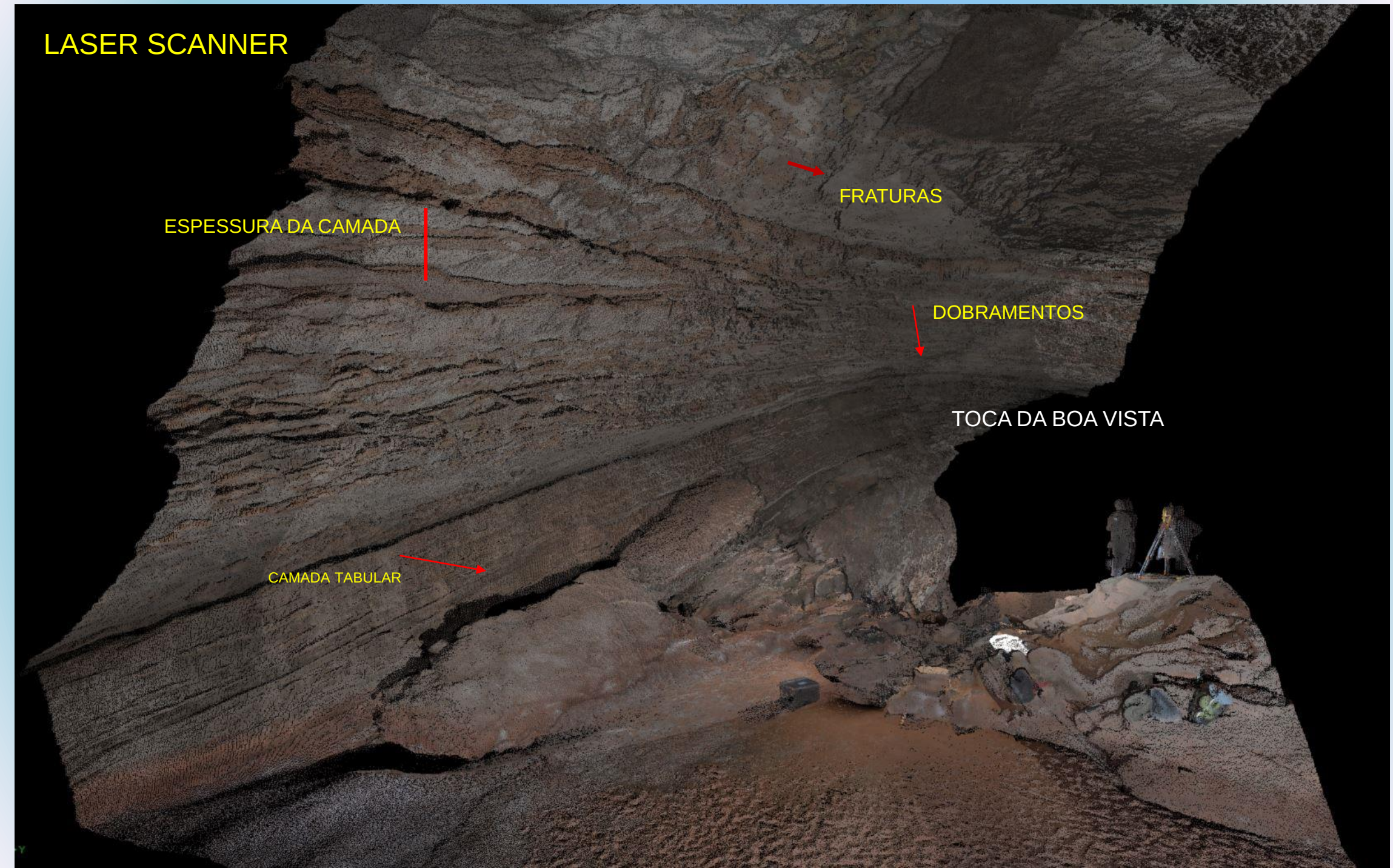


Análogo hipogênico:

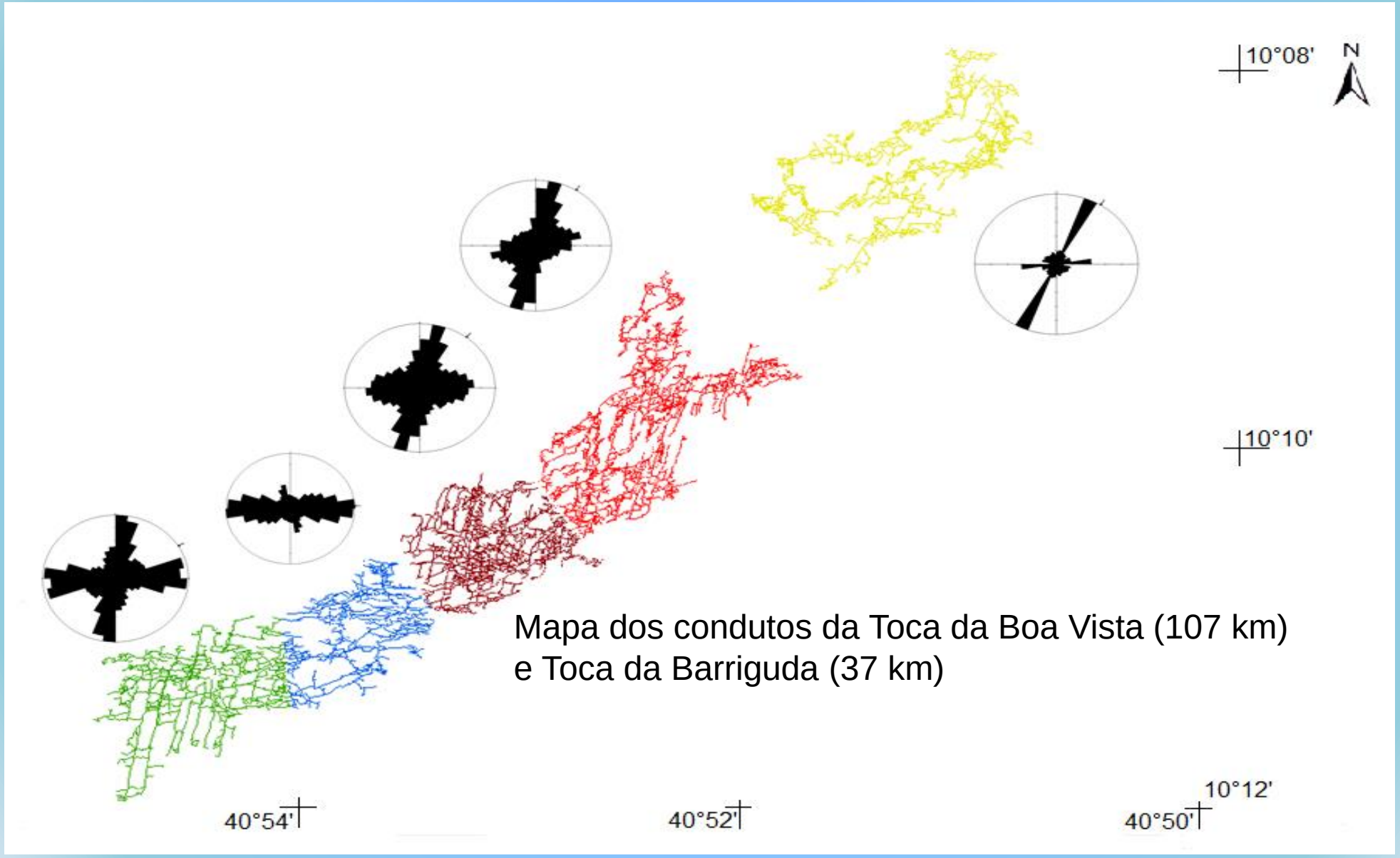
O sistema de falhas e fraturas nas cavernas podem ser correlacionados à sistemas regionais; o sistema conduto-barreira na escala da caverna pode ser correlacionado regionalmente na bacia.





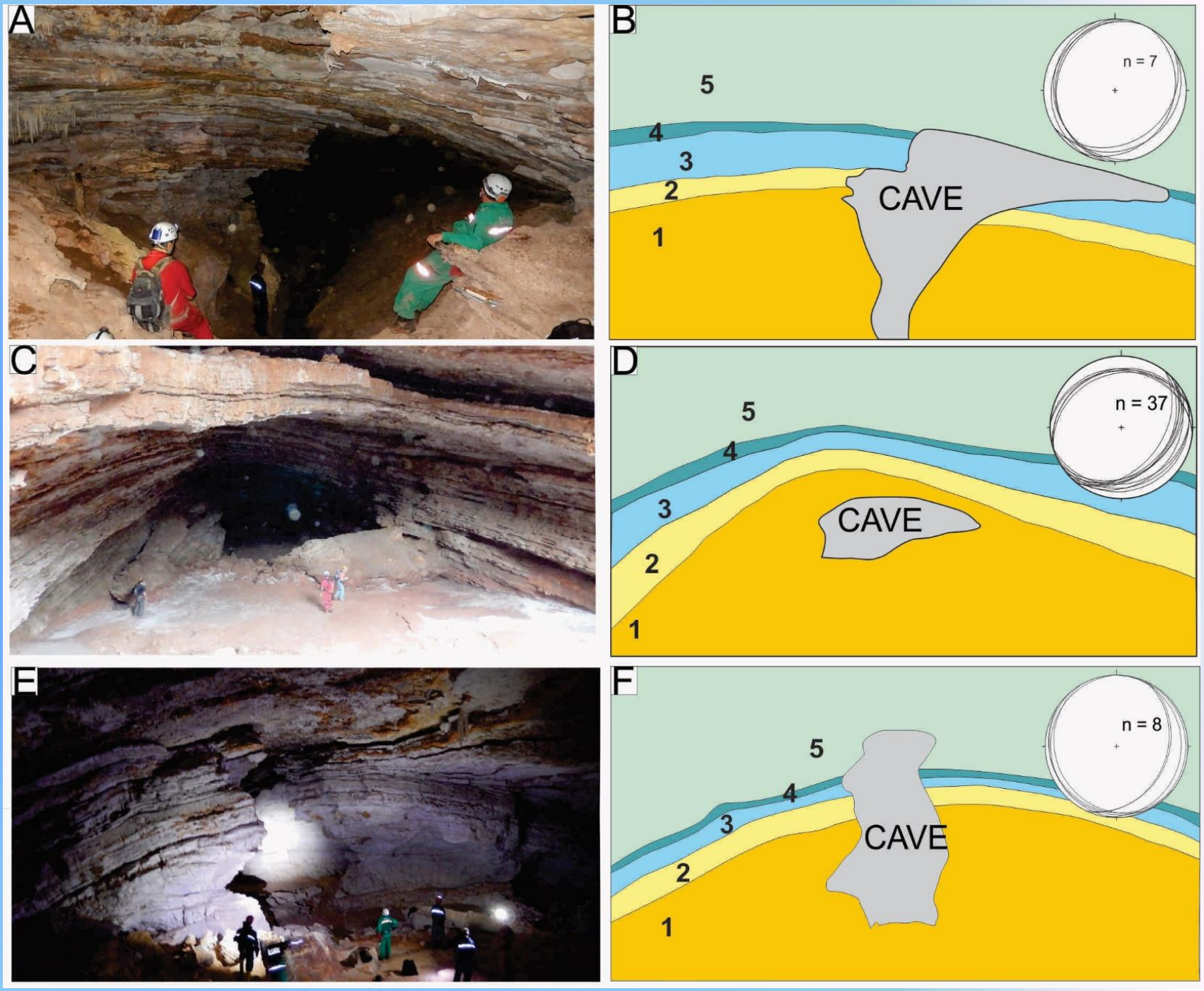

LASER SCANNER
FRATURAS
ESPESSURA DA CAMADA
DOBRAMENTOS
TOCA DA BOA VISTA
CAMADA TABULAR

Distribuição/organização e os controles estruturais e estratigráficos do sistema de cavernas TBV-TBR

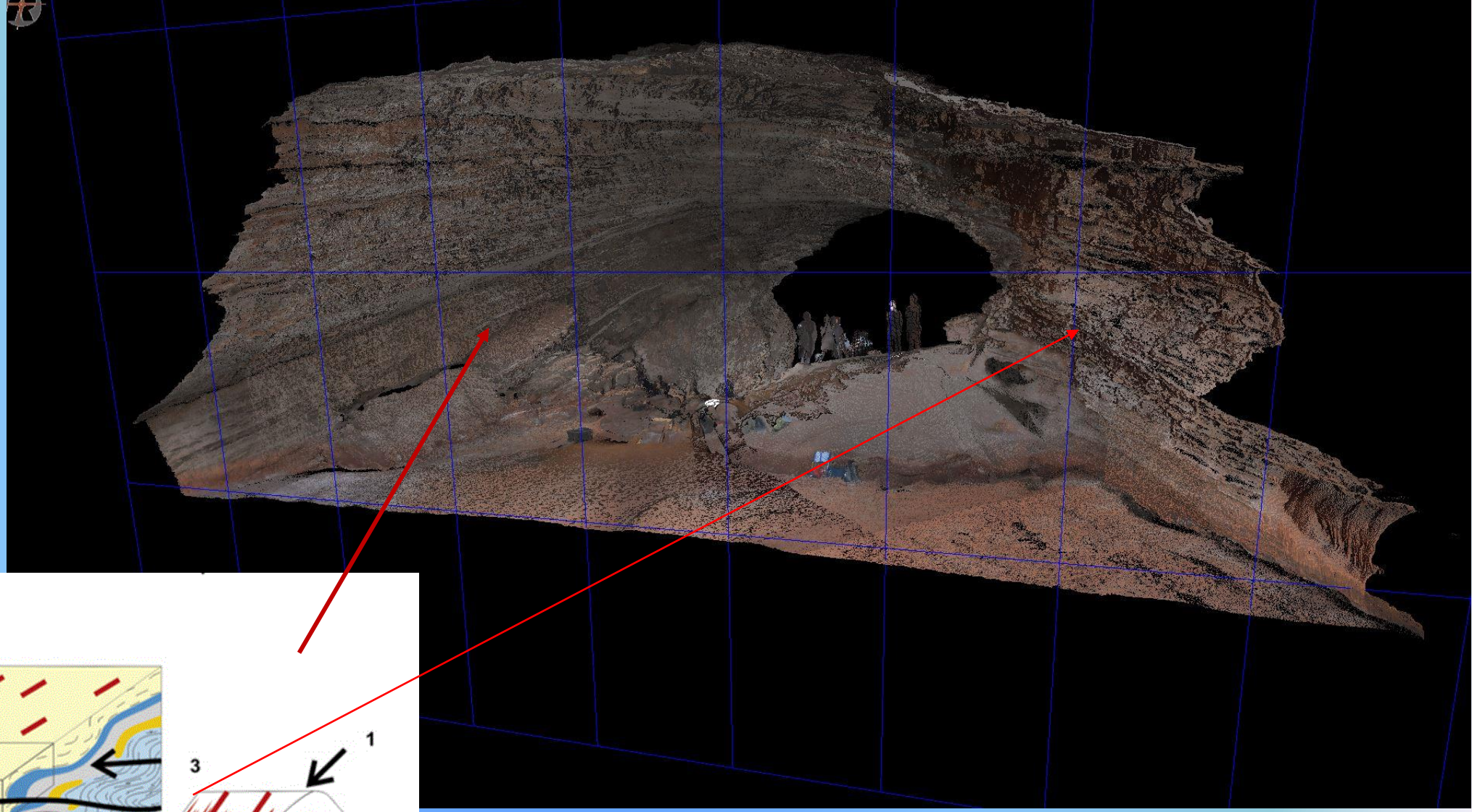


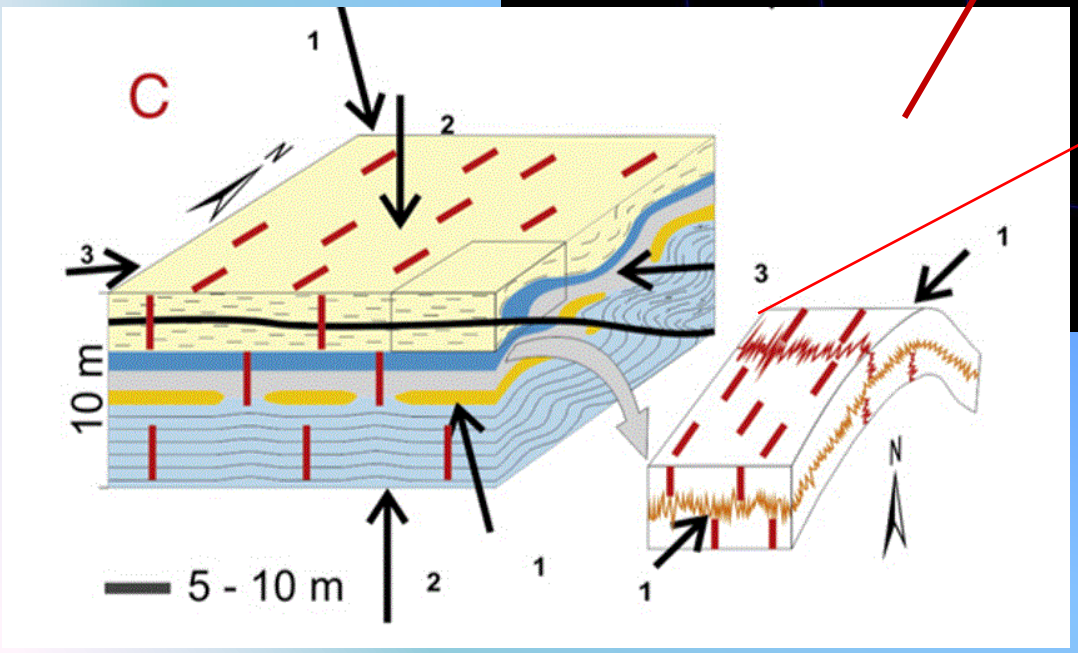
Mapa dos condutos da Toca da Boa Vista (107 km)
e Toca da Barriguda (37 km)

Os condutos das cavernas se desenvolvem lateralmente ao longo de charneiras de dobras



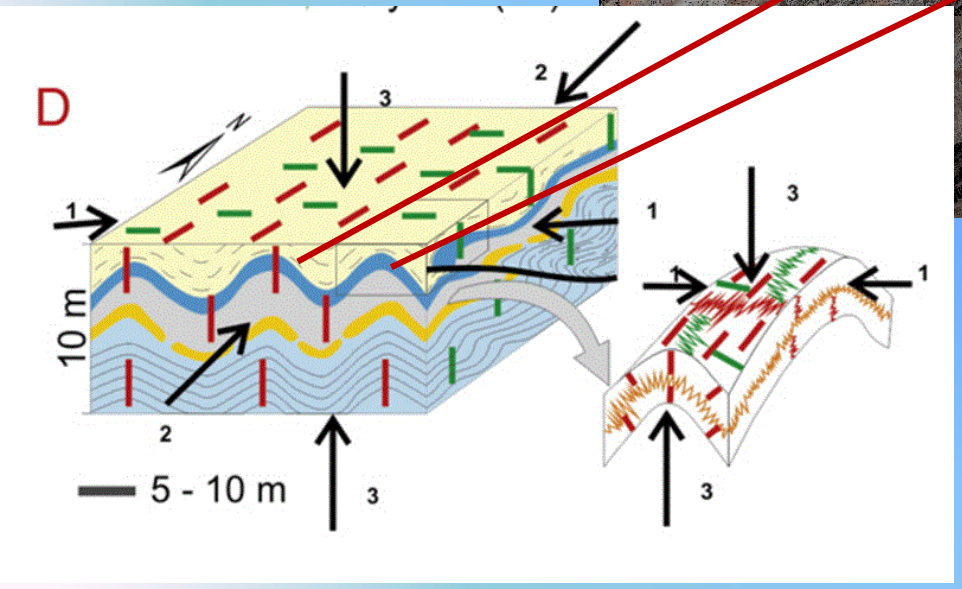
Ennes-Silva *et al.*
Tectonophysics, 2016



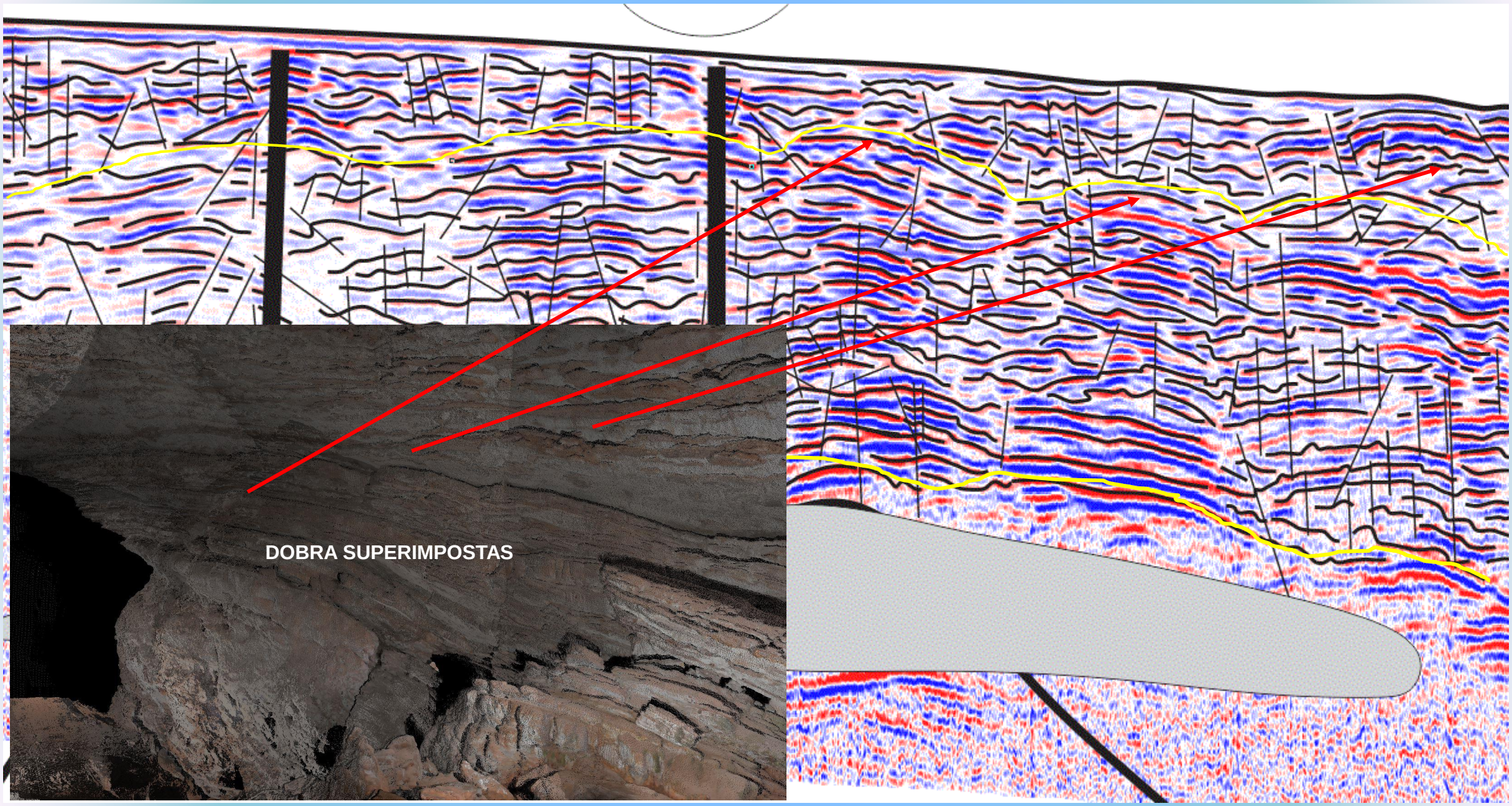


Ennes-Silva *et al.*
Tectonophysics, 2016

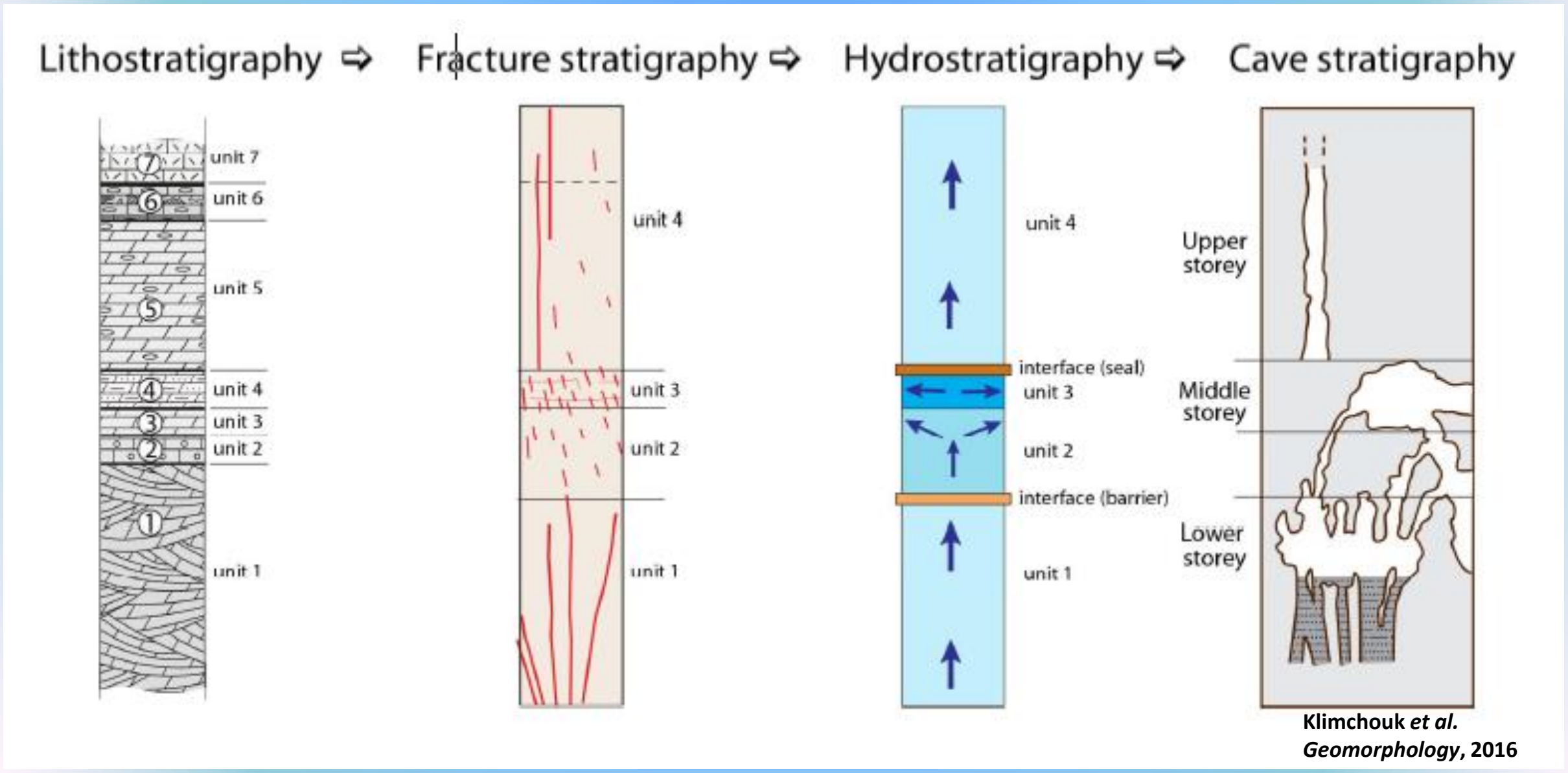




Ennes-Silva *et al.*
Tectonophysics, 2016

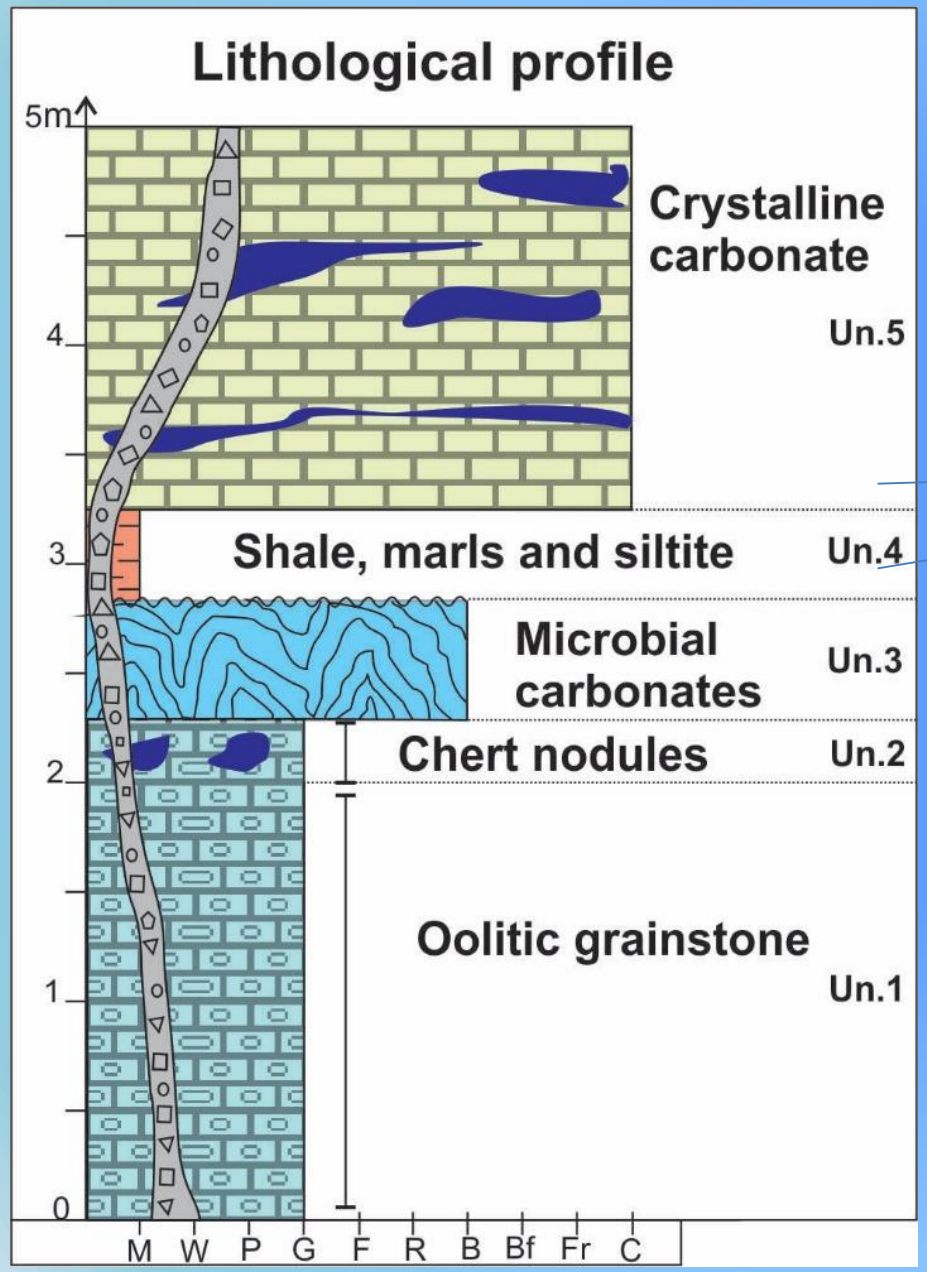

DOBRA SUPERIMPOSTAS

Estratigrafia da caverna: a subdivisão do sistema de condutos em andares é baseada na posição vertical dos componentes em relação às unidades estratigráficas



Klimchouk *et al.* *Geomorphology*, 2016

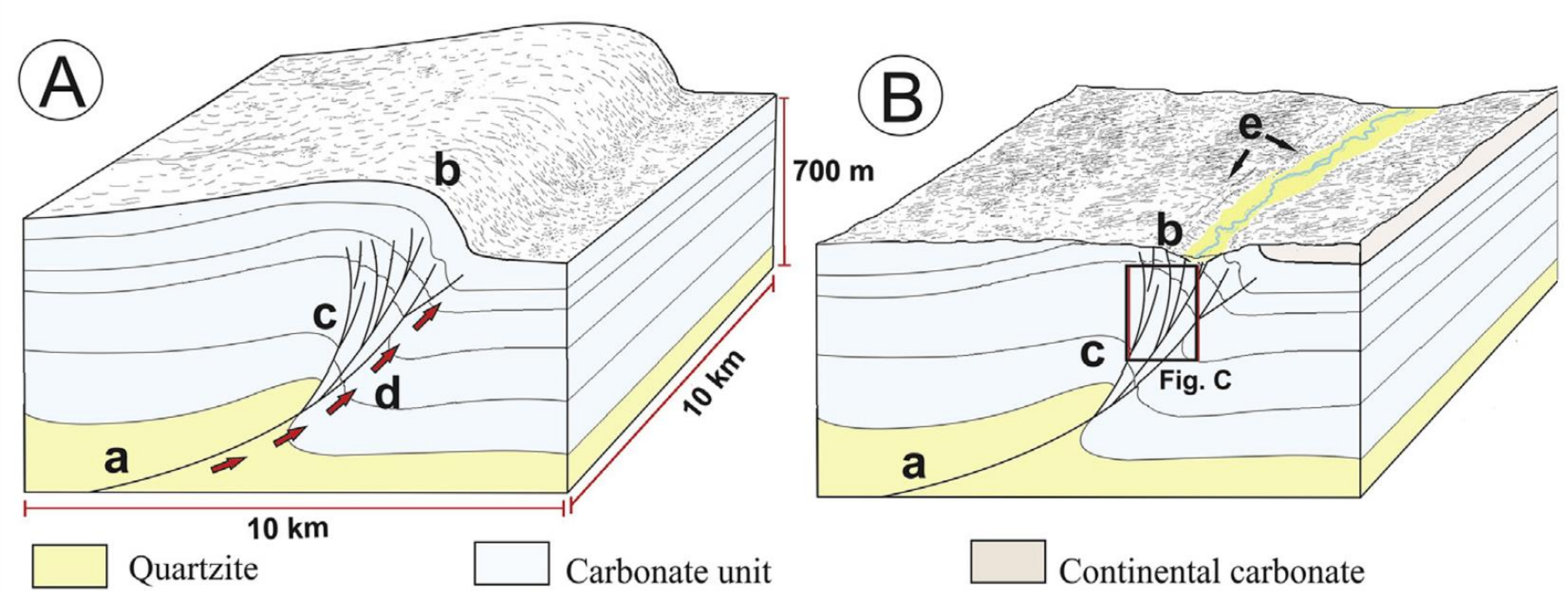
Sistema conduto-barreira





Cazarin *et al.*
M&P Geology, 2019

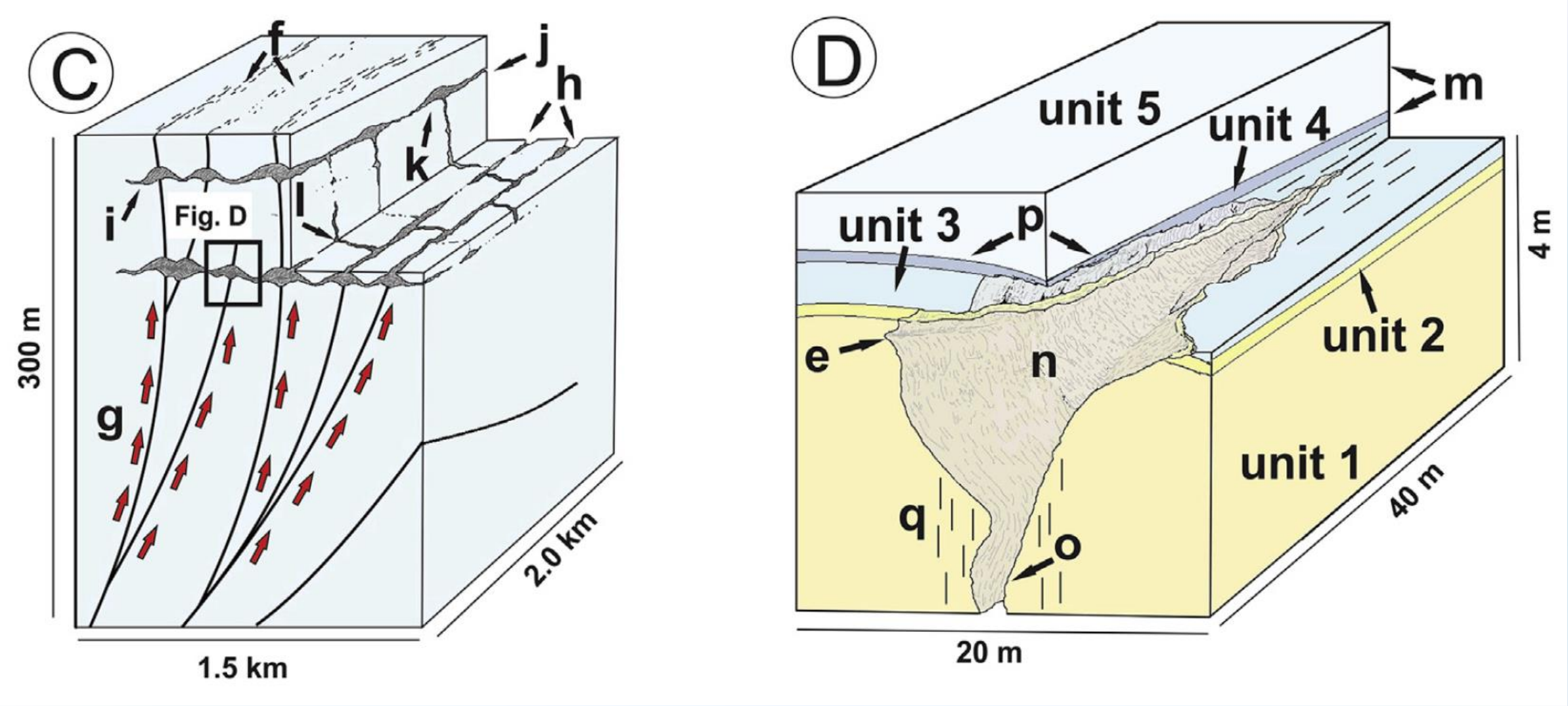
Modelo Conceitual de Formação das Cavernas



Conceptual model of lithostratigraphic and structural setting of the TBV-TBR caves depicts where fluid-rock interaction took place and where karstification concentrated. Letters in circle show components of the hypogene system.
(A) Original thrust system in the TBV-TBR cave area. (B) Present-day setting of the TBV-TBR cave area after a period of subsidence and subsequent erosion. Thrust structure is based on the study from Bizzi et al. (2003). Anticline structure was modified from Ennes-Silva et al. (2016). Key: (A) (B) (a) basal detachment, (b) crest of thrust zone, (c) thrust-related fold, (d) arrows show fluid migration pathways, (e) river incision along fracture corridors.

Cazarin *et al.*
***M&P Geology*, 2019**

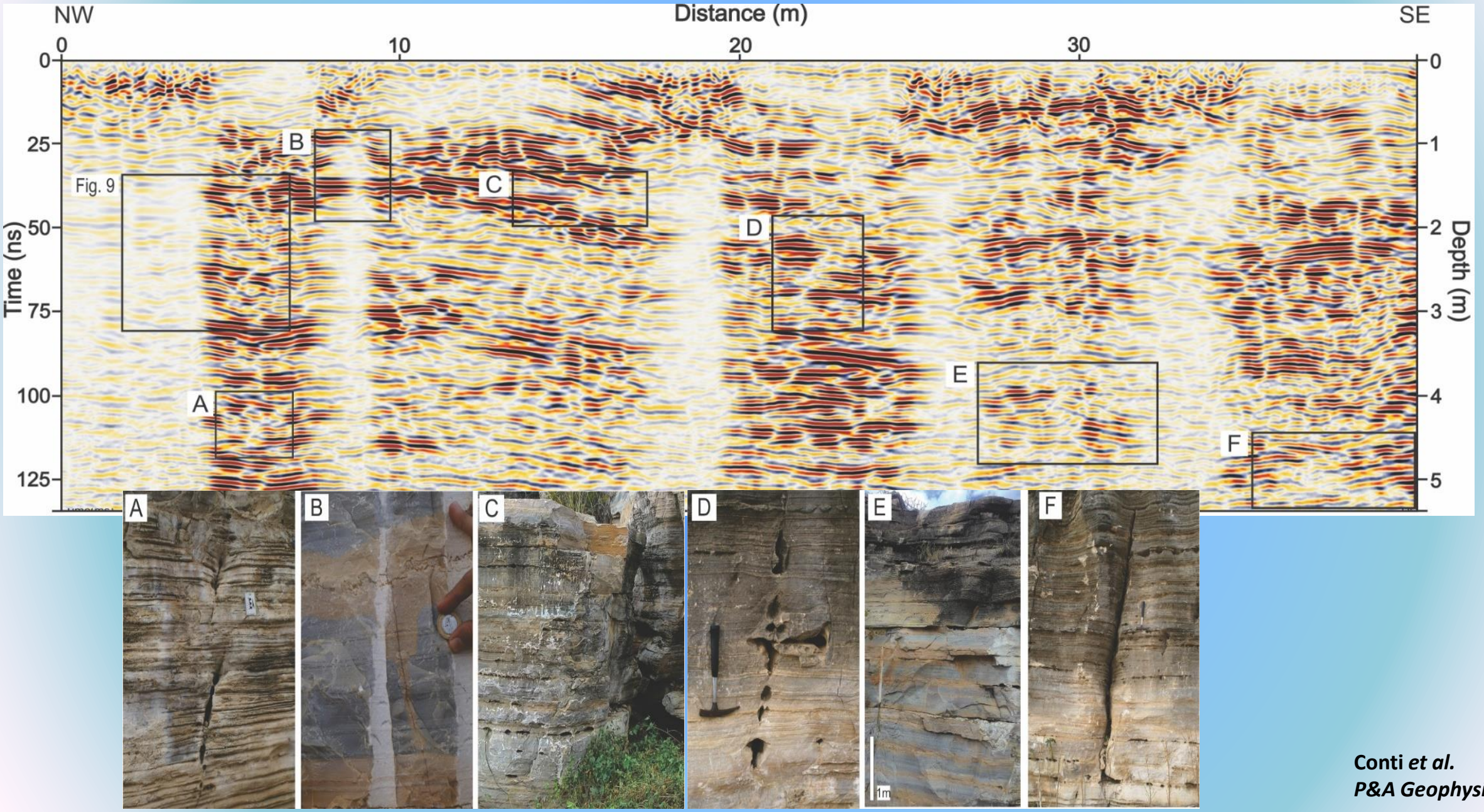
Modelo Conceitual de Formação das Cavernas



(C) Karst concentration along fracture corridor and at seal levels. (D) Cave formation along units (1), (2), and (3) at anticlinal hinge and below sealing units (4) and (5). Hypogenic system is modified from the studies from Klimchouk et al. (2016) and Auler et al. (2017). The local stratigraphy is based on the present study. Key: (C) (f) fracture corridor and fault termination, (g) arrows mark fluid migration along fractures, (h) karst zone in anticlinal hinge, (i) dissolution (gray) below stratigraphic seals (j) karstification due to lateral fluid migration, (k) hypogenic fluid accumulation below seal, (l) local seal breaches give rise to ascending fluids. (D) (m) lithostratigraphic seal, (n) large cave passage, (o) feeder of hypogenic fluids, (p) anticline hinge, (q) fracture corridor.

Cazarin *et al.*
***M&P Geology*, 2019**

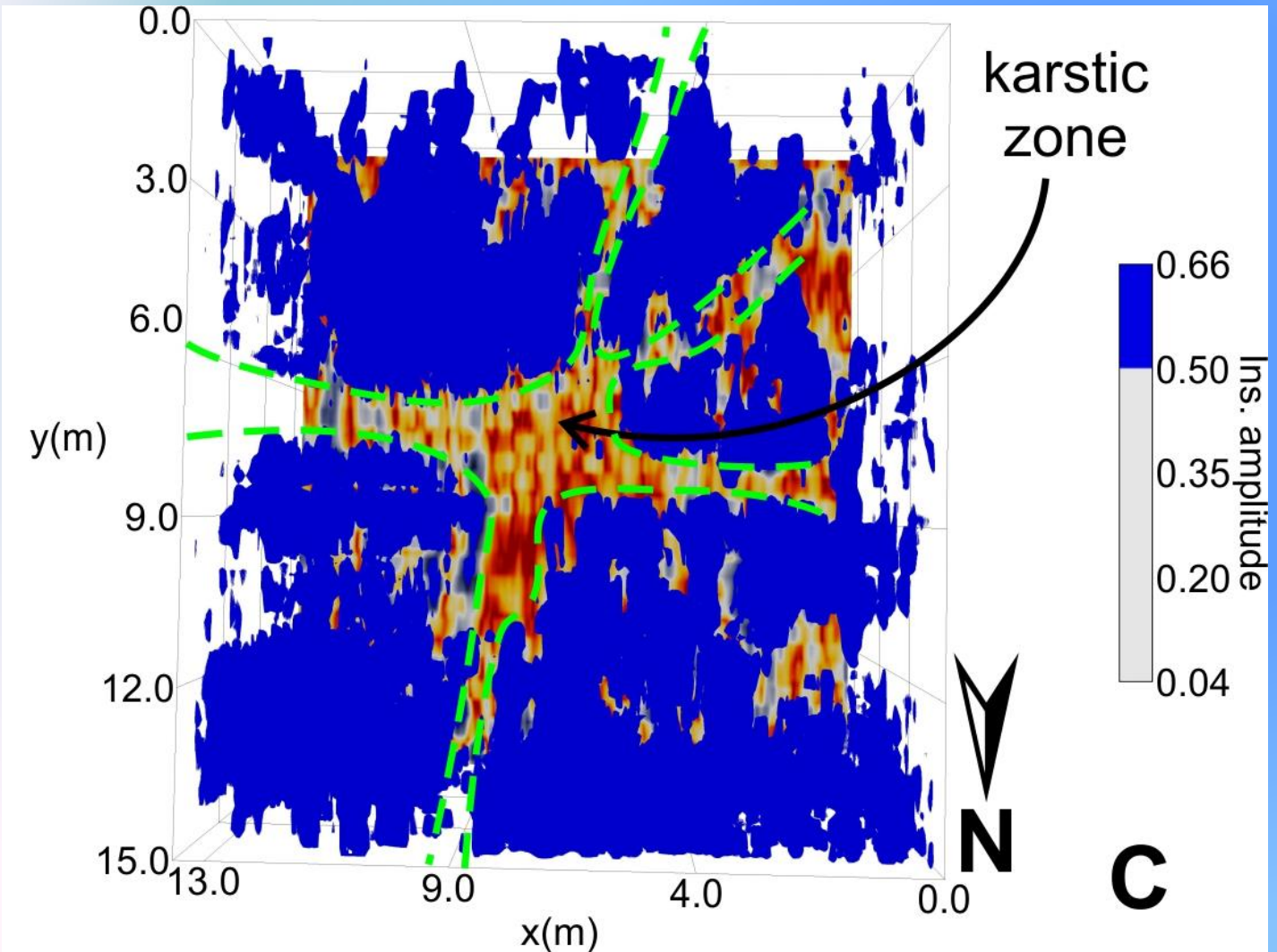
Identificação de assinatura GPR típica de zonas de carstificadas

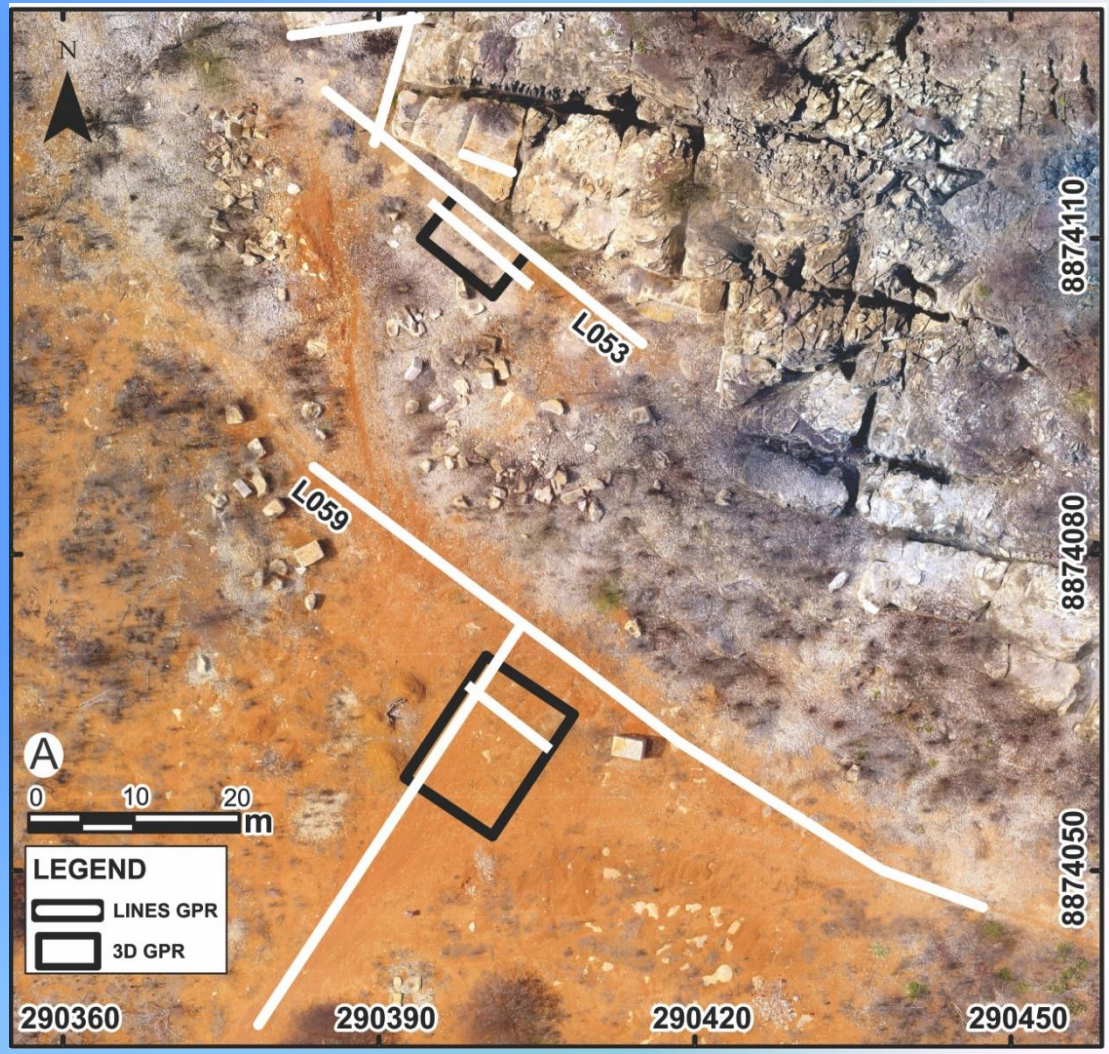


Conti *et al.*
P&A Geophysics, 2018

Geração de volumes 3D de Porosidade Estimada com base em dados GPR

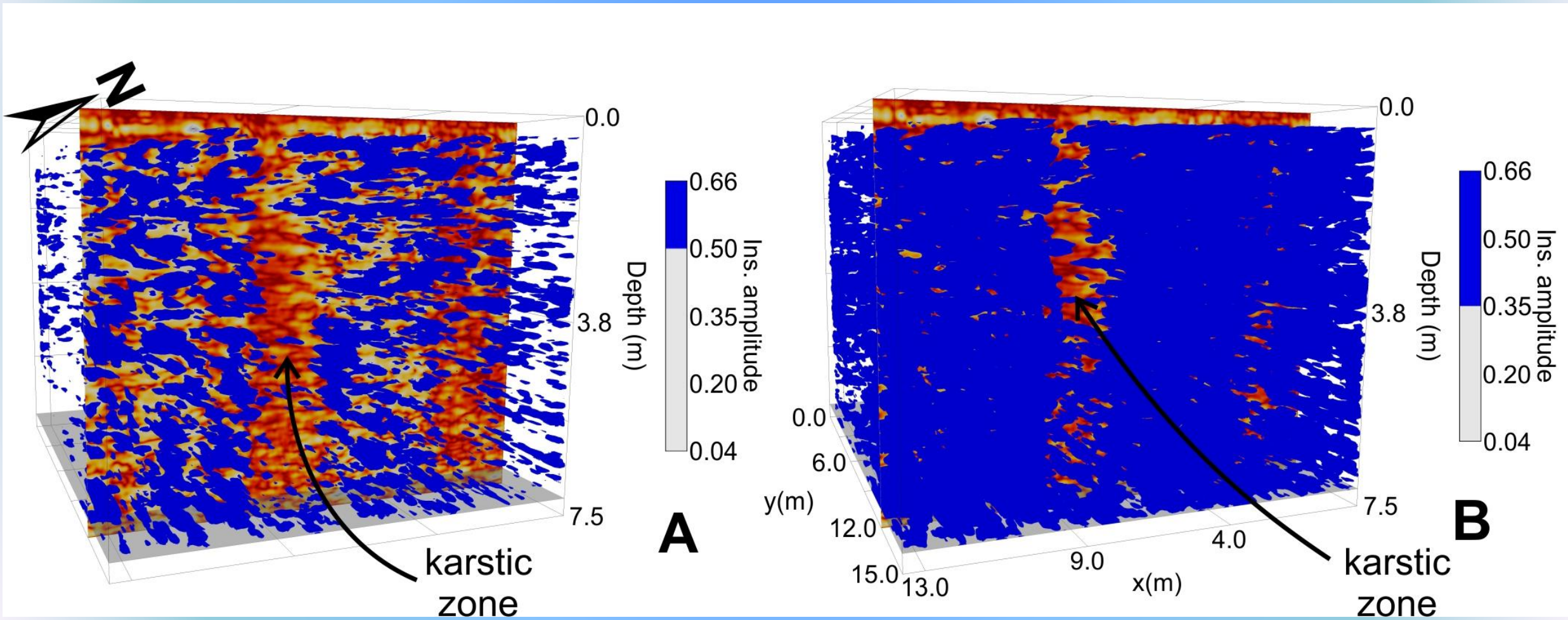
Volume de Porosidade Estimada → zonas carstificadas formam corredores NNE-SSW e E-W paralelos ao fraturamento ortogonal observado na pedreira



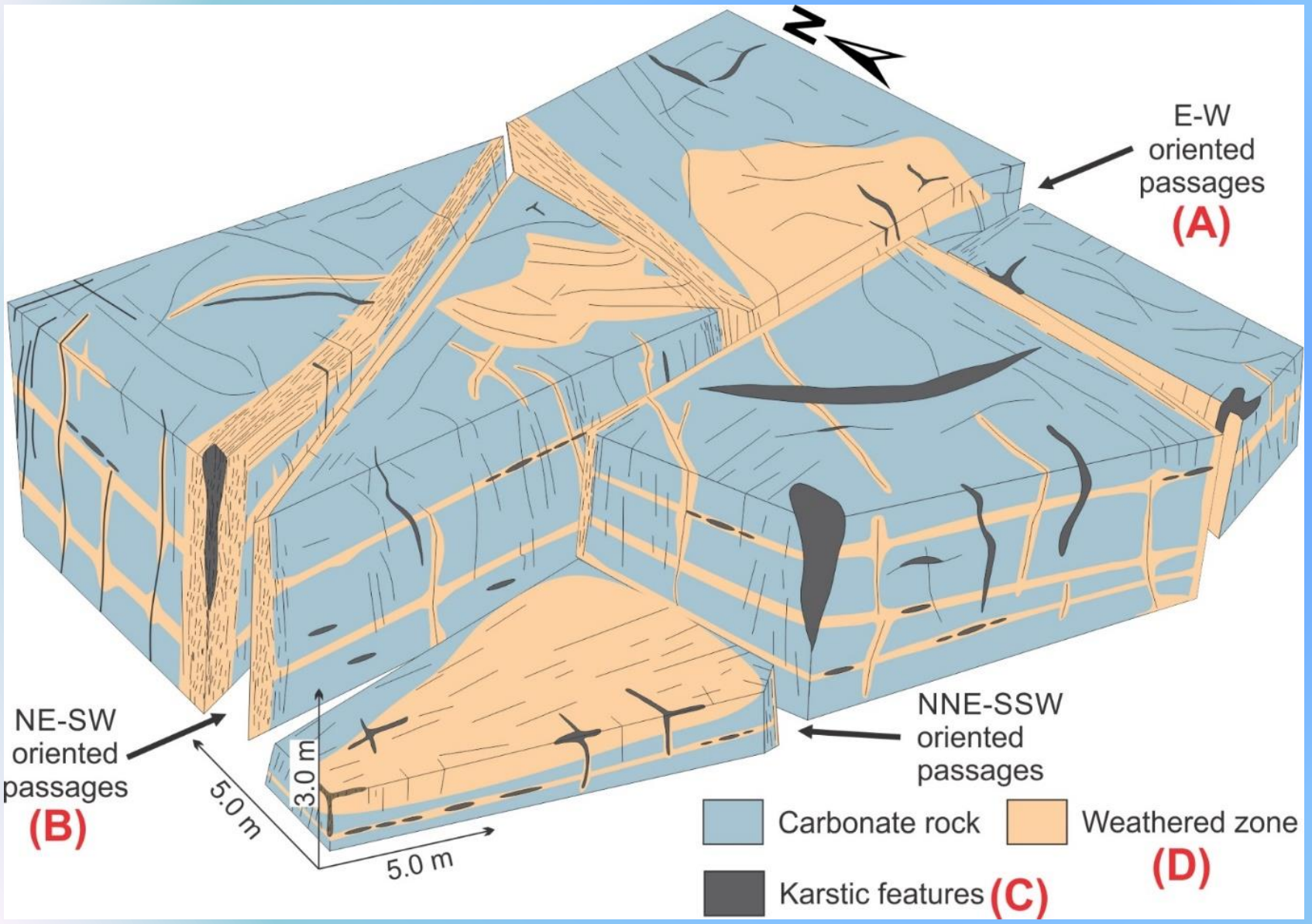


Geração de volumes 3D de Porosidade Estimada com base em dados GPR

Volumes de Porosidade Estimada da Zona Não-Alterada (0,953 %) (azul) para amplitudes >0,5 (A) e amplitudes >0,35 (B)



Zonas de Porosidade incrementadas por fraturamento e dissolução

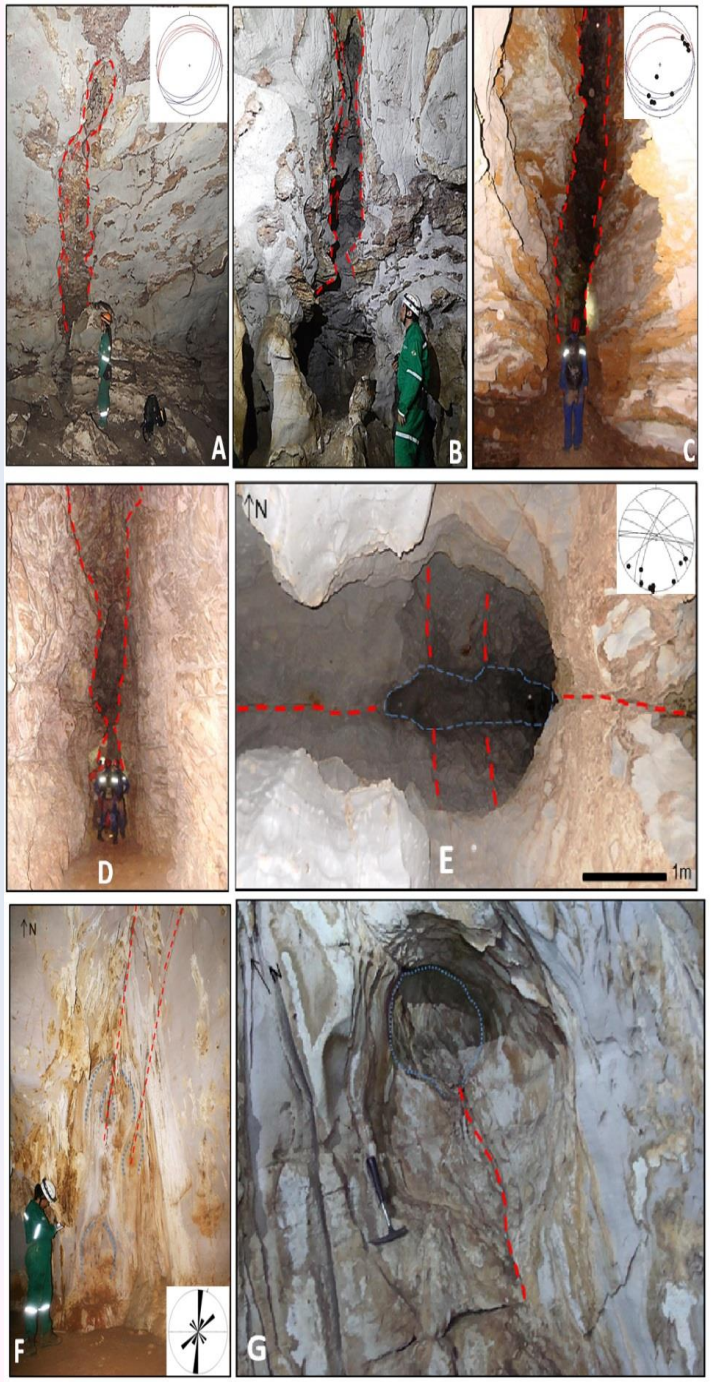


A) Zonas de fraturas conjugadas NNE-SSW e E-W → maiores porosidades e alta conectividade;

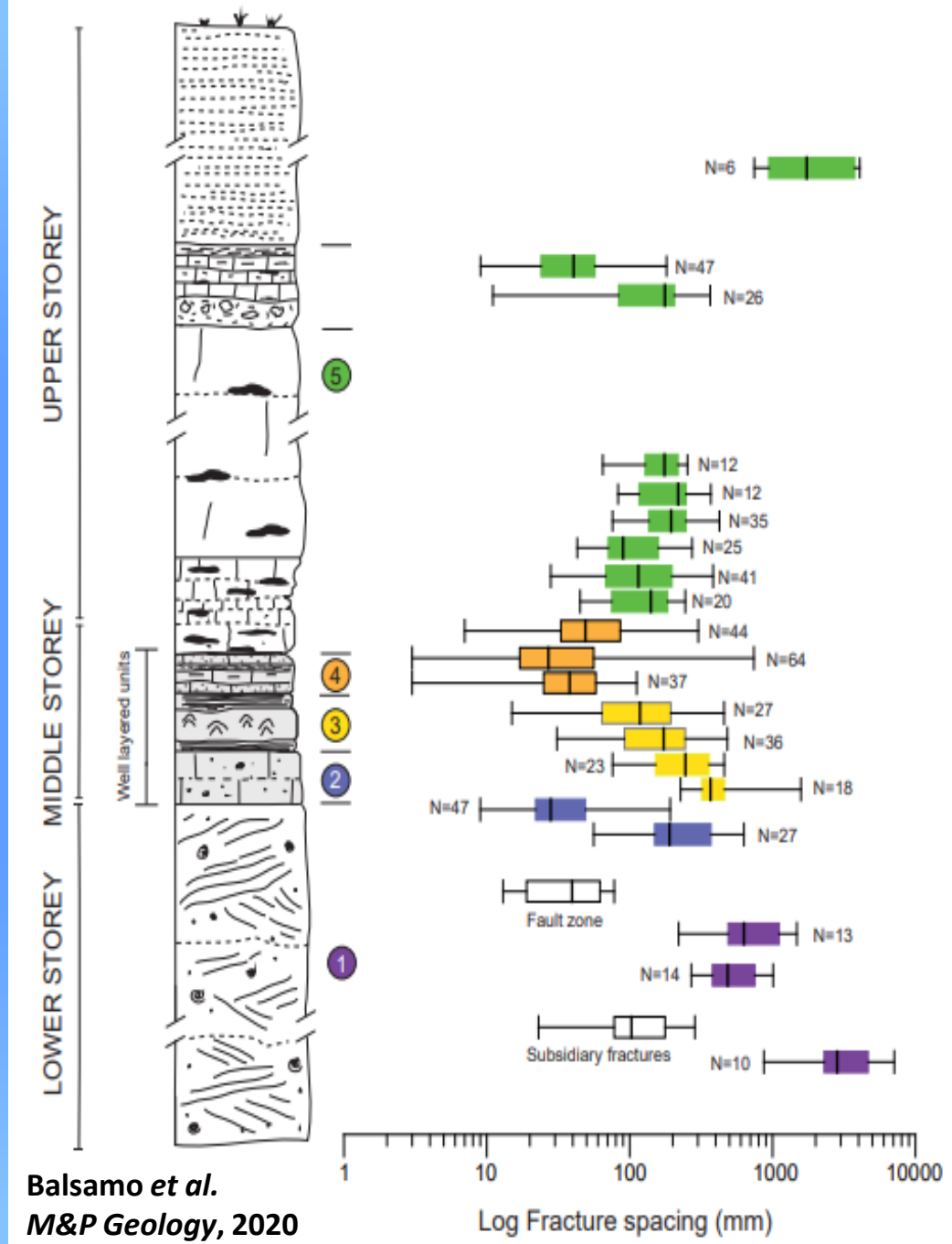
B) Zonas de fraturas NE-SW → alta porosidade e boa contribuição para a conectividade do sistema de fraturas;

C) Feições cársticas → aumento da porosidade e conectividade intermediária

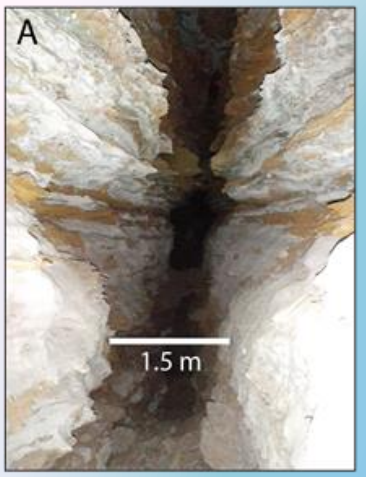
D) Zonas alteradas → aumento da porosidade e conectividade devido à dissolução mineral

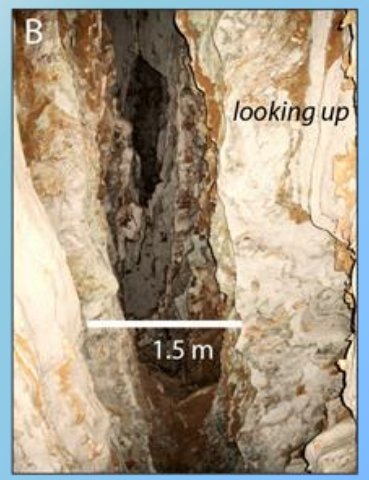






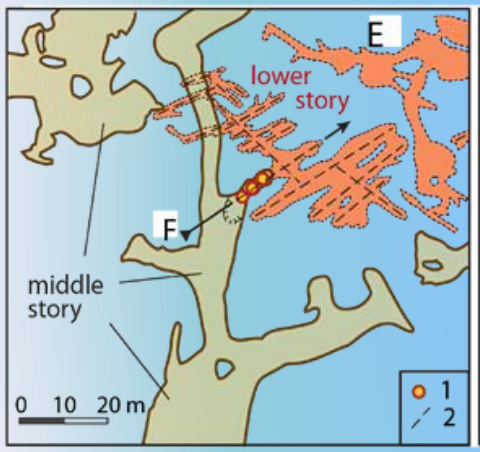
Balsamo *et al.*
***M&P Geology*, 2020**

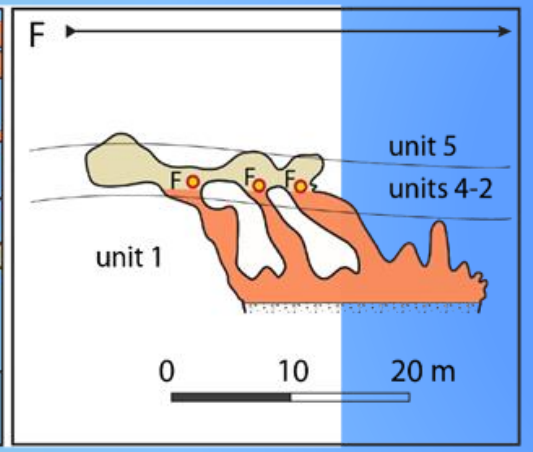














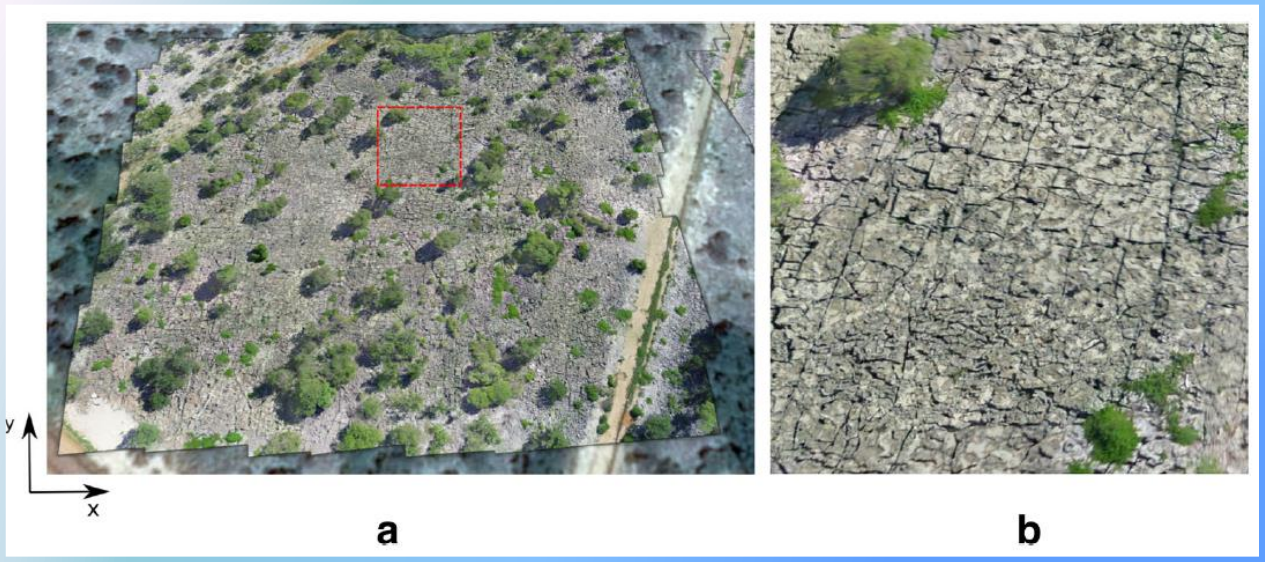


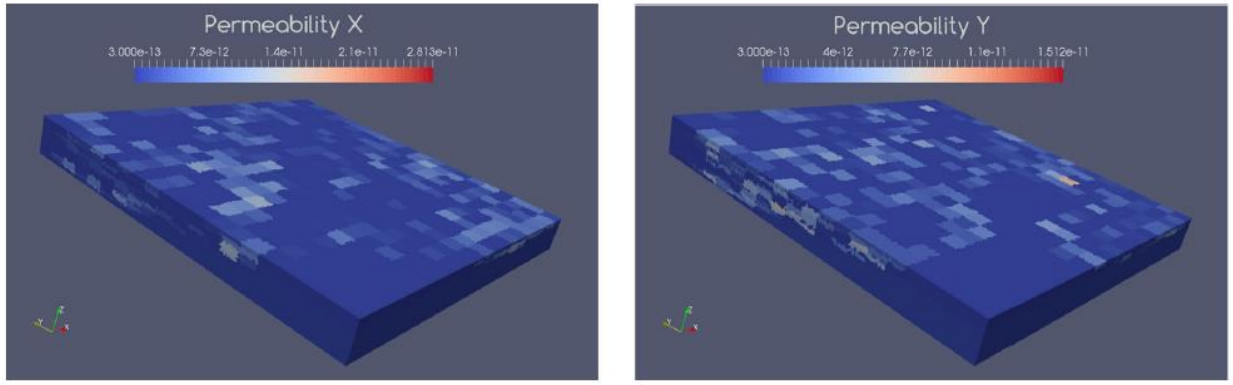




As fraturas mais longas, não confinadas a uma camada, são as mais dissolvidas e por onde passou o fluxo de fluidos hidrotermais.

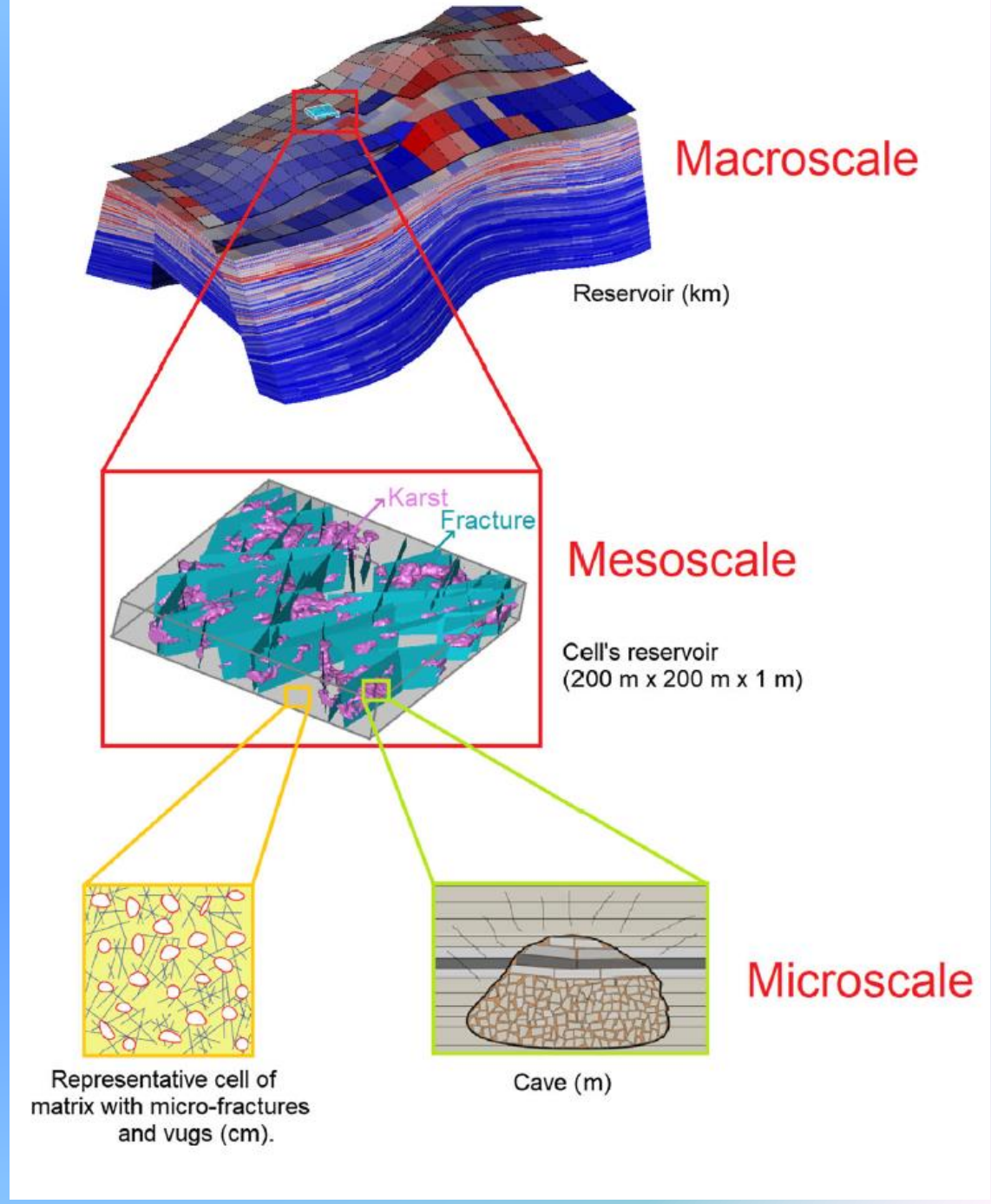
A-D – Camada superior do selo (5) com fraturas longas;
H-G – fraturas
na camada (1) da Toca da Boa Vista. Ambos grupos raramente se ligam.





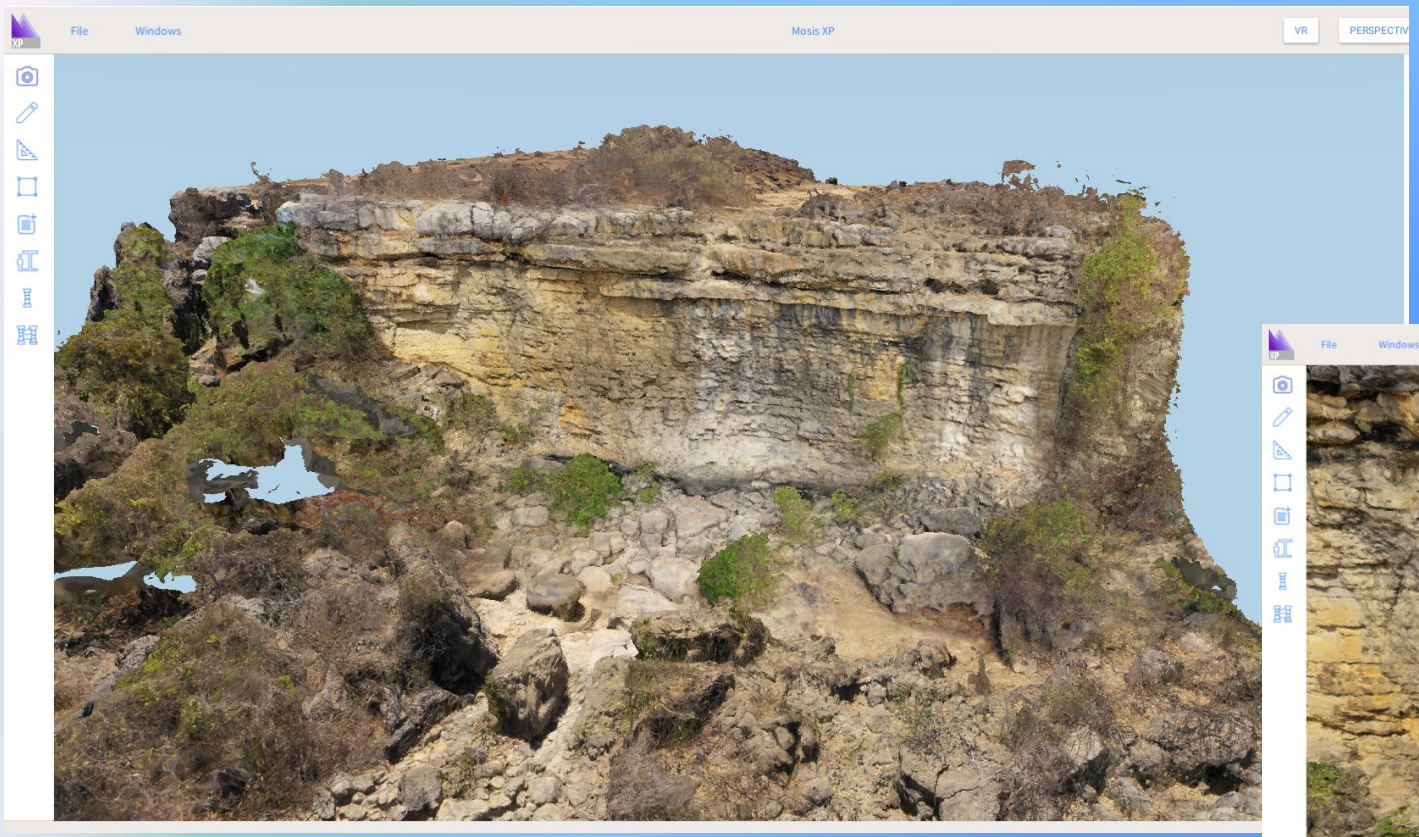
a Permeability of the matrix in the x-direction (K_{M_x}). **b** Permeability of the matrix in the y-direction (K_{M_y}).

Homogenized permeability of the matrix computed by Oda's method

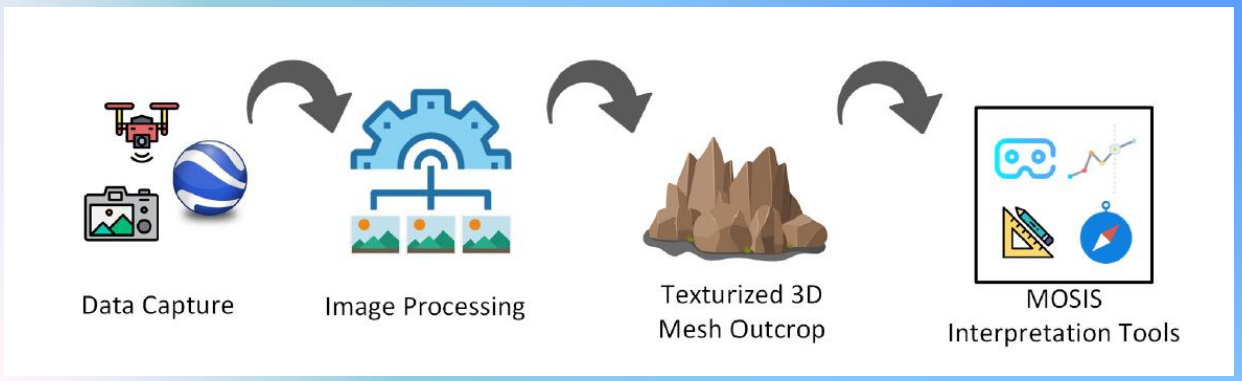


Lopes *et al.*
***Comput Geosci*, 2020**

(Multi Outcrop Sharing and Interpretation System)







Rossa *et al.*
***IEEE*, 2020**


OBRIGADA
BORN TO
CAVE
FORCED TO WORK