Study cases in São Paulo, Brazil

Structural hydrogeology studies: from regional to local scales

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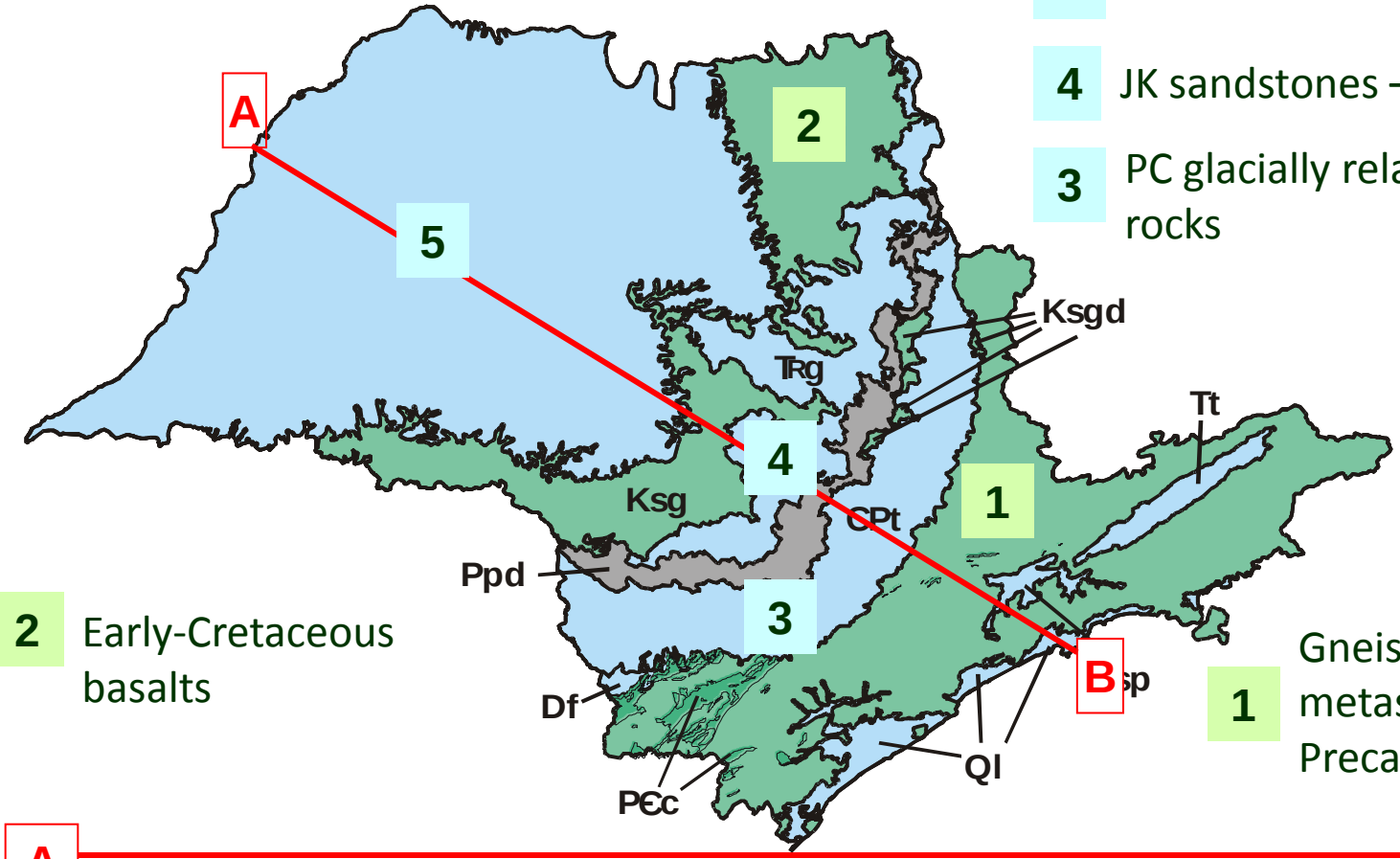
IG
INSTITUTO GEOLÓGICO

AQUIFERS OF THE STATE OF SÃO P

5 Late-Cretaceous

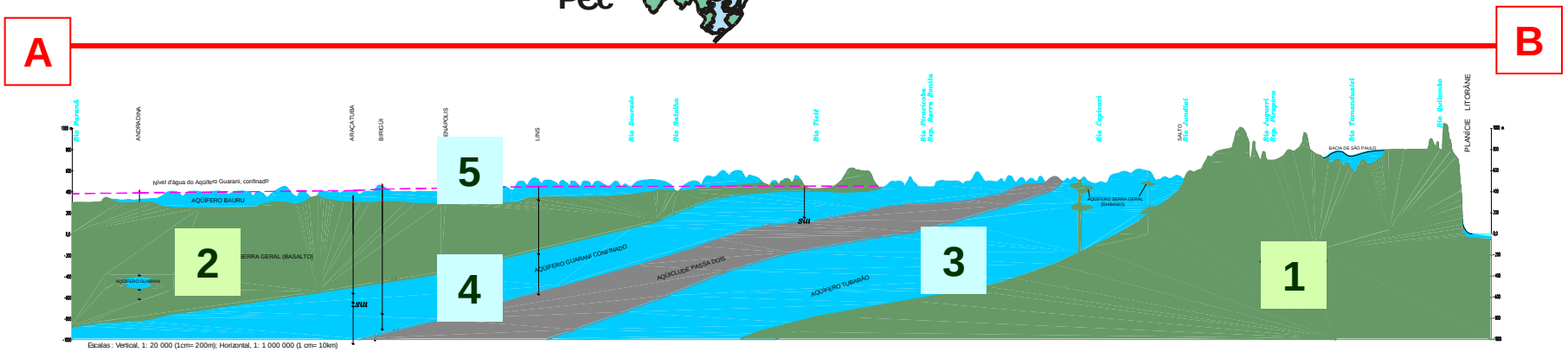
4 JK sandstones –

3 PC glacially relat rocks

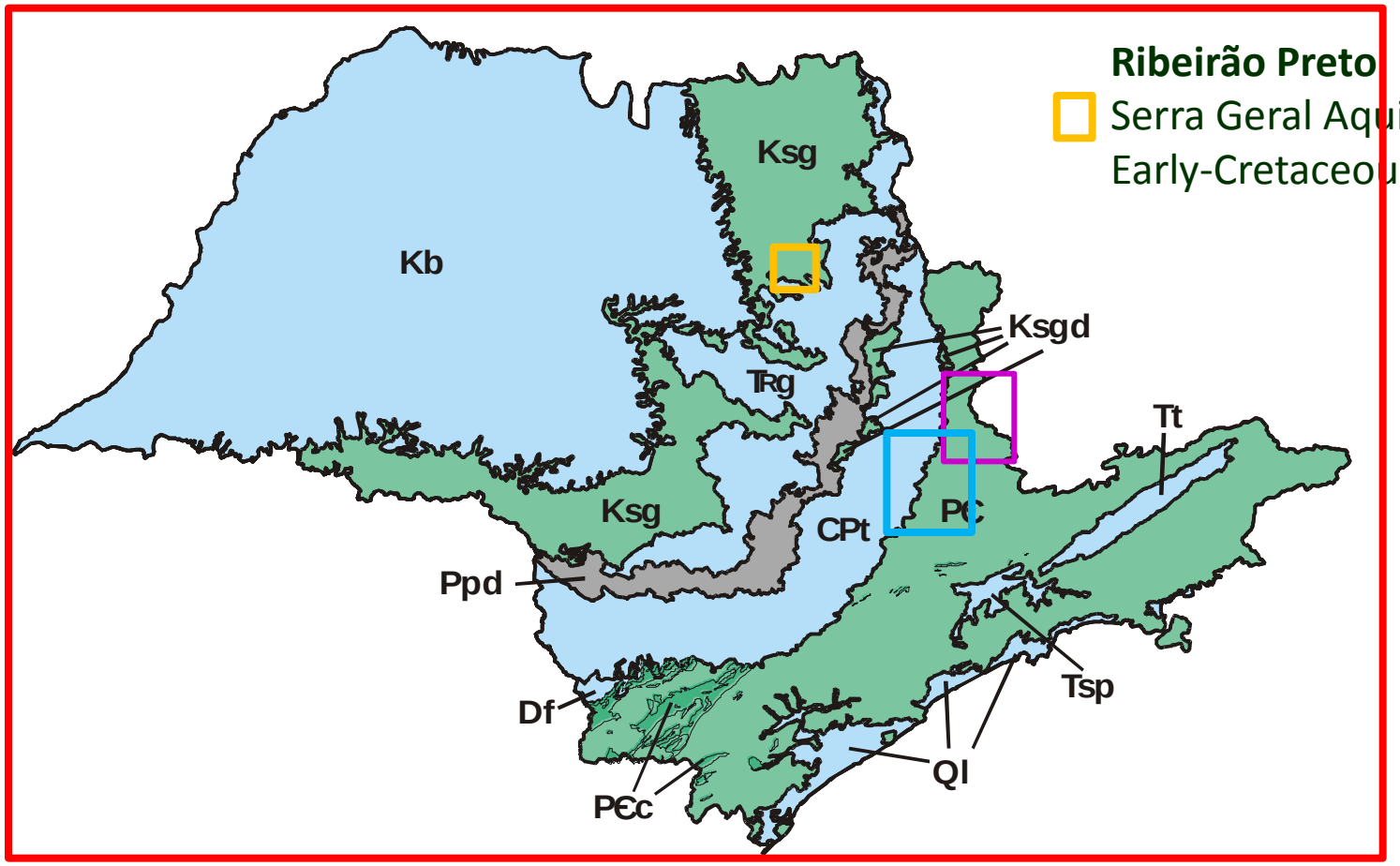


2 Early-Cretaceous basalts

1 Gneisses, granites and metassedimentary Precambrian rocks



STUDY CASES LOCATION



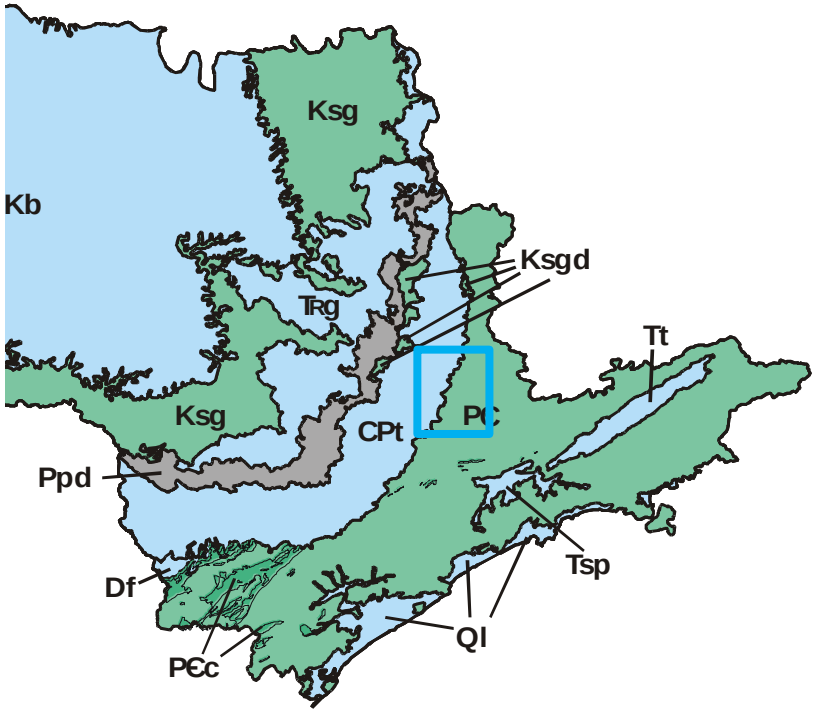
Ribeirão Preto
Serra Geral Aquifer
Early-Cretaceous Basalts

Campinas
Tertiary sediments
EK basalts
PC sedimentary rocks
P€ Gneisses and granites

Lindóia
Gneisses and granites
Precambrian

São Paulo State

CAMPINAS STUDY CASE



OBJECTIVE

Applying the knowledge of Cenozoic Tectonics evolution on the groundwater circulation understanding

METHODS

- Geological mapping
- Analysis of the Cenozoic Tectonics
- Lineament analysis
- Analysis of the production of wells with regard to the lineament direction to which they are close .

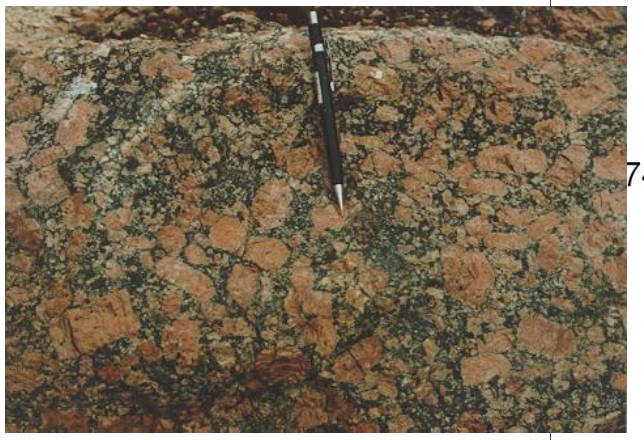
INTERMEDIATE SCALE

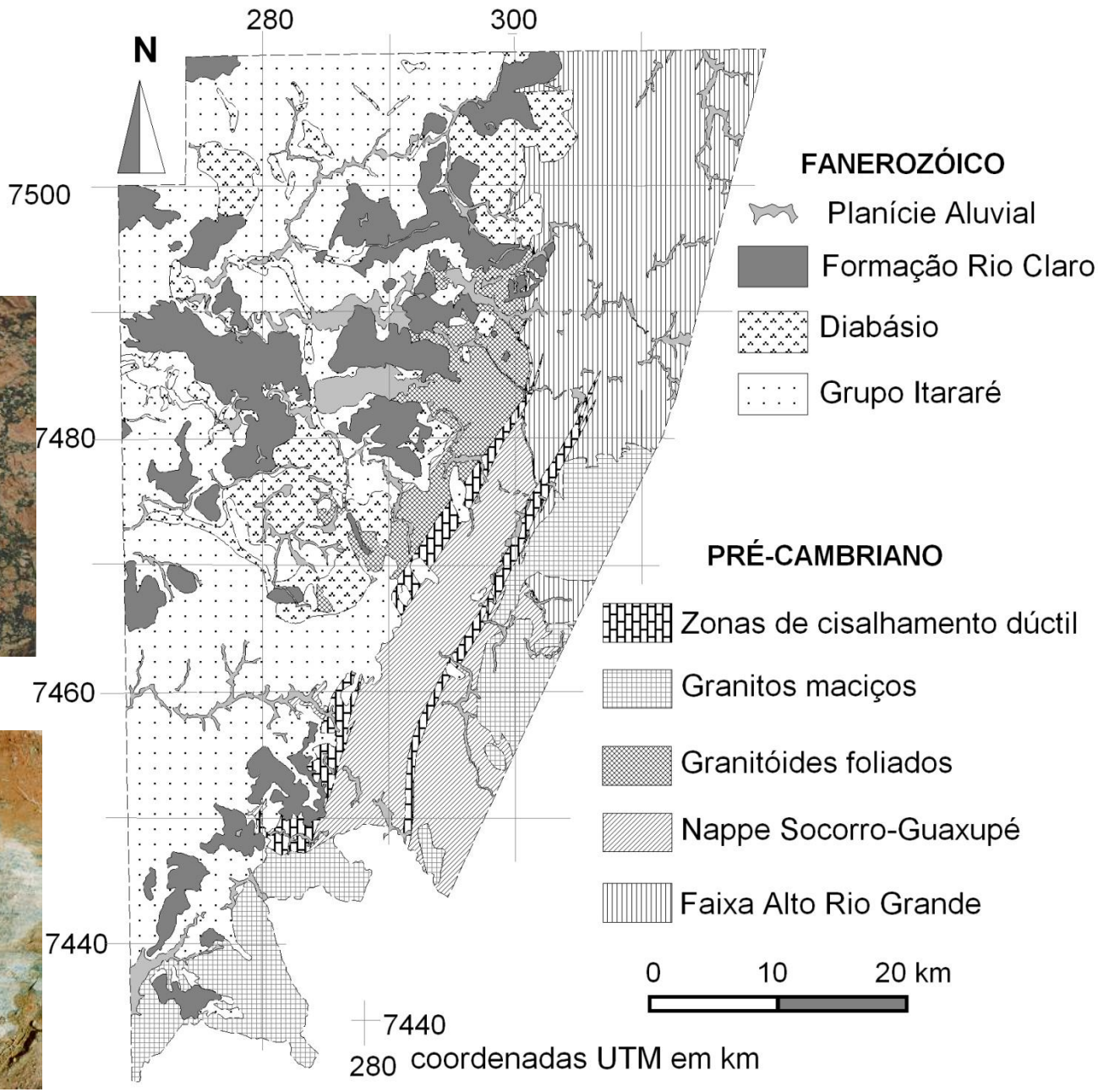
- 1:50.000 for the entire area

- 1:25.000 for smaller selected areas (depending on the available well data)

CAMPINAS STUDY AREA

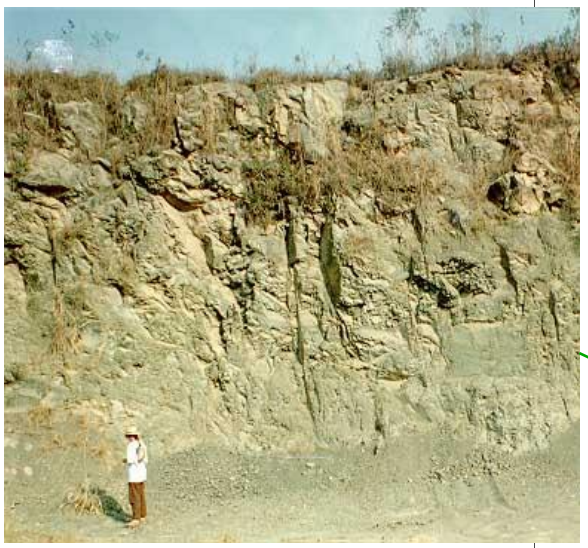
Pre-Cambrian rocks

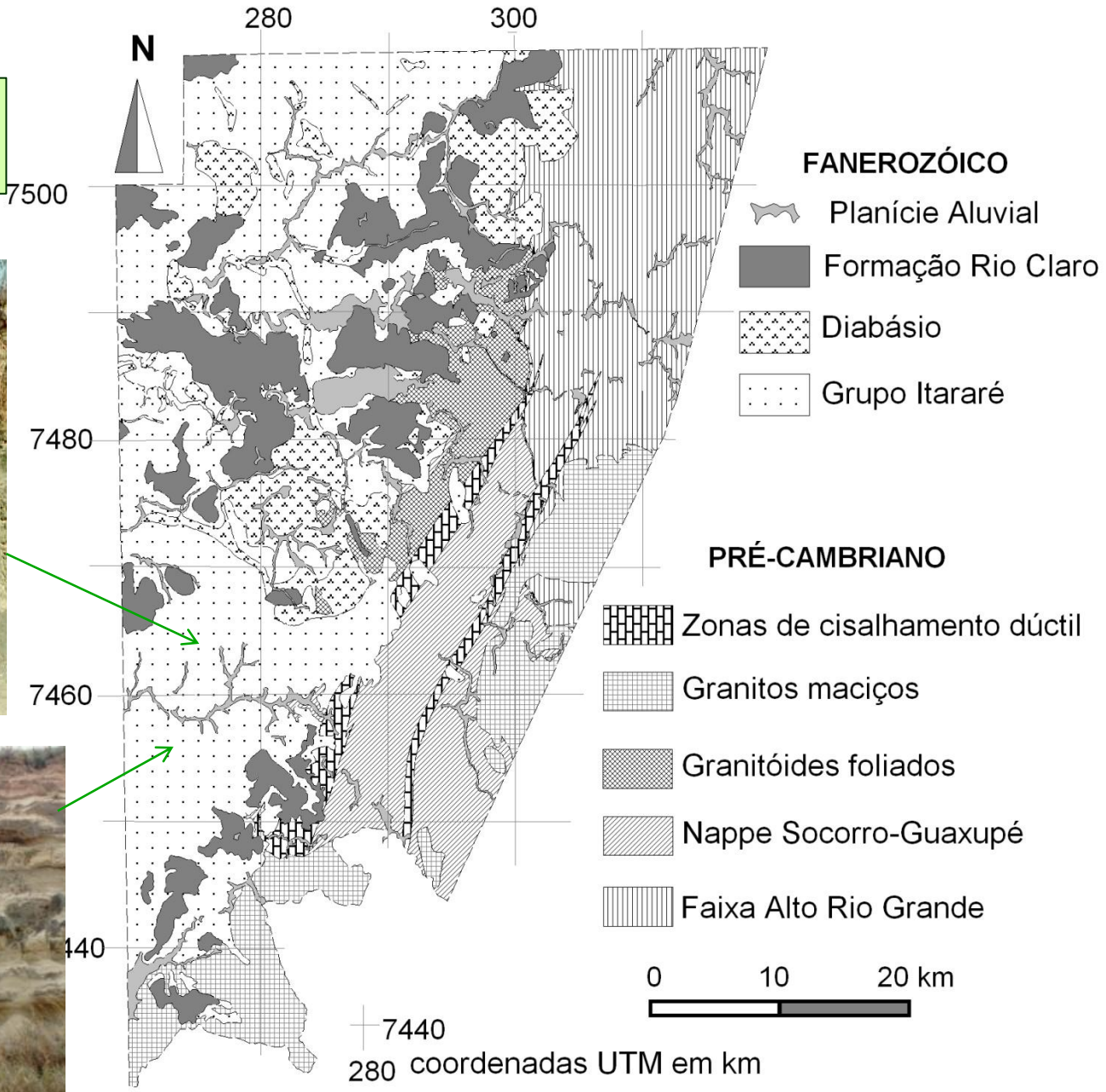




Fernandes 1997, Fernandes & Amaral 2002

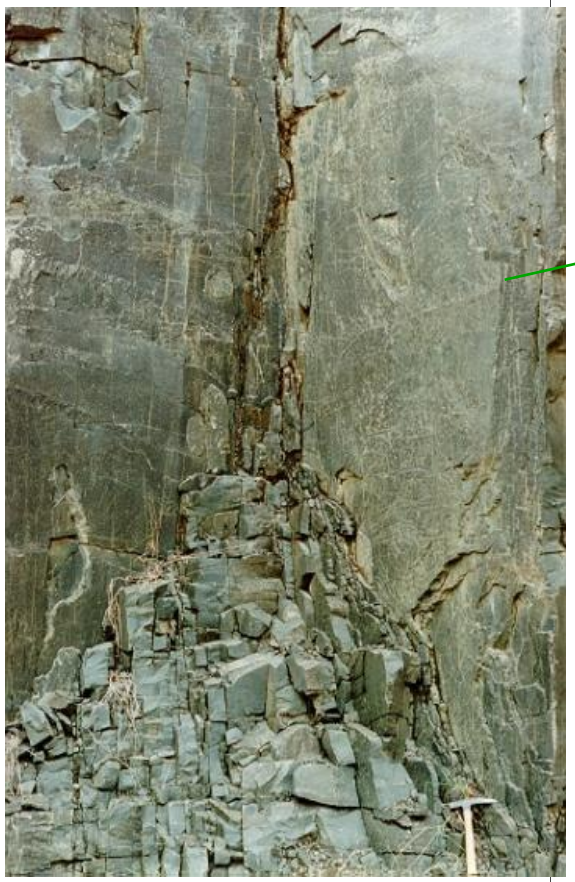
Itararé Group – PC
glacially related sed. rocks

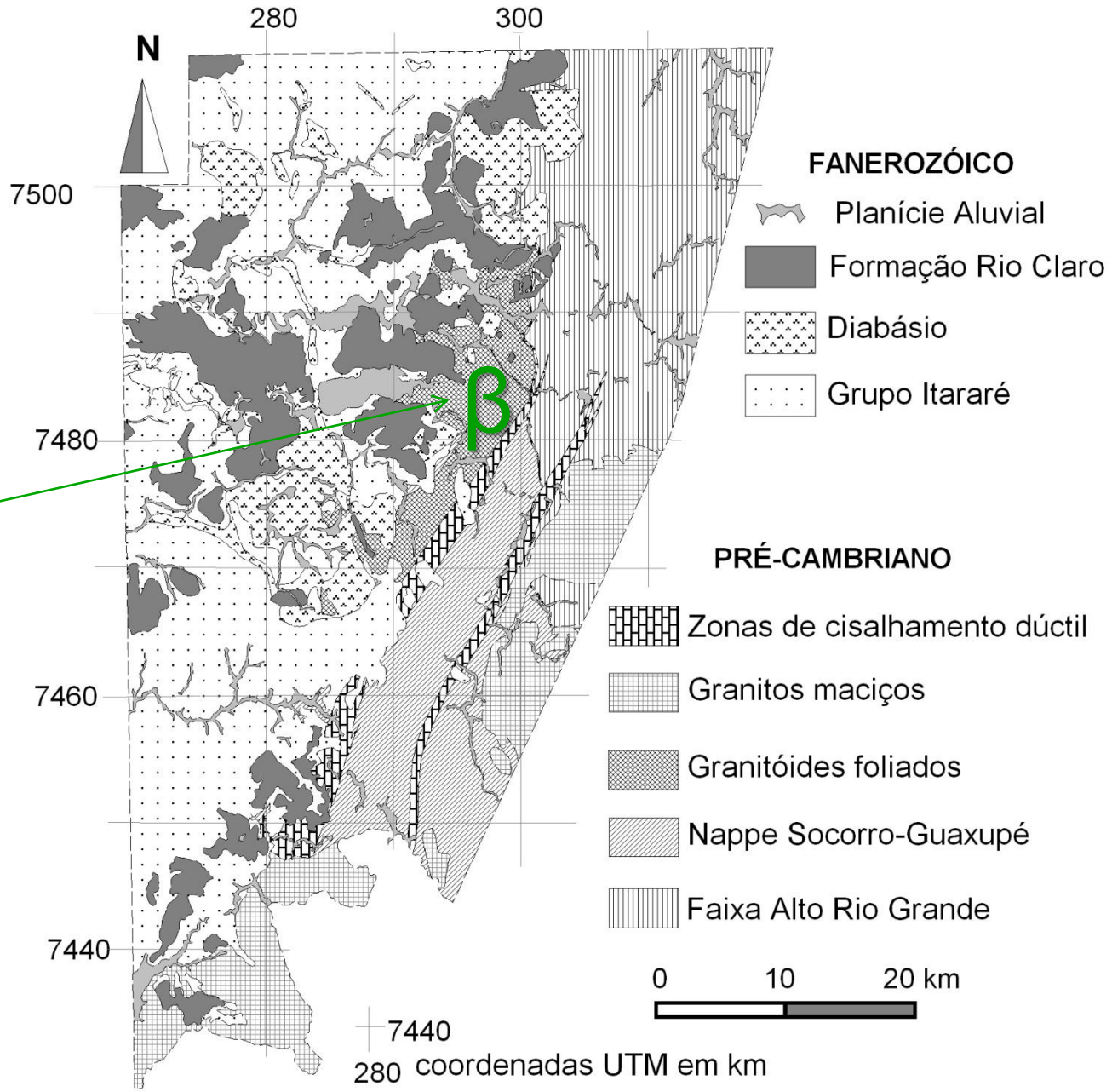




Fernandes 1997, Fernandes & Amaral 2002

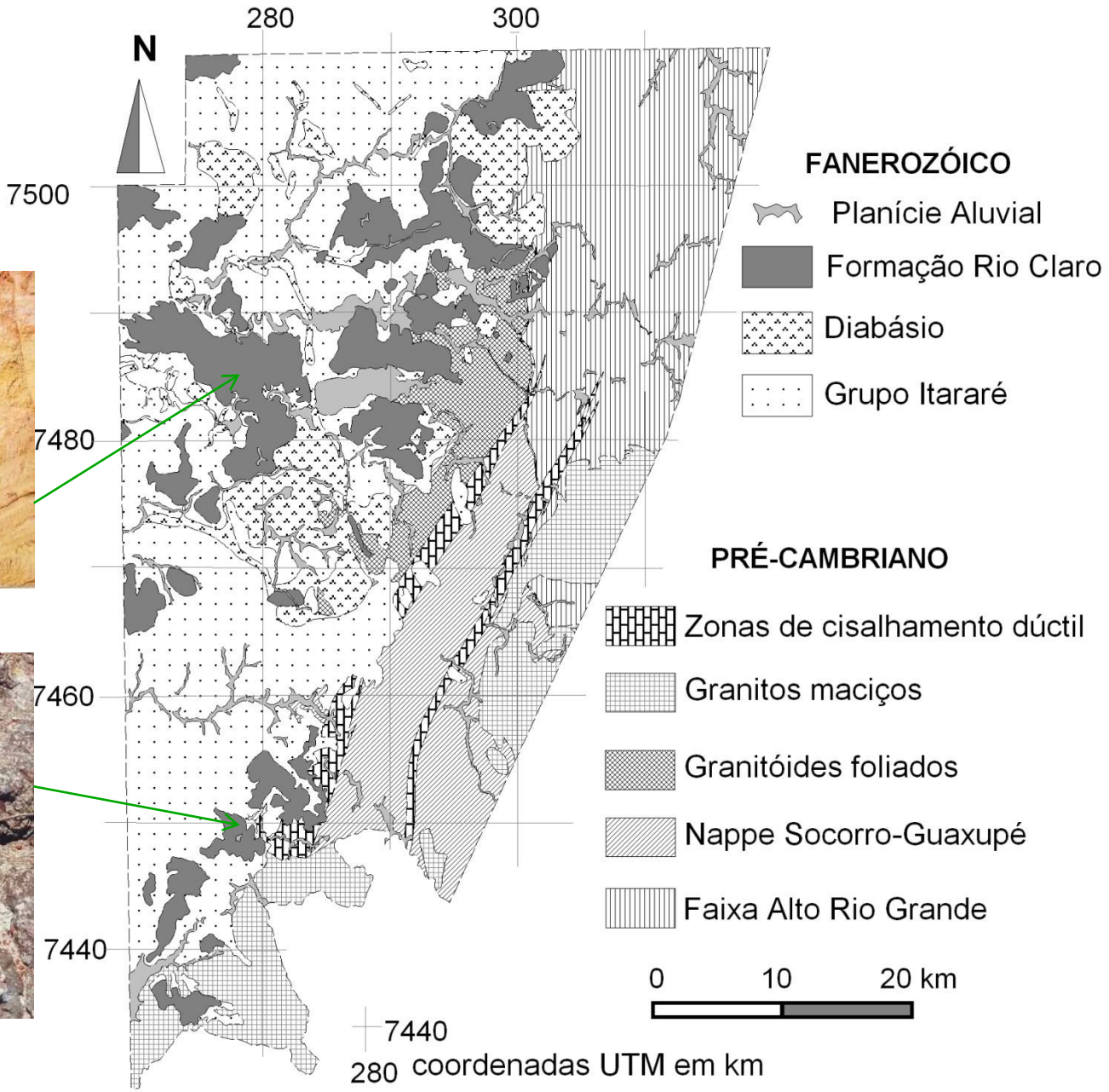
EK diabases





Fernandes 1997, Fernandes & Amaral 2002

Miocene to Plicone - Rio Claro Formation



Fernandes 1997, Fernandes & Amaral 2002

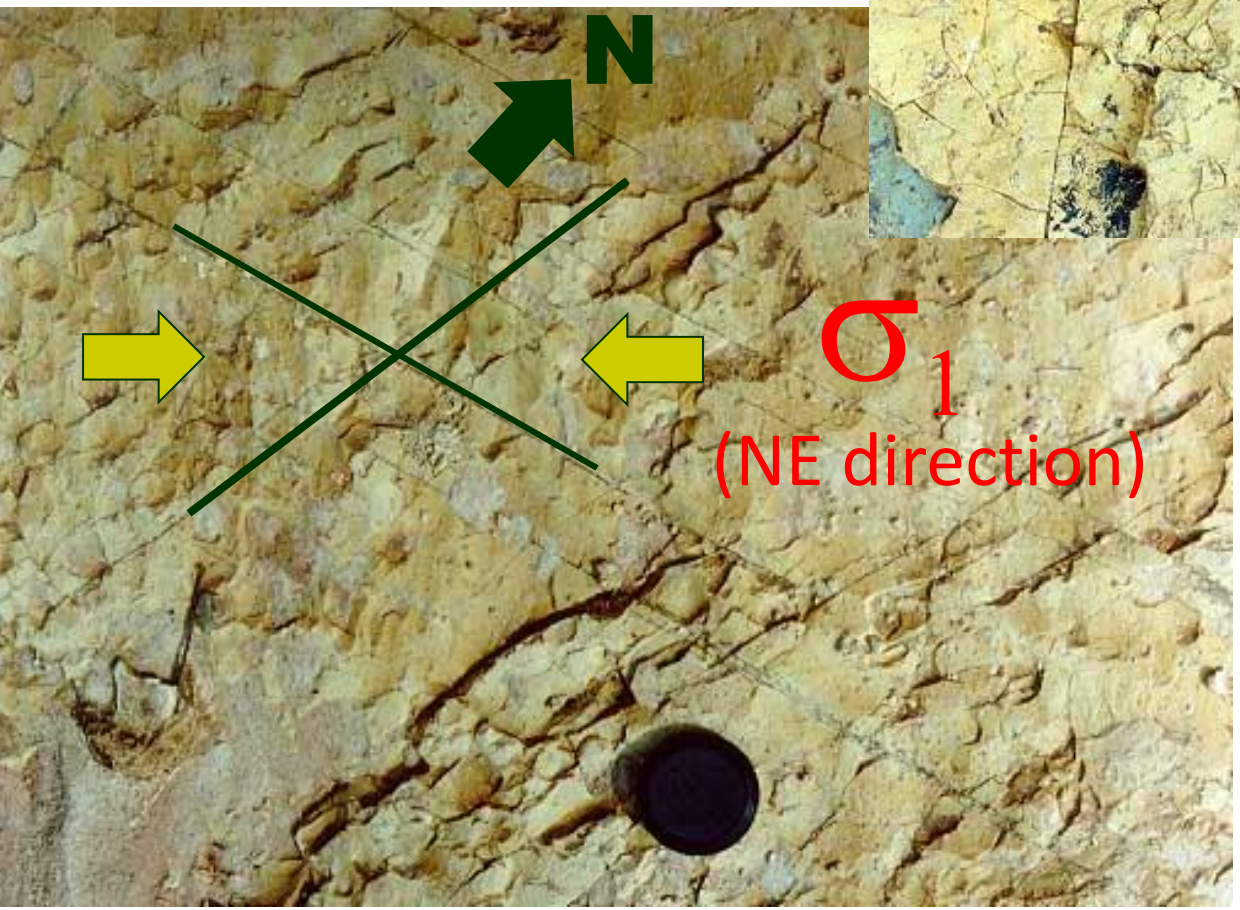
CAMPINAS STUDY CASE

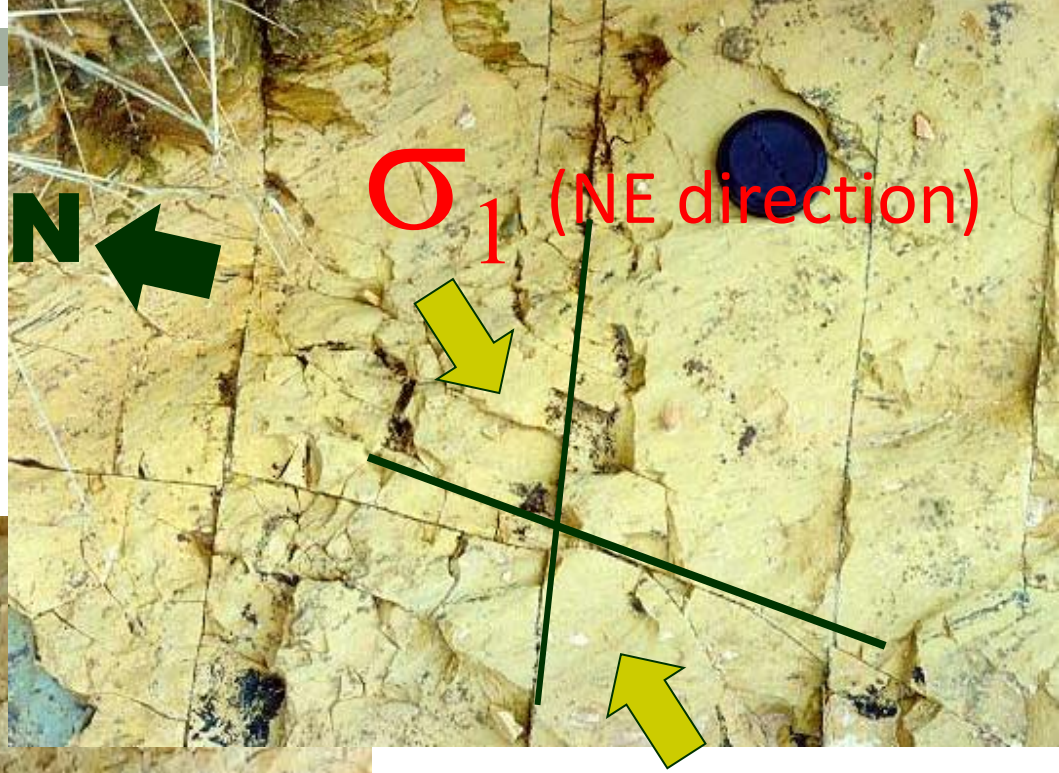
OVERVIEW OF THE EVOLUTION OF THE BRITTLE TECTONICS

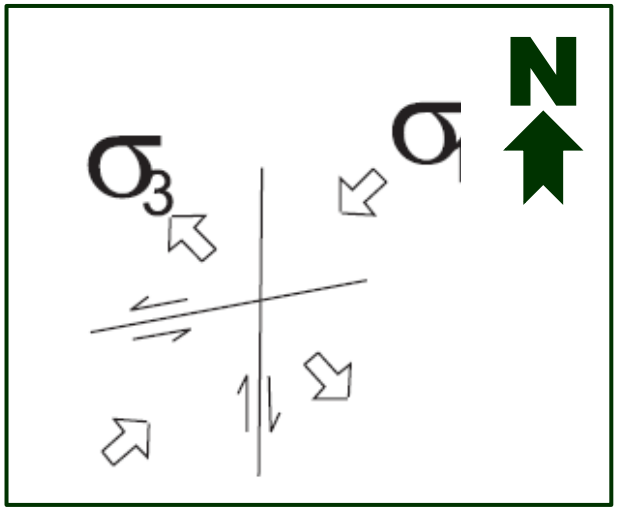
CENOZOIC

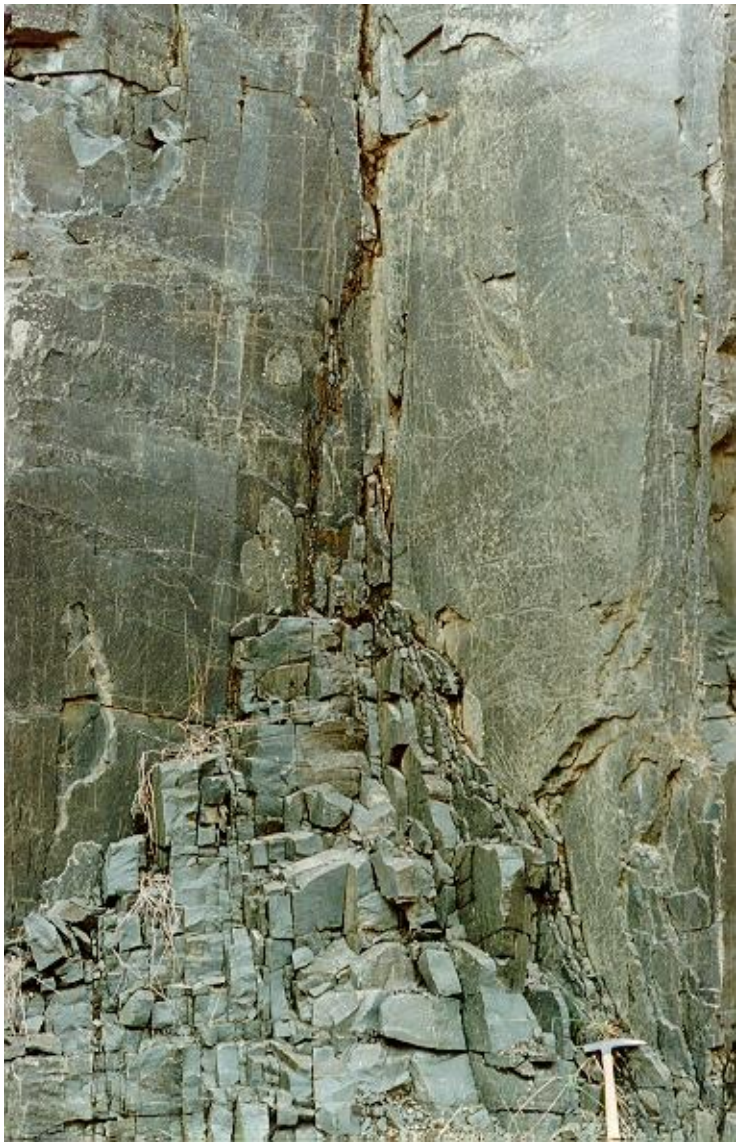
PC Itarare Group (very fine silty sandstone)

PLAN VIEW

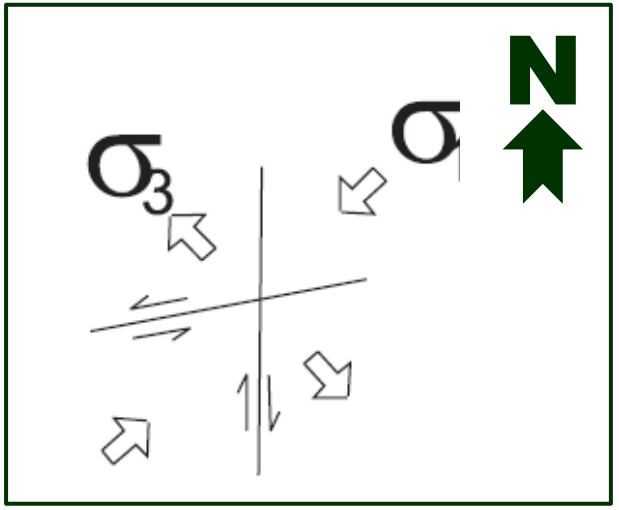




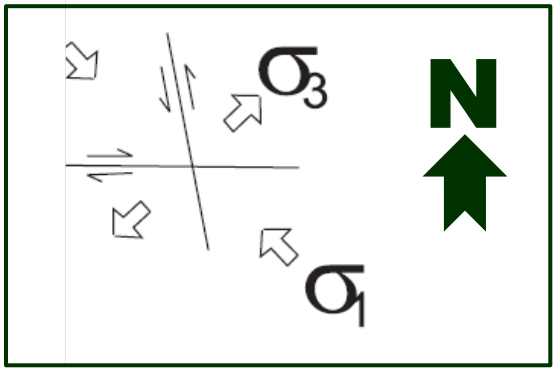


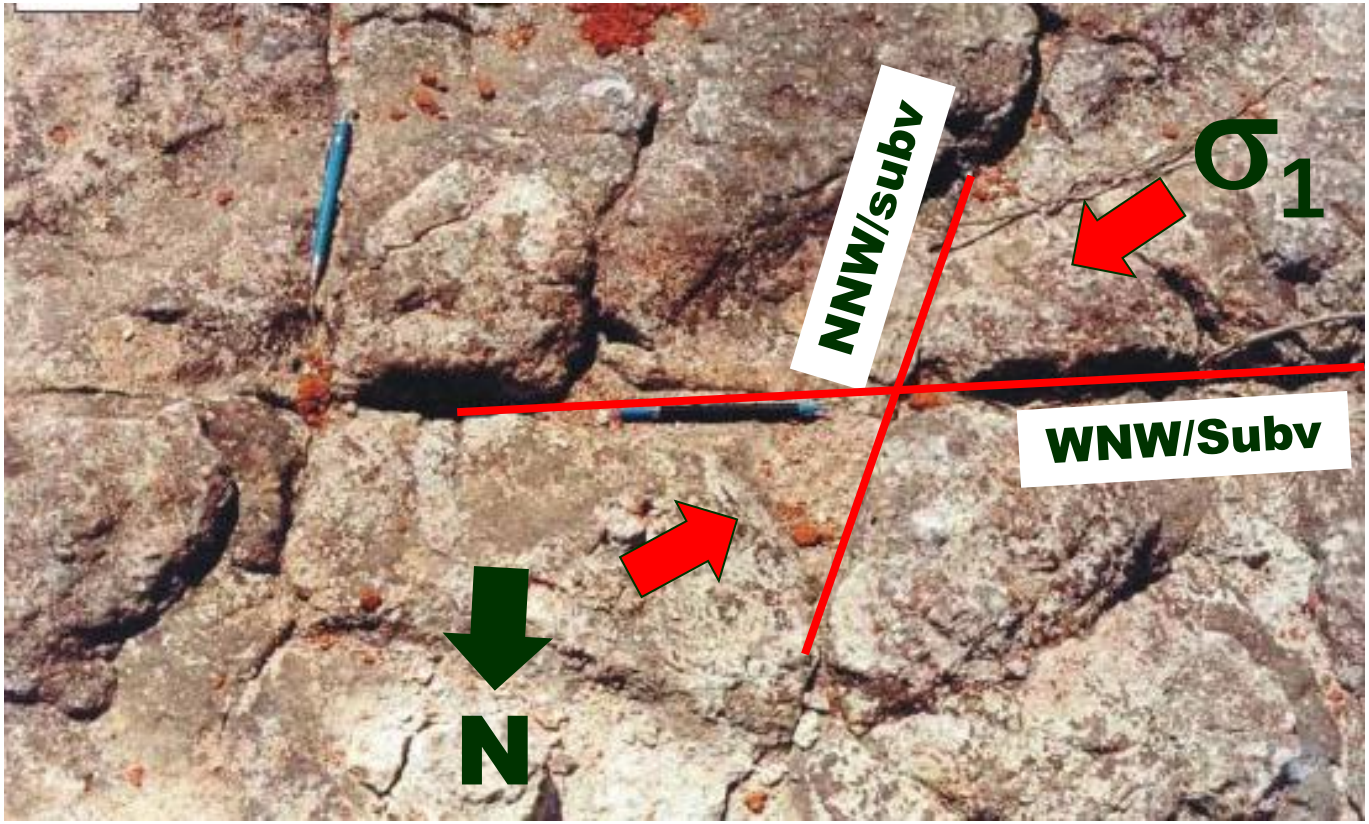


Early-Cretaceous diabases

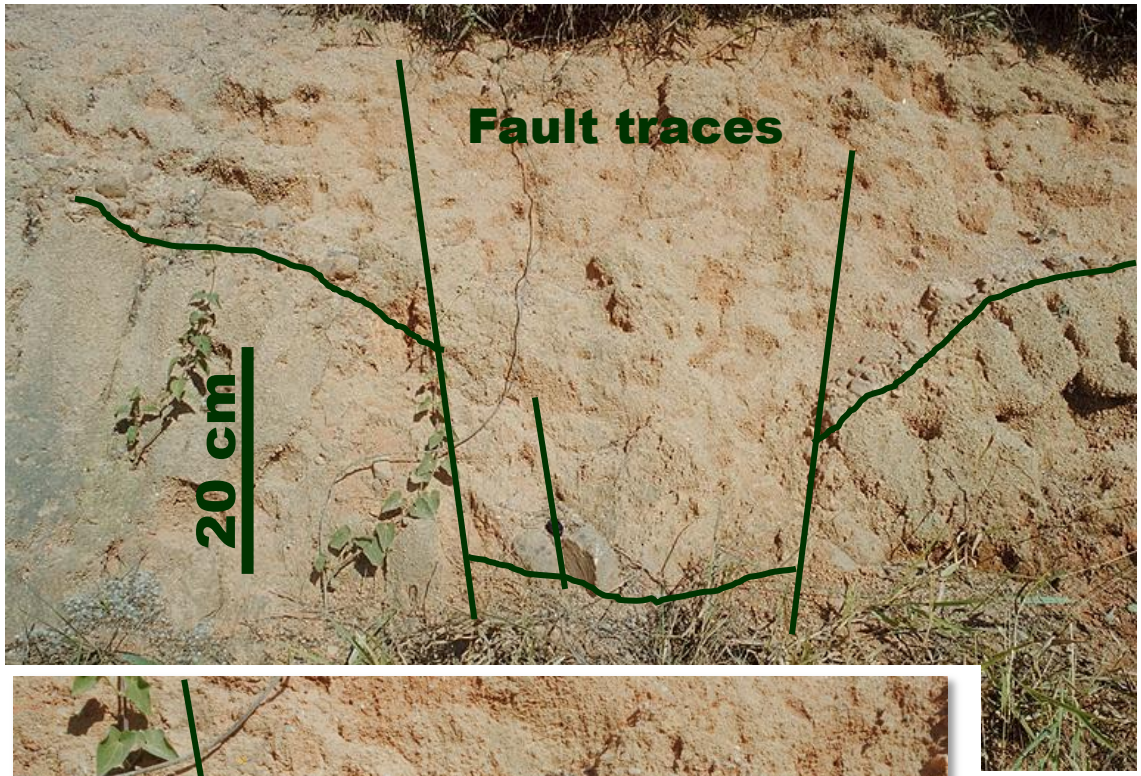


Miocene to Pliocene Rio Claro Formation mudstones

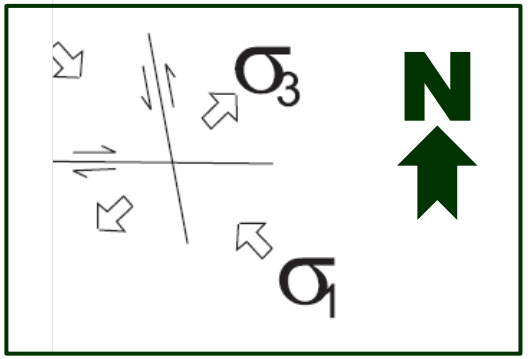


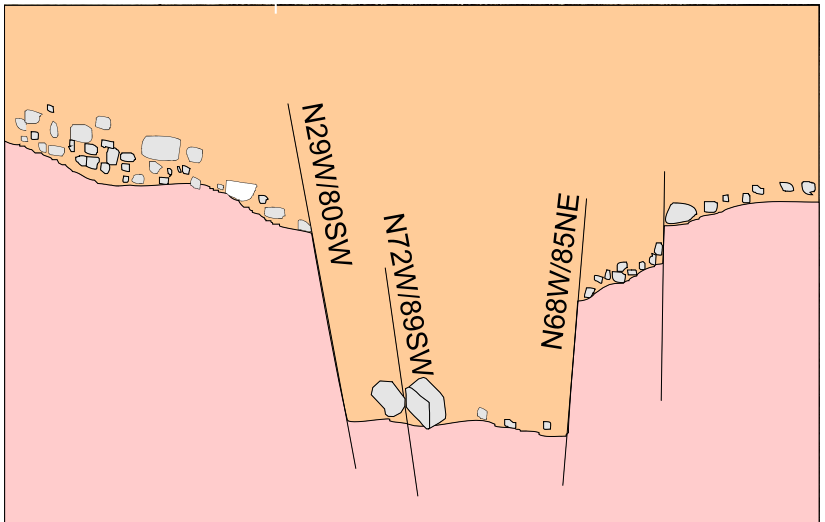


Tertiary to Quaternary covers underlain by stone lines



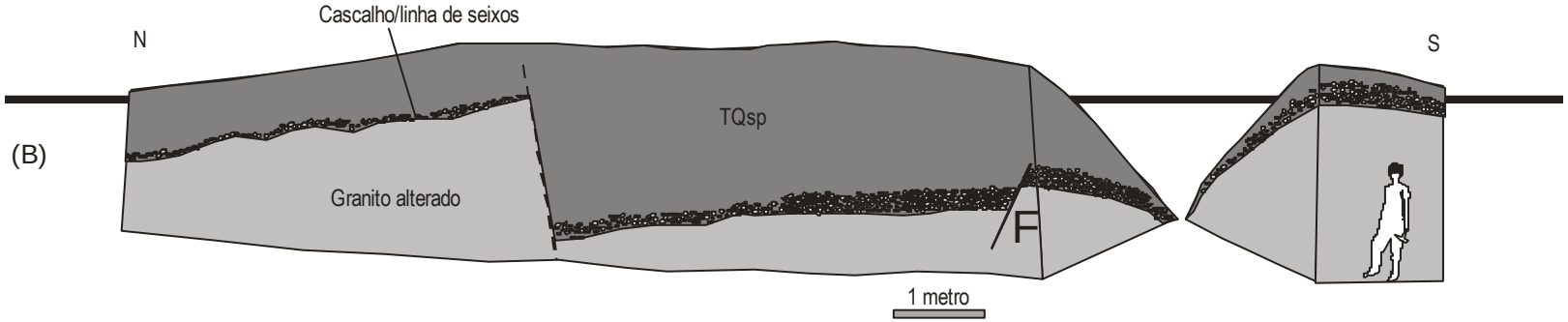
N30W left-hand and N70W right-hand oblique faults (important normal component)



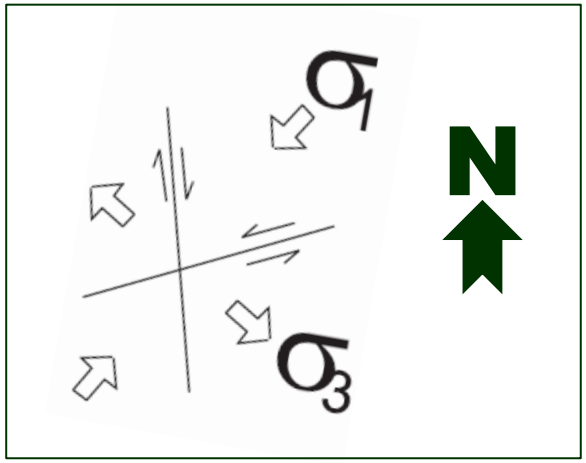


Tertiary to Quaternary covers bounded by stone lines (overlying weathered Precambrian granites)

Normal faults ~ N50E/60ºNW-SE displacing stone lines.



Extensional to strike-slip tectonic event

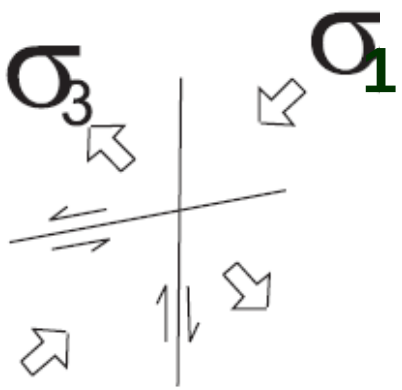


Fernandes & Mello 2005

SUMMARY OF THE MOST IMPORTANT BRITTLE TECTONICS EVENTS IN CAMPINAS AREA

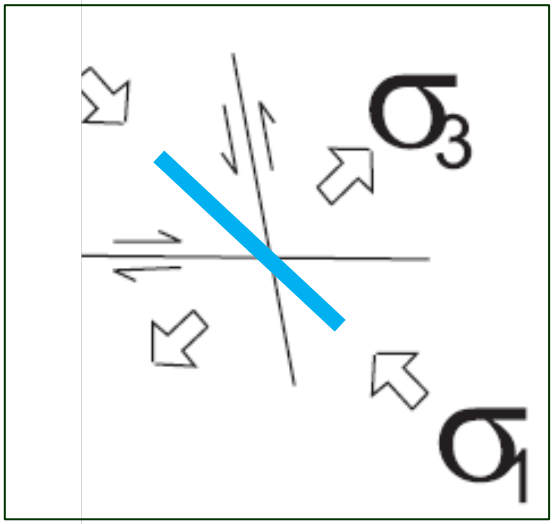
Lower Tertiary

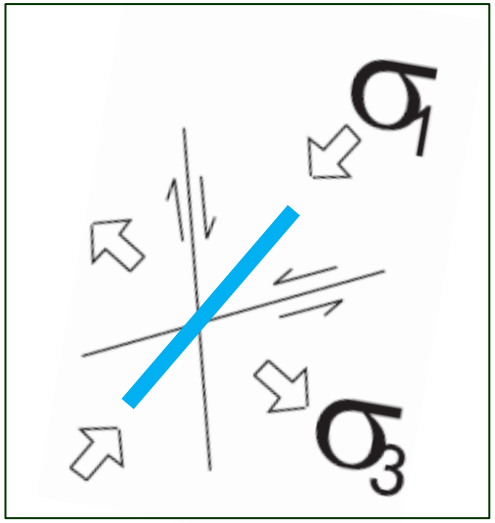
Permo-Carboniferous and Early-Cretaceous rocks



Quaternary

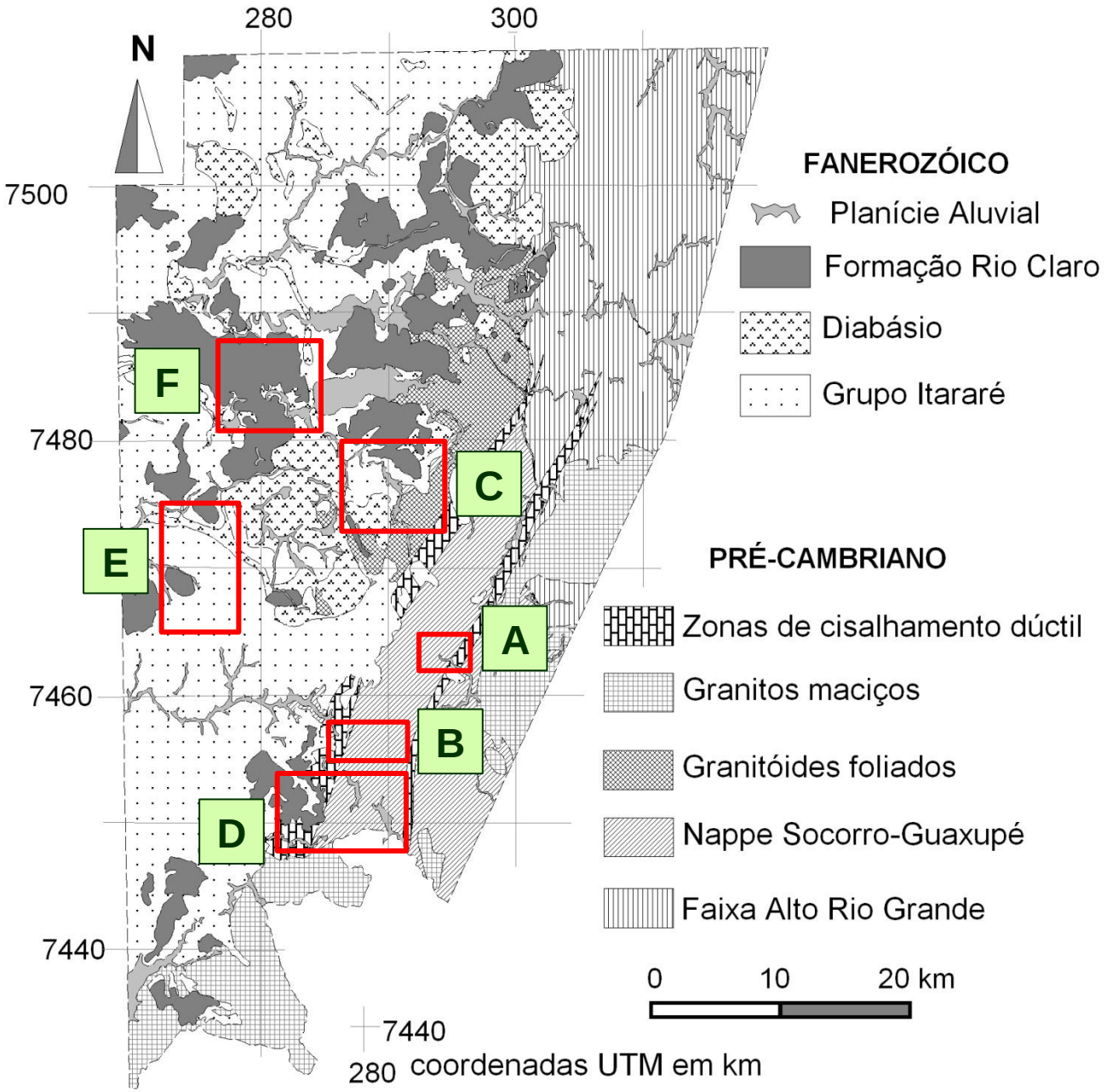
Miocene-Pliocene and Tertiary to Quaternary sediments





N

Areas where the production of wells (Q/s) was analysed with regard to the direction of the lineaments (1:25.000) to which they are close.

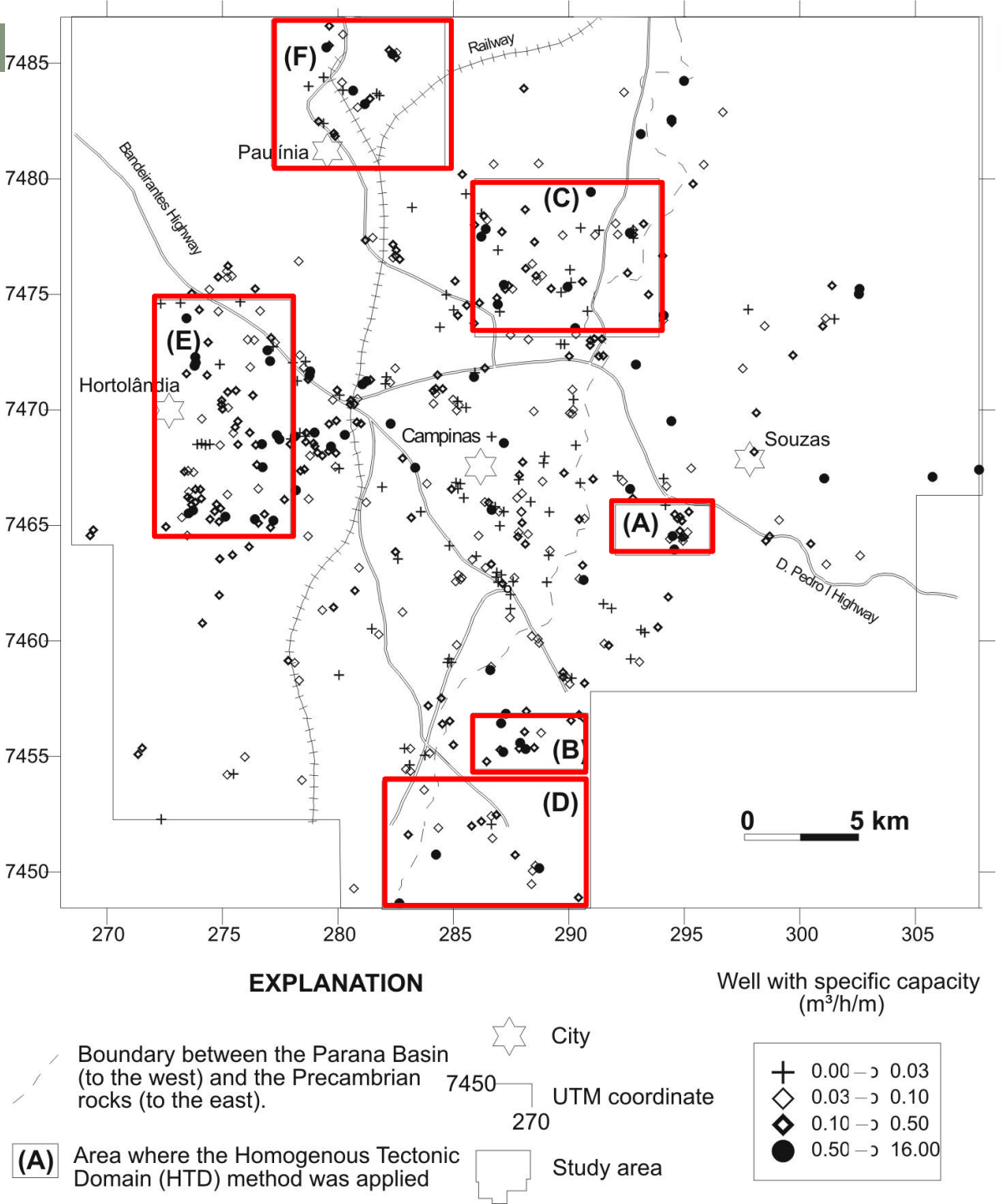


Fernandes 1997, Fernandes & Amaral 2002

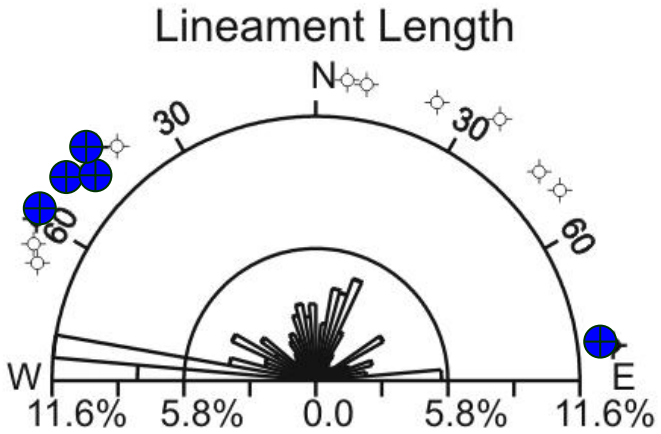
LOCATION OF WELLS

The density of well data in these areas were larger and the lineament pattern had a clear relationship with the trends of each Cenozoi event.

Fernandes (1997) e Fernandes & Rudolph (2001)

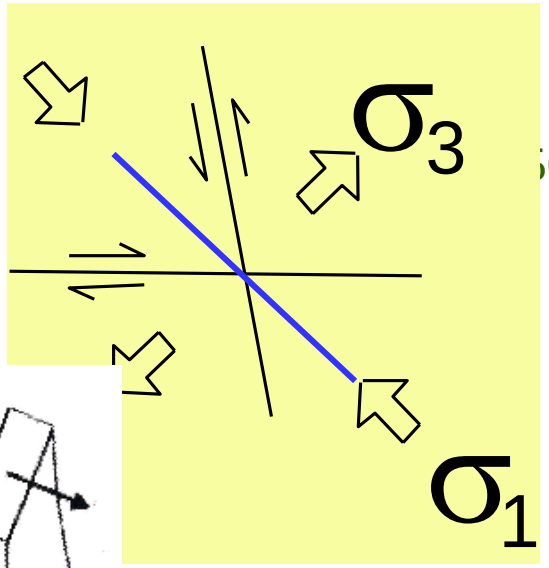


Lineament analysis on air-photos of 1:25.000 and 1:60.000 scales



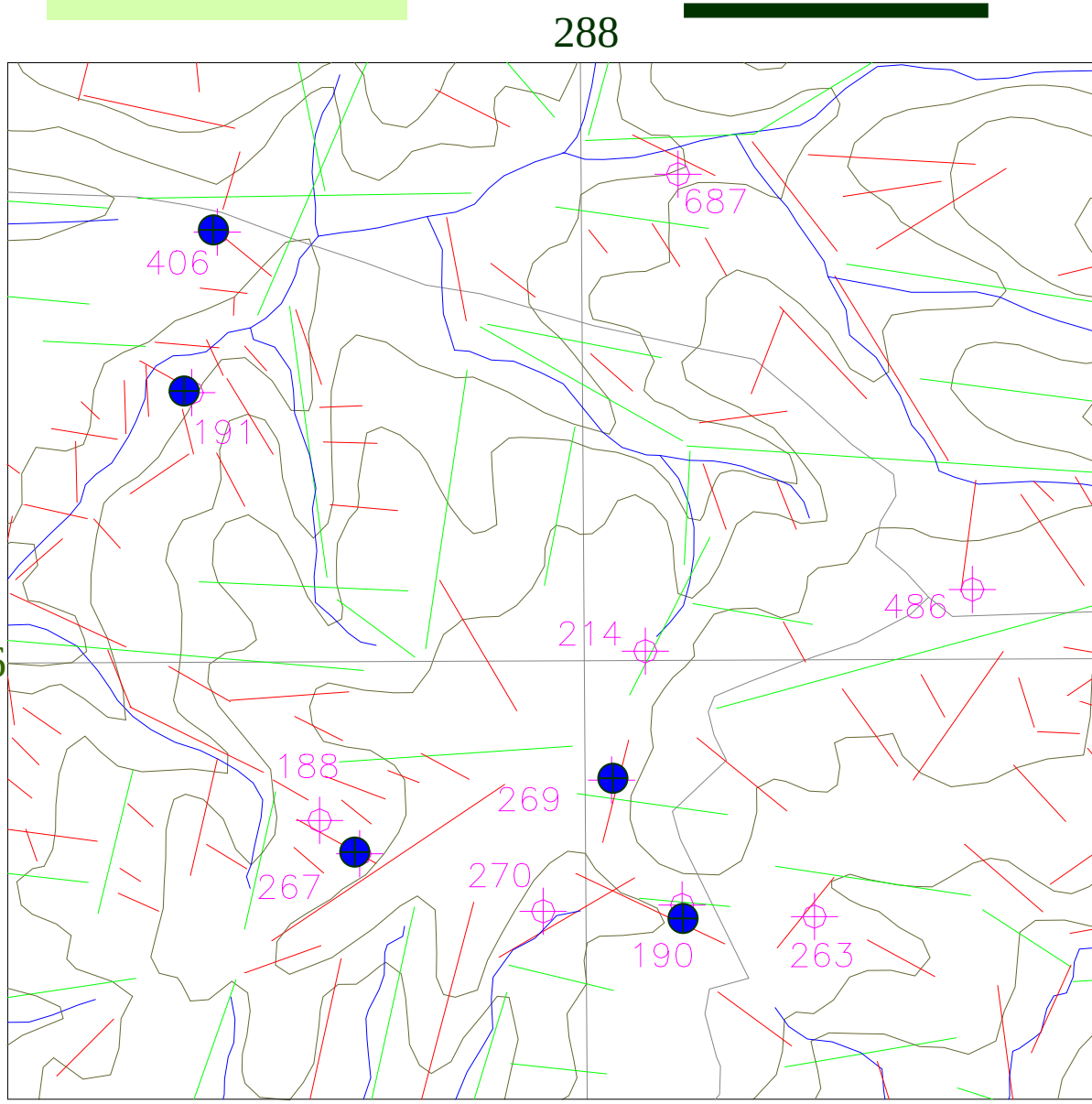
Angular Interval = 5°
Whole Length = 42,739 m

- Q/s > 0,5 m³/h/m

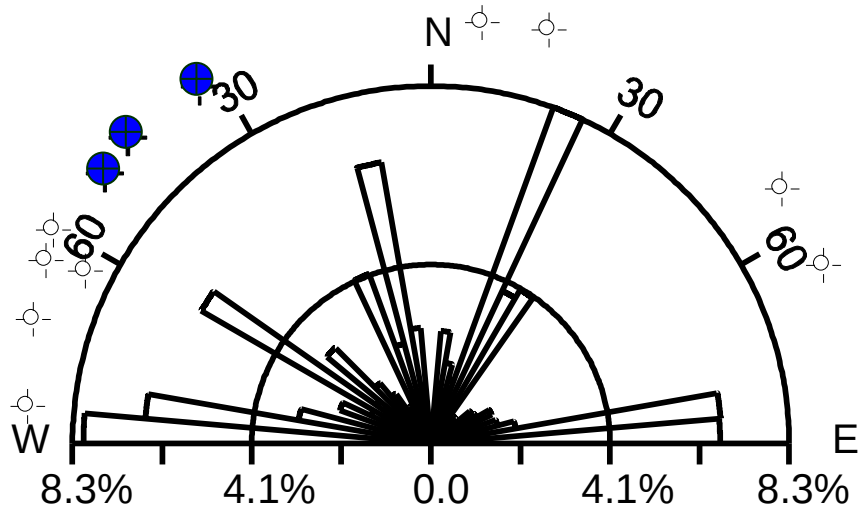


AREA A

1000 m

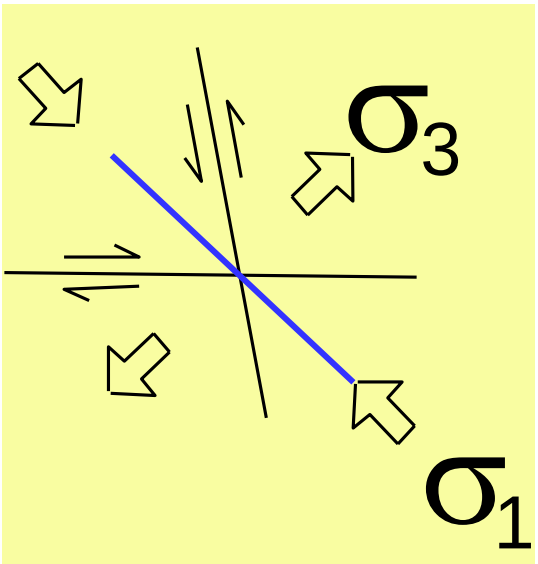


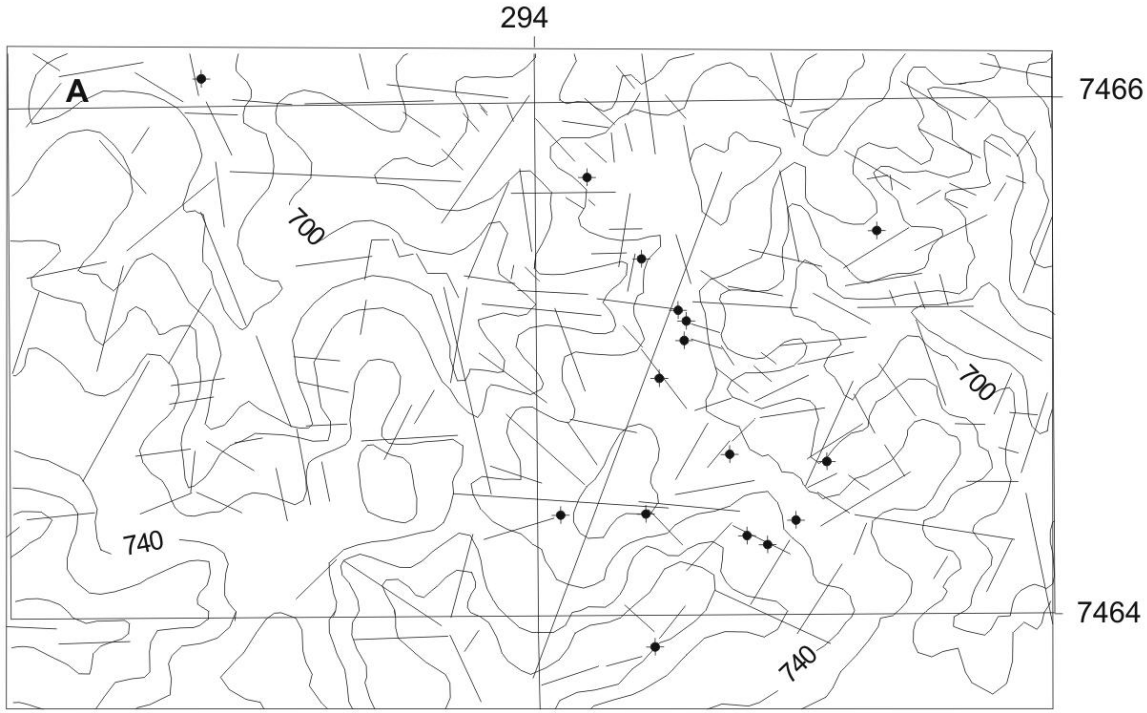
Fernandes (1997) e Fernandes & Rudolph (2001)



Q/s > 0,5 m³/h/m

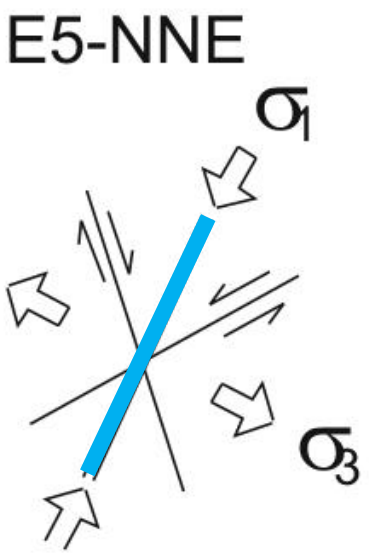
AREA B

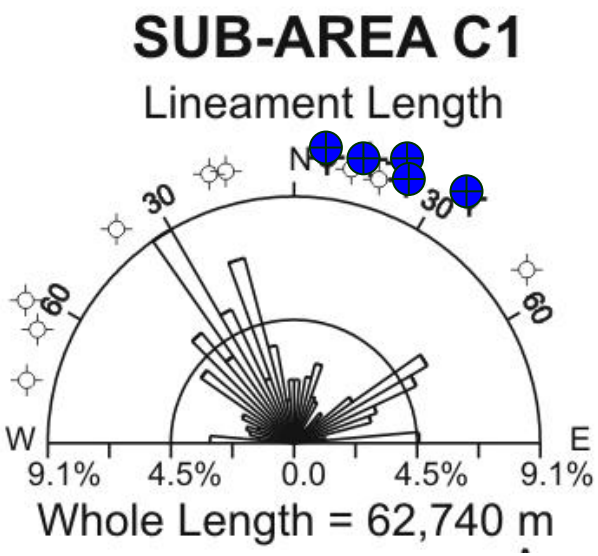


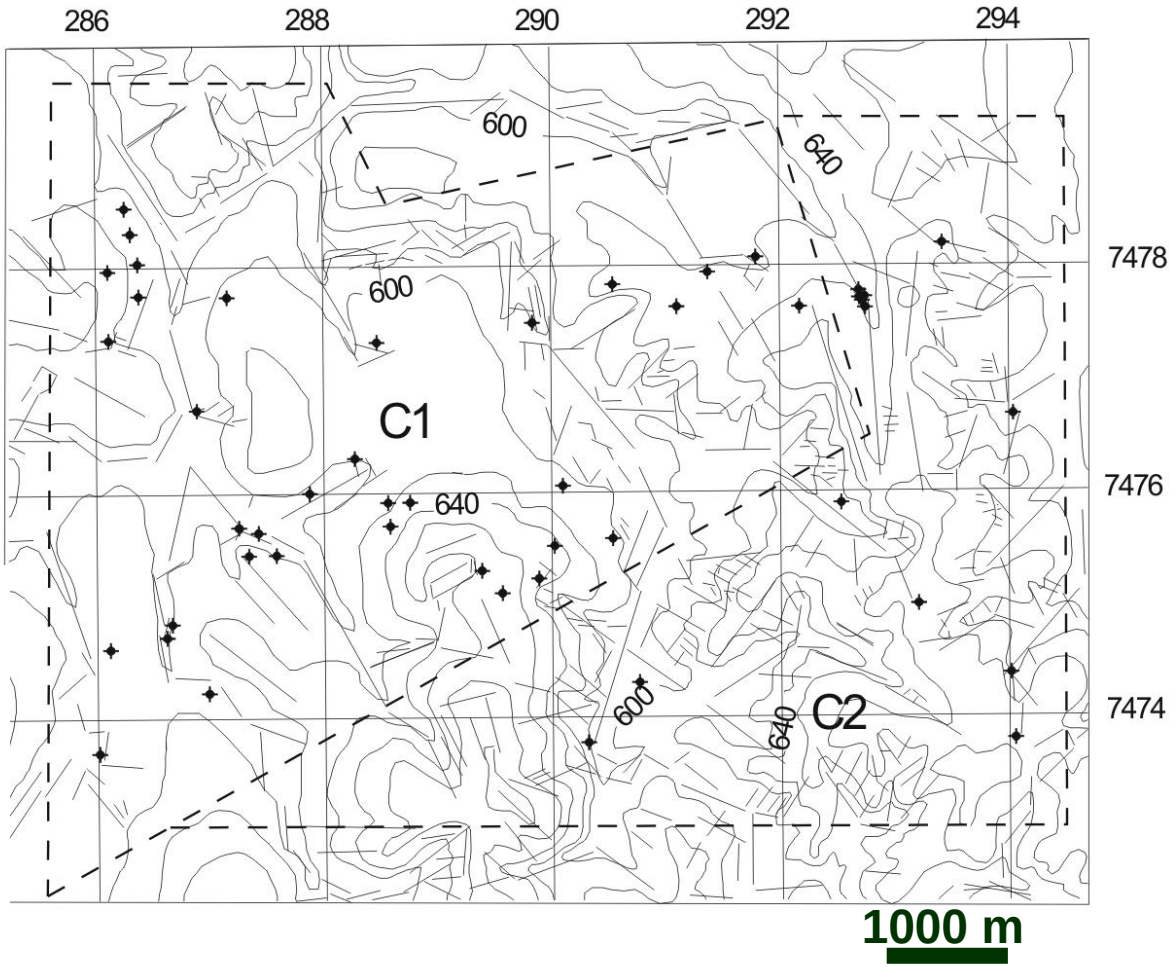


Fernandes (1997) e Fernandes & Rudolph (2001)

1000 m





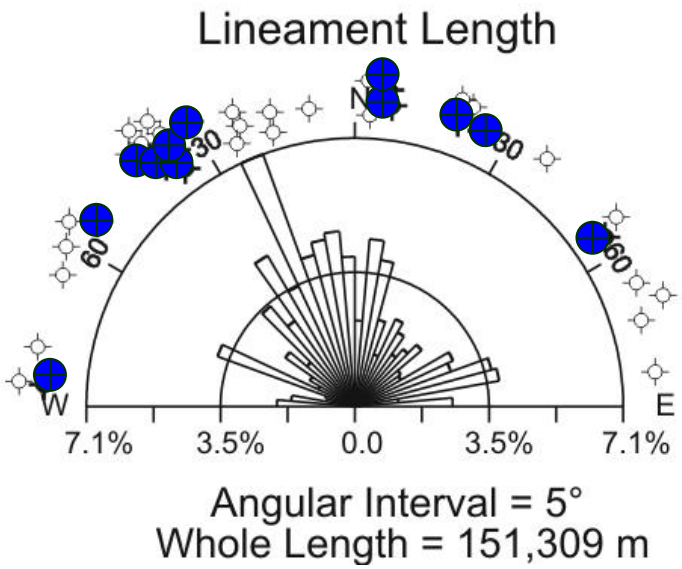


AREA C

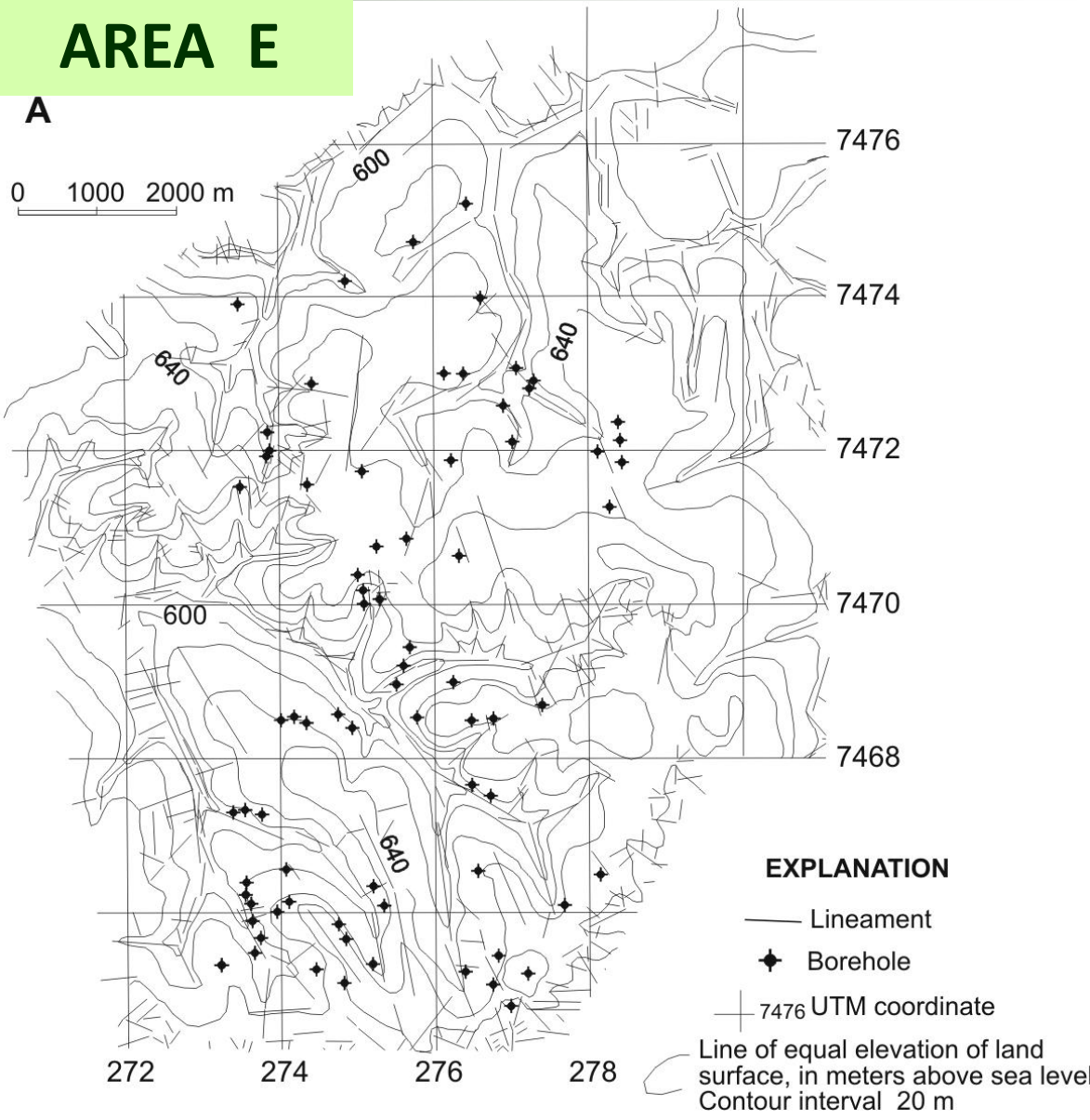
- Q/s > 0,5 $m^3/h/m$

Fernandes (1997) e Fernandes & Rudolph (2001)

AREA E

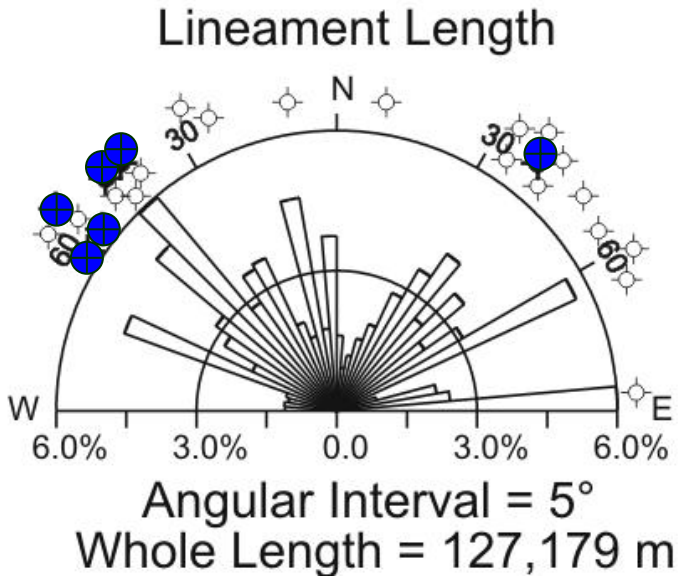


- Q/s > 0,5 $m^3/h/m$

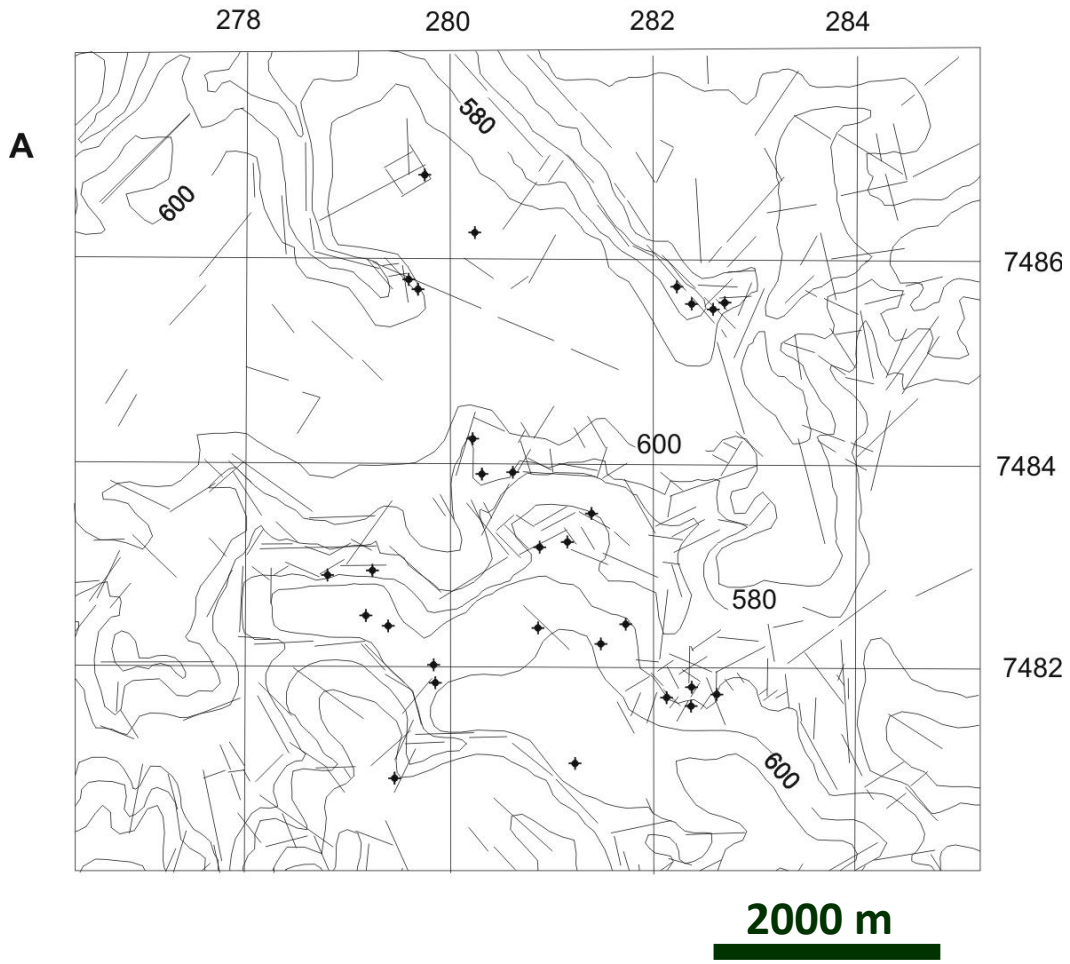


Fernandes (1997) e Fernandes & Rudolph (2001)

AREA F



- Q/s > 0,5 $m^3/h/m$



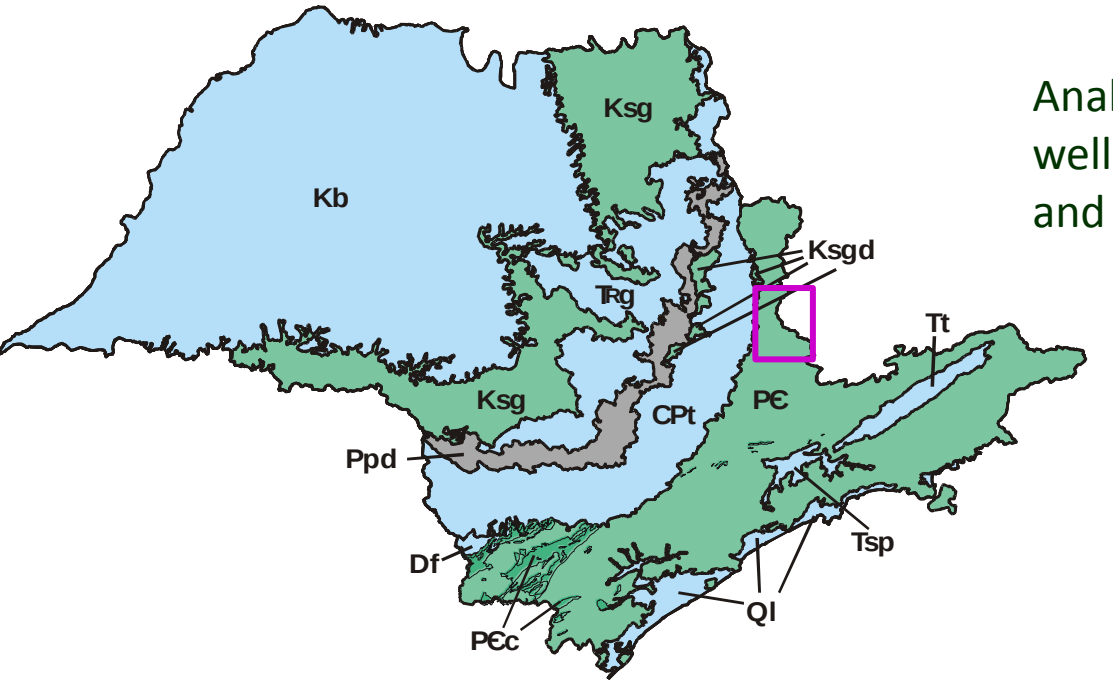
Fernandes (1997) e Fernandes & Rudolph (2001)

CONCLUSIONS

- Quaternary stress fields control the preferential flow of groundwater in Campinas area (NW and NE directions)

- Campinas area is not homogeneously affected by the Quaternary stress fields

LINDOIA STUDY CASE



Gneisses and granites
Precambrian

Madrucci 2004

OBJECTIVE

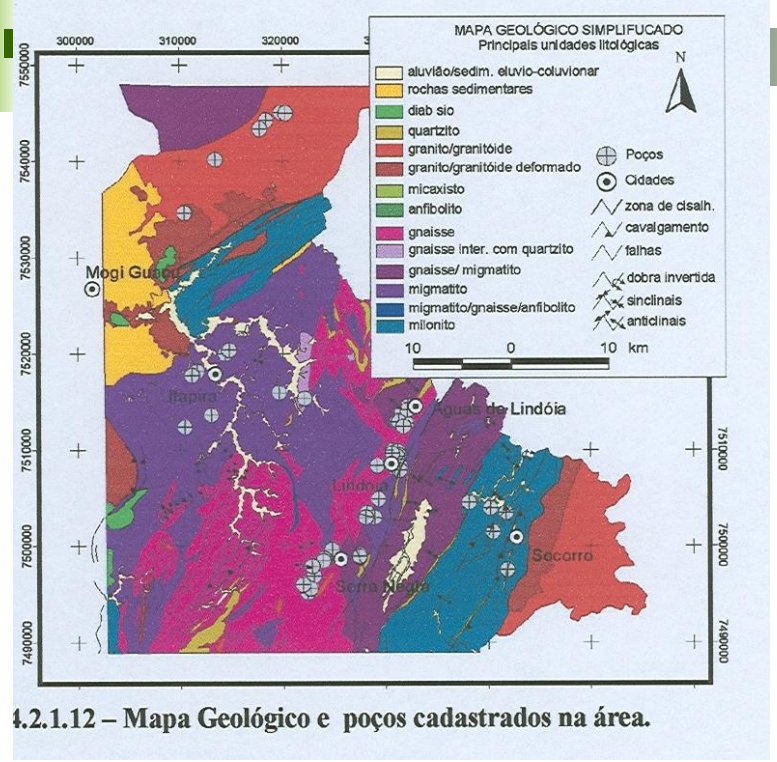
Analysing the correlation between well production (specific capacity) and lineament parameters

METHODS

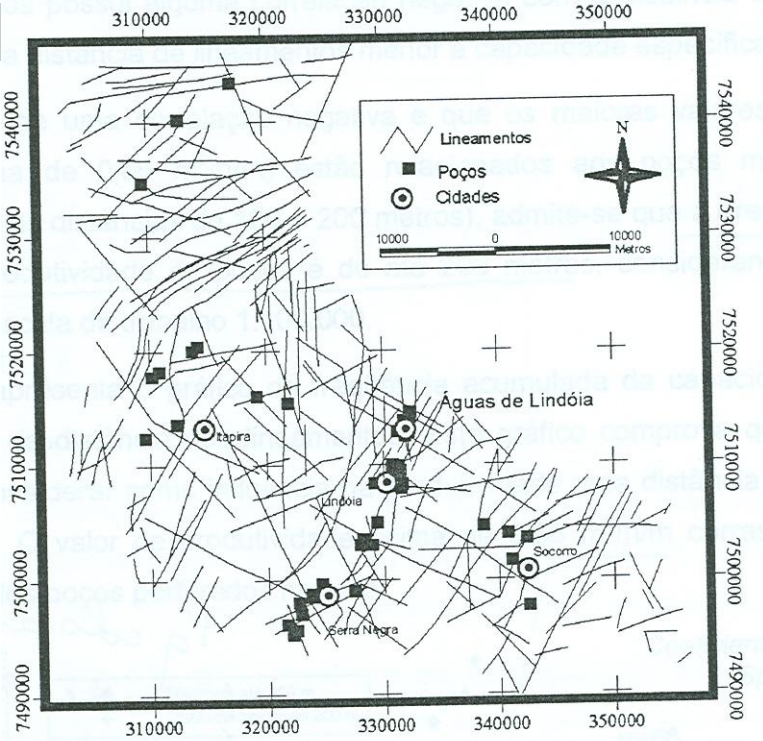
- Lineament analysis (1:100.000)
- Analysis of the production of wells with regard to lineament direction, intersections and densities using GIS

REGIONAL SCALE

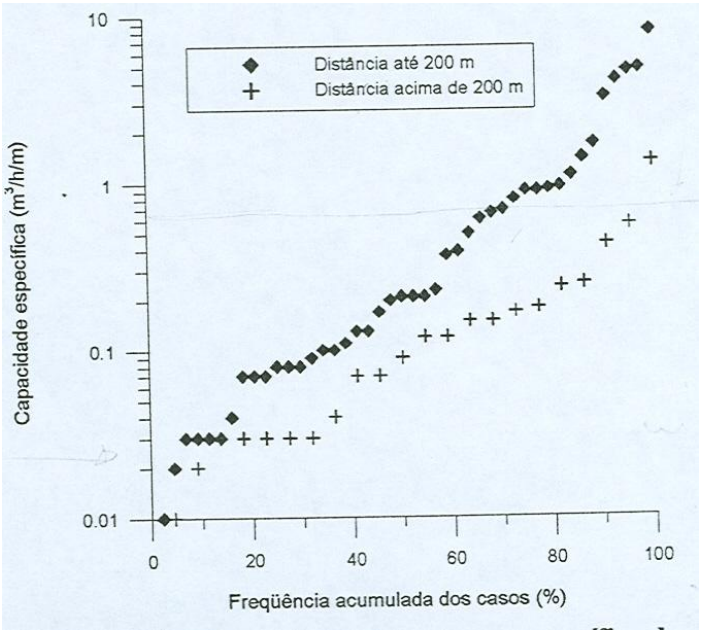
- 1:100.000 for the entire area



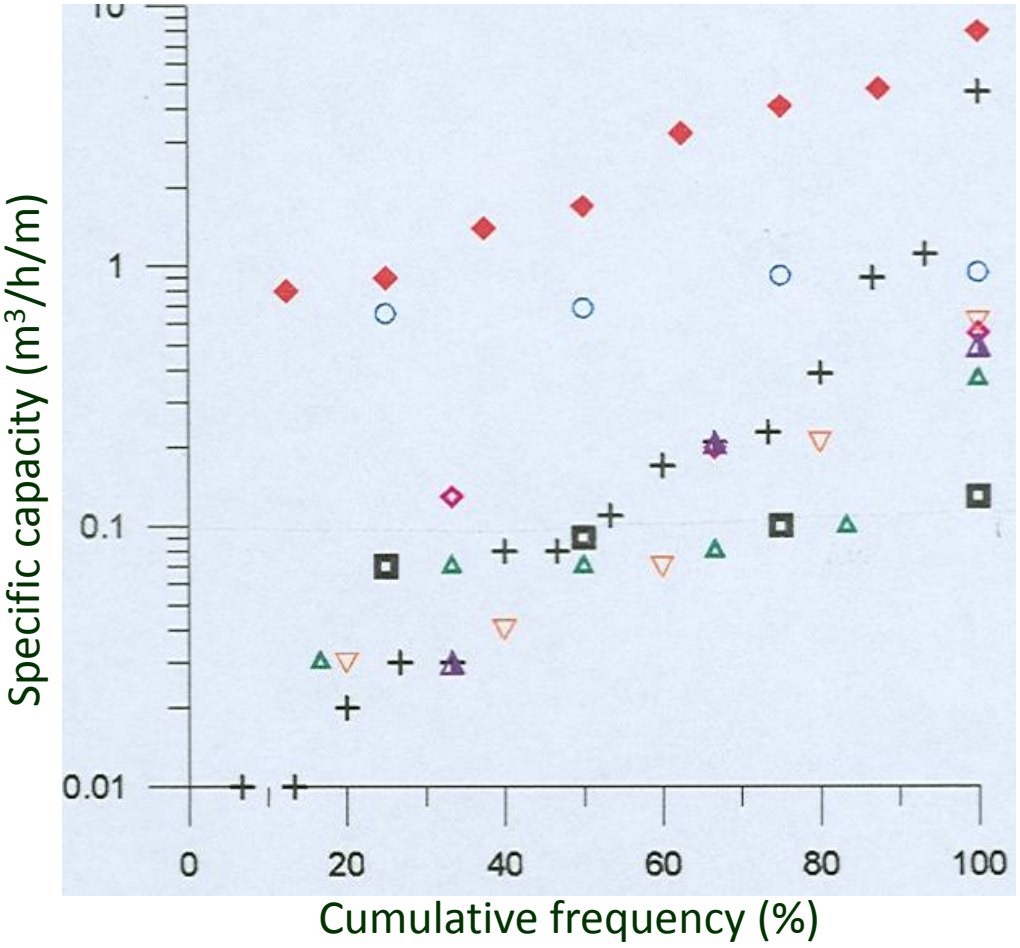
4.2.1.12 – Mapa Geológico e poços cadastrados na área.



Madrucci (2004)



Lineament direction and specific capacity

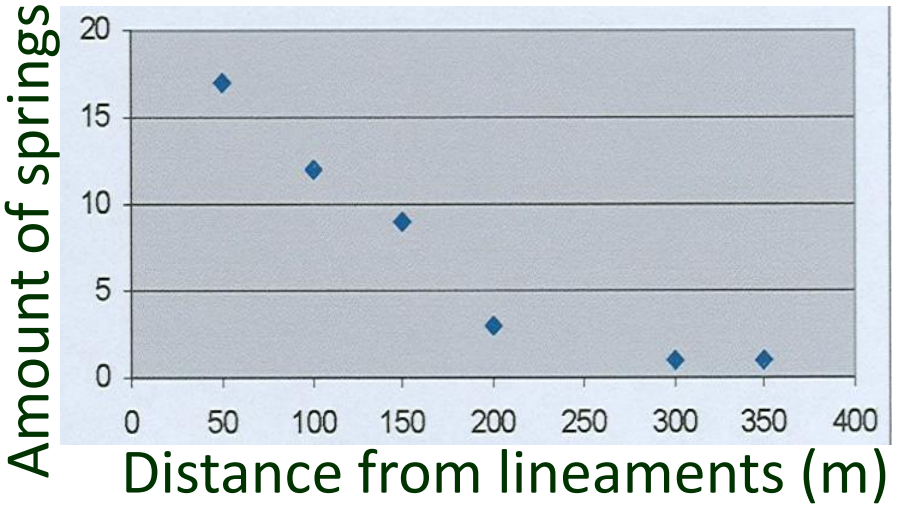


Lineament direction

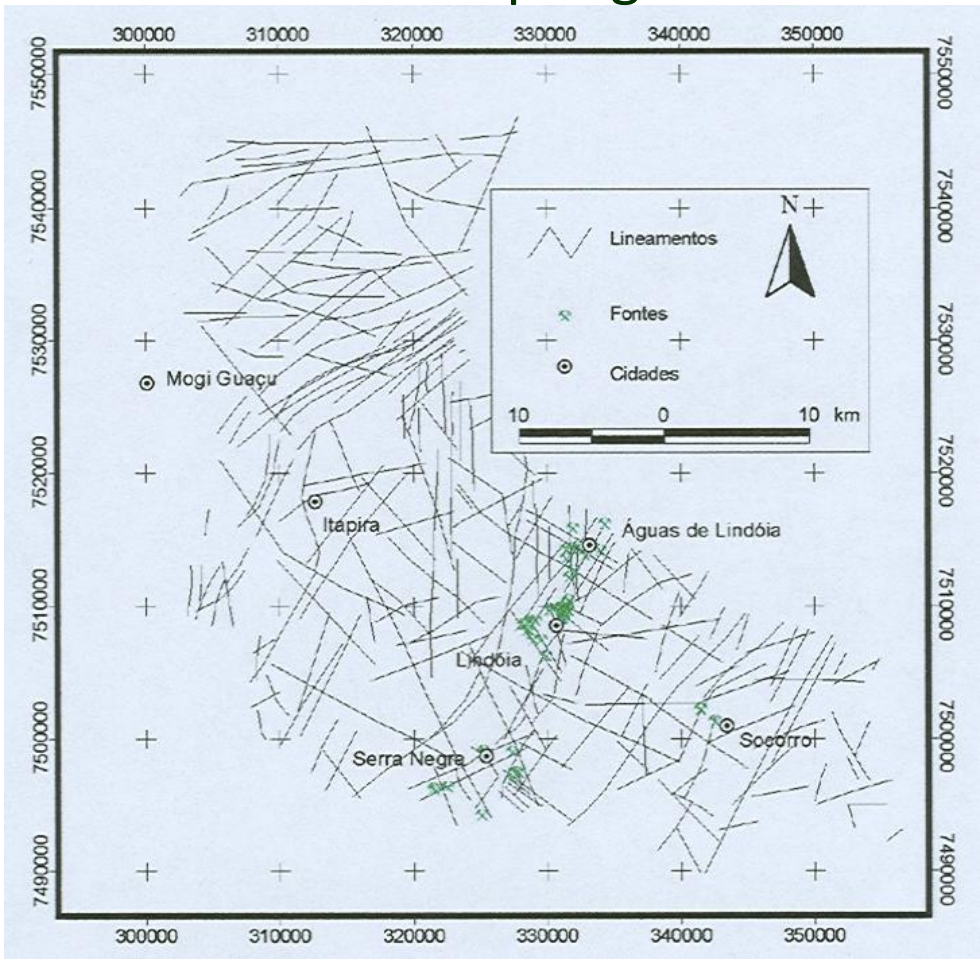
- NE
- NW
- EW
- NE e NW
- NE e EW
- NE e NS
- NW e NS
- NW e EW

Madrucci (2004)

Springs are distributed along NNE-NE lineaments



Lineaments and spring ocurrence

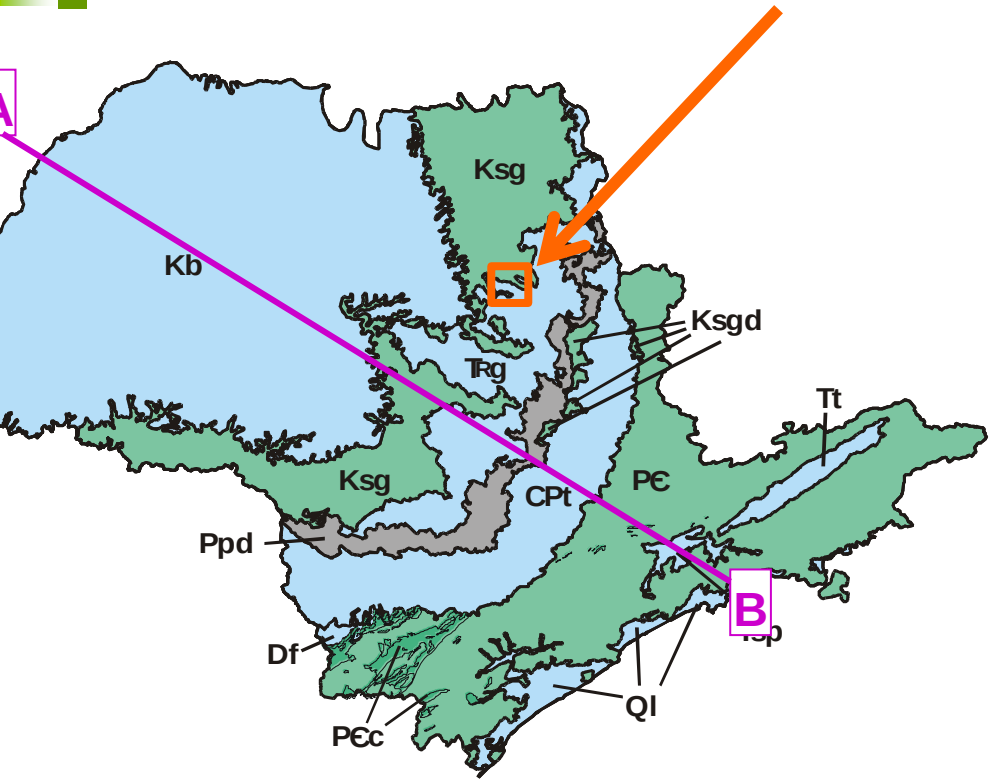


Madrucci (2004)

CONCLUSIONS

- In Lindoia area the preferential groundwater pathways are probably controled NE trending fractures (related to a Quaternary event where $\sigma 1$ is NE trending

RIBEIRÃO PRETO STUDY CASE



OBJECTIVE

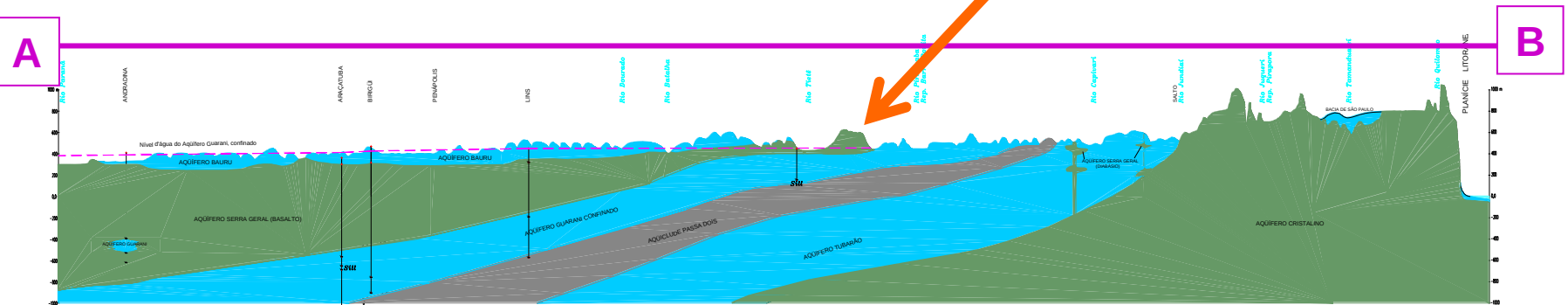
Is there recharge of the Guarani Aquifer through the basalts?
What are the preferential pathways for gw flow in the basalts?

METHODS

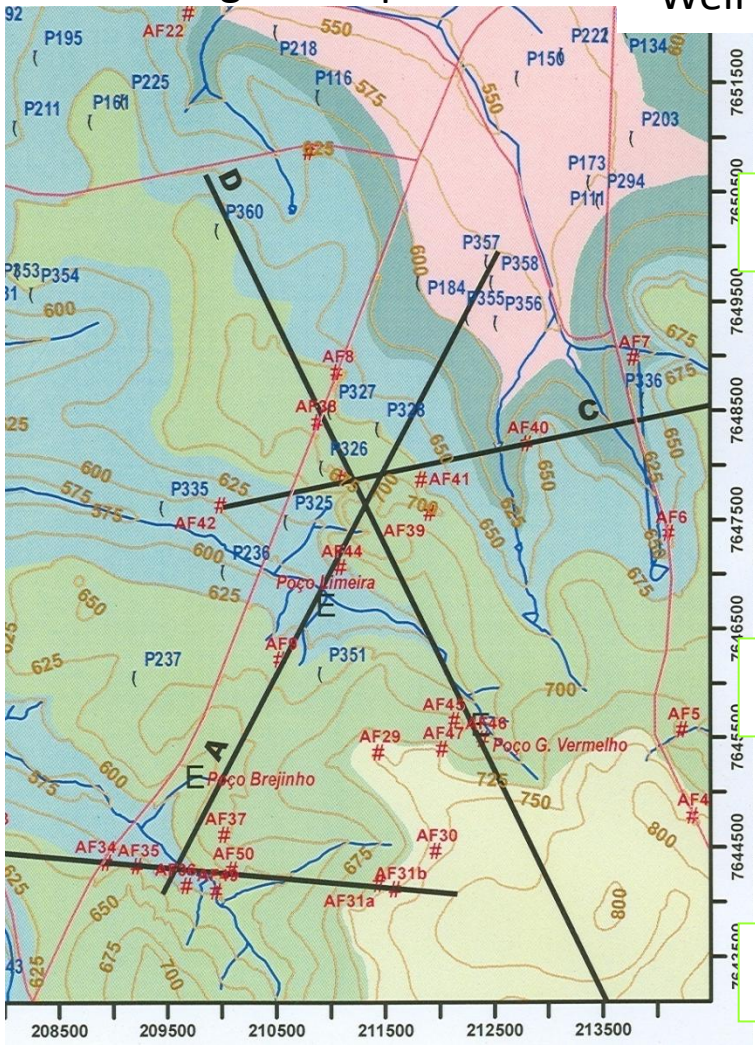
- Geological mapping (1:25.000)
- Detailed fracture and tectonic analysis
- Well geophysical logging
- Hydraulic tests (packers)
- Chemical and isotope analysis

INTERMEDIATE TO LOCAL SCALE

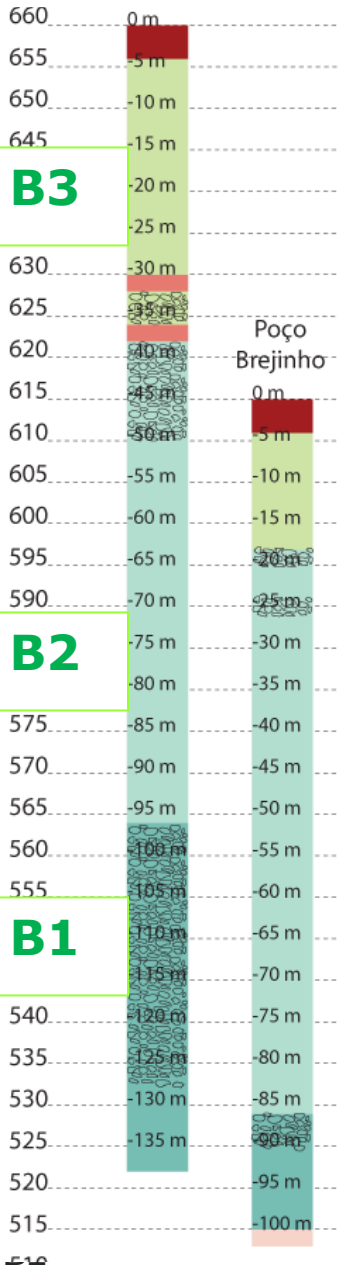
- 1:25.000 or more



Geological map



Well lithological profile



Formação Serra Geral

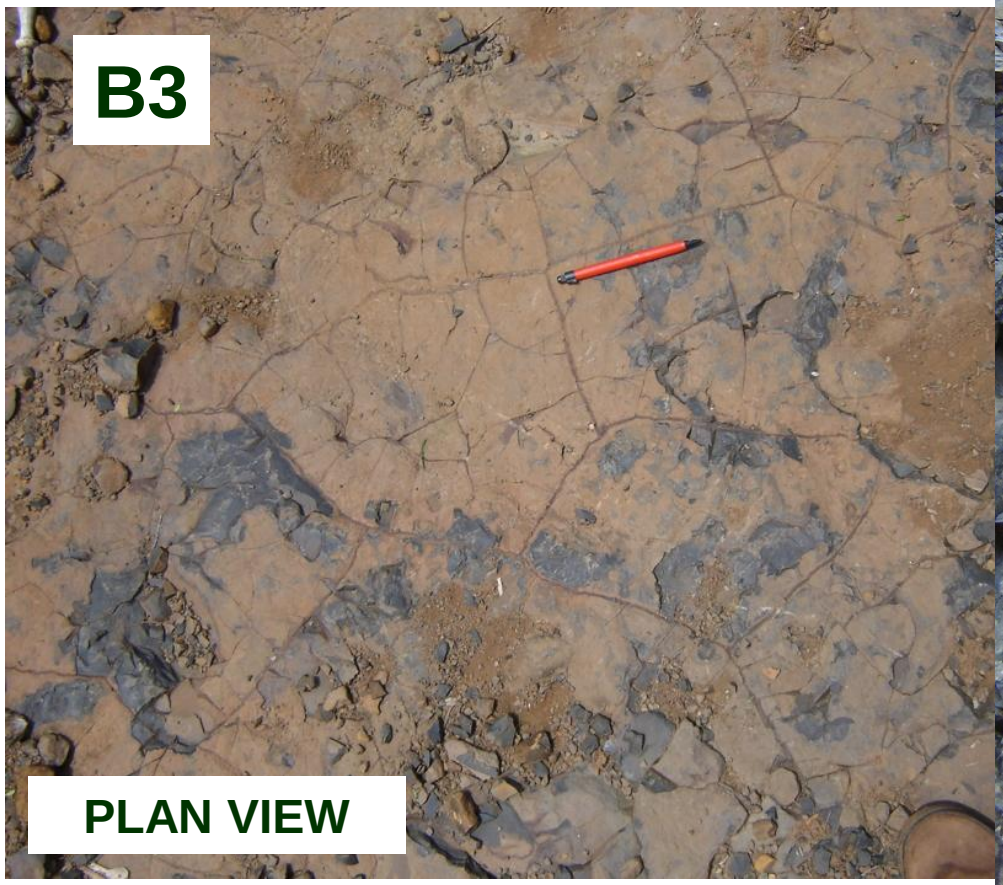
- Basalto 4 - B4
- Basalto 3 - B3
- Basalto 2
- Basalto 1

VERTICAL AND HORIZONTAL FRACTURES

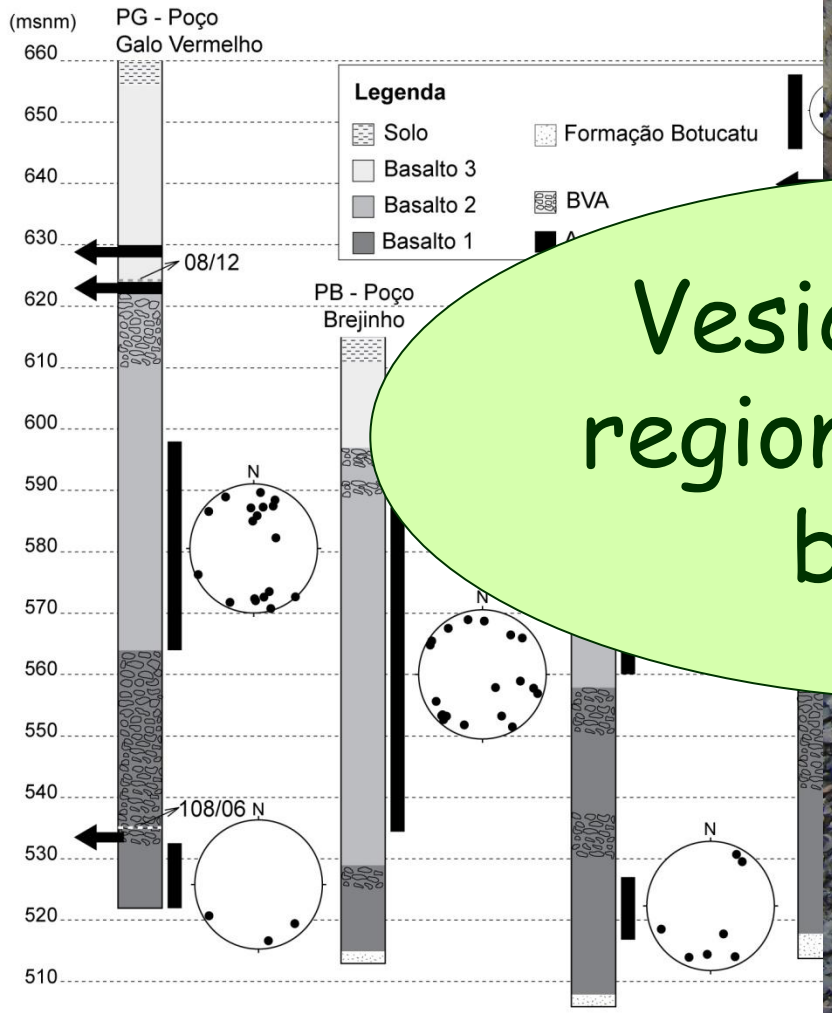
Close to the surface

VERTICAL COOLING FRACTURES

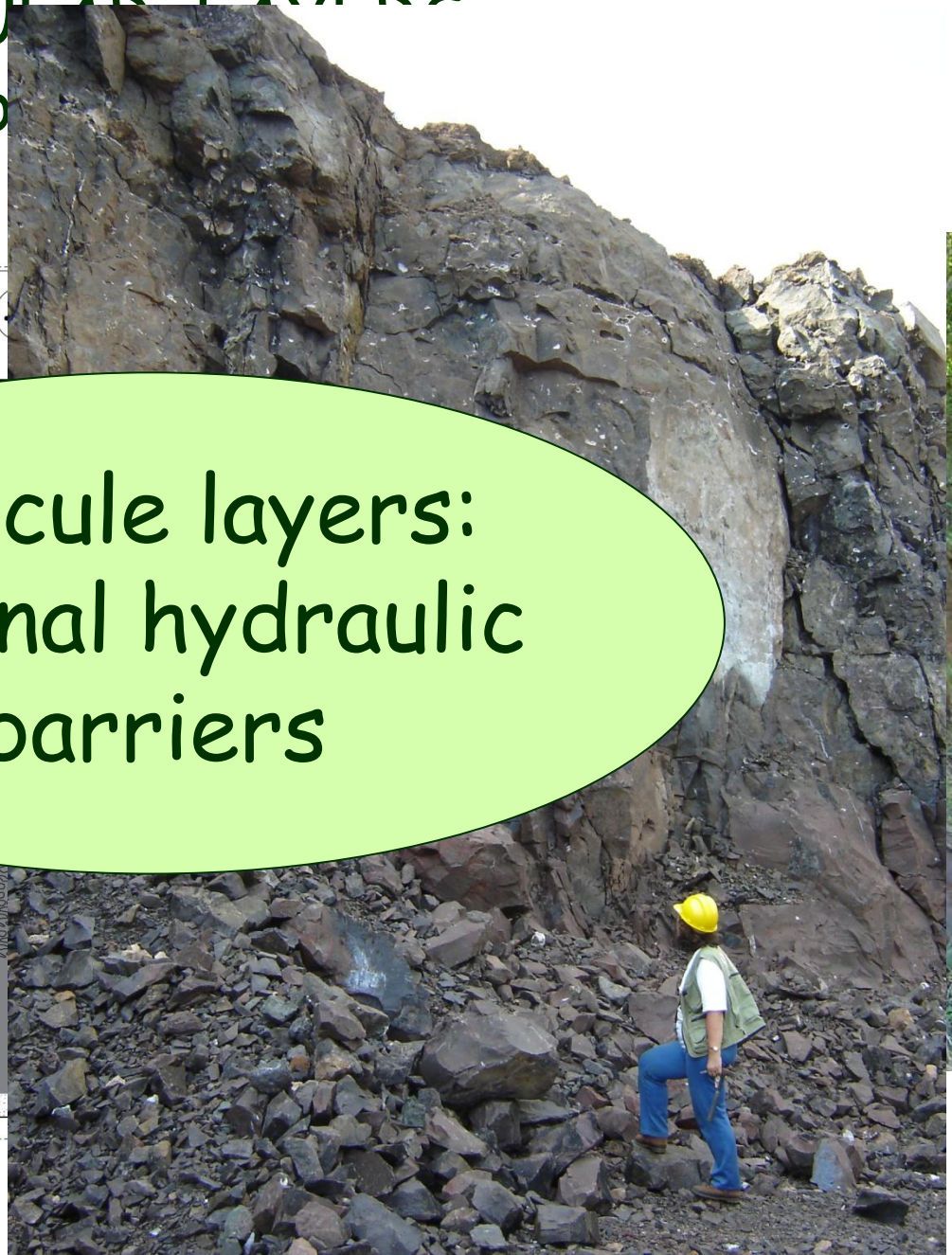
Infilled



VESICU
Few and disco



Vesicule layers: regional hydraulic barriers



CONTINUOUS AND HORIZONTAL FRACTURES

They constitute the preferential flow pathways
Up to the depth of 40-50 m
They occur mainly at contacts

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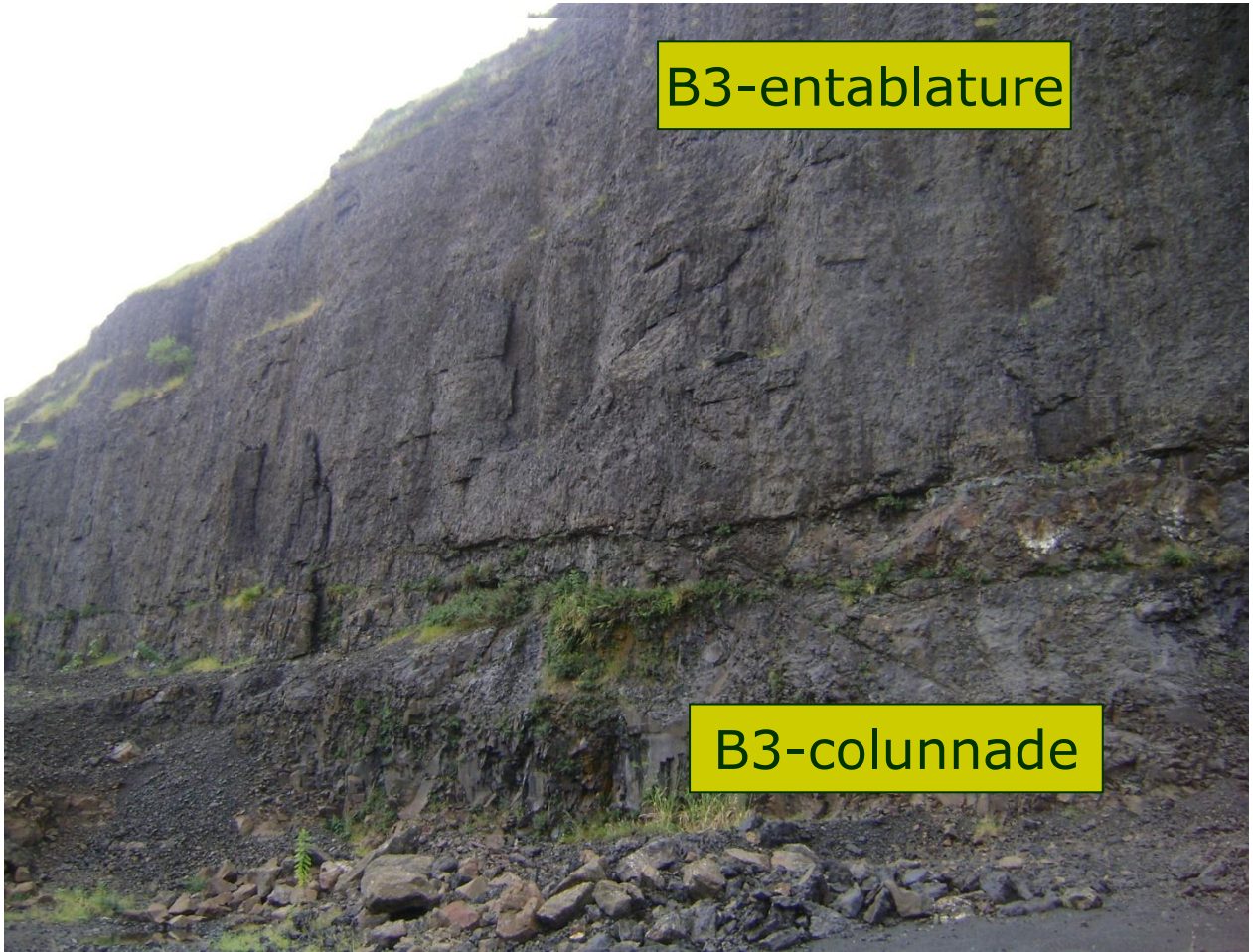
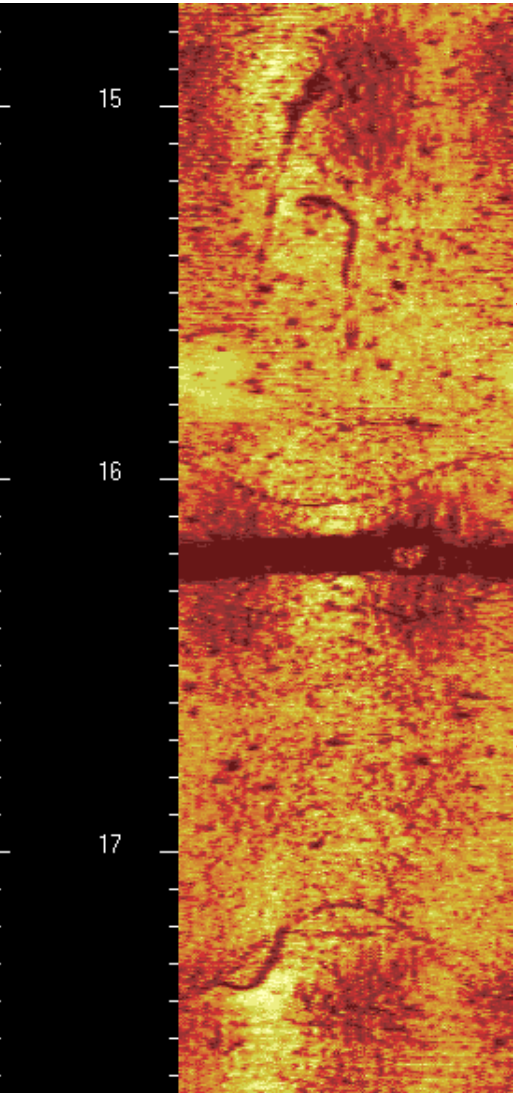
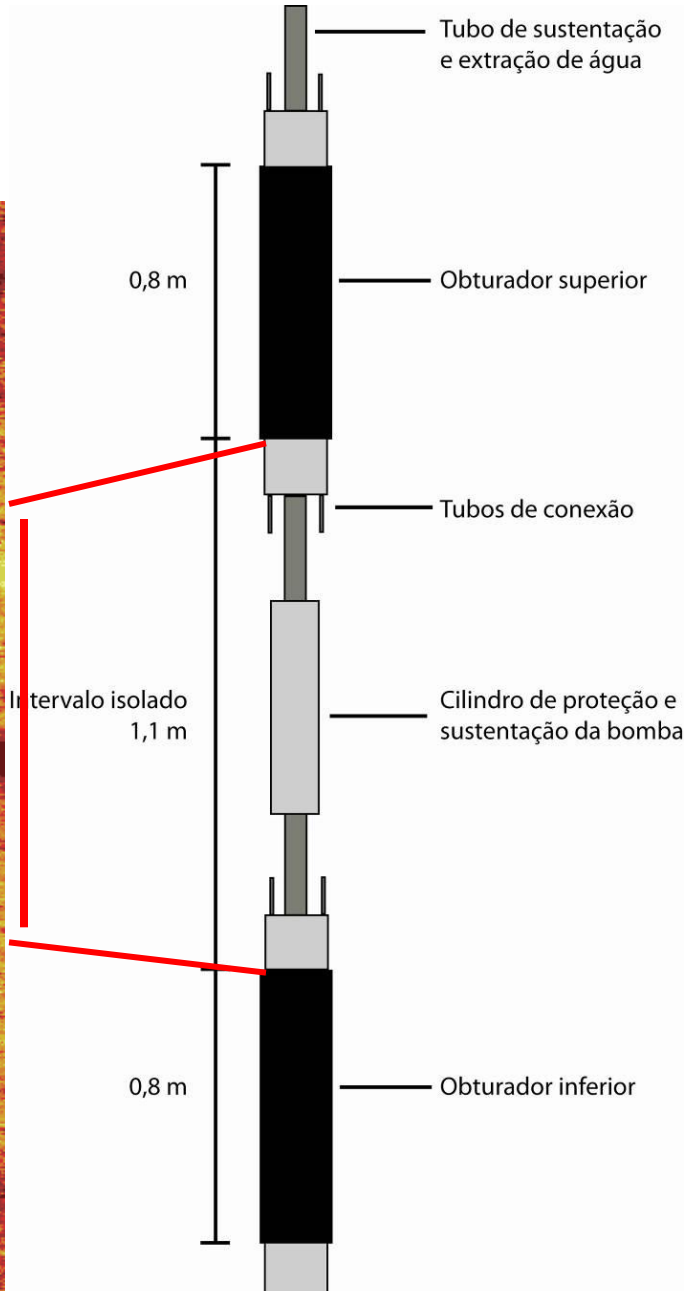


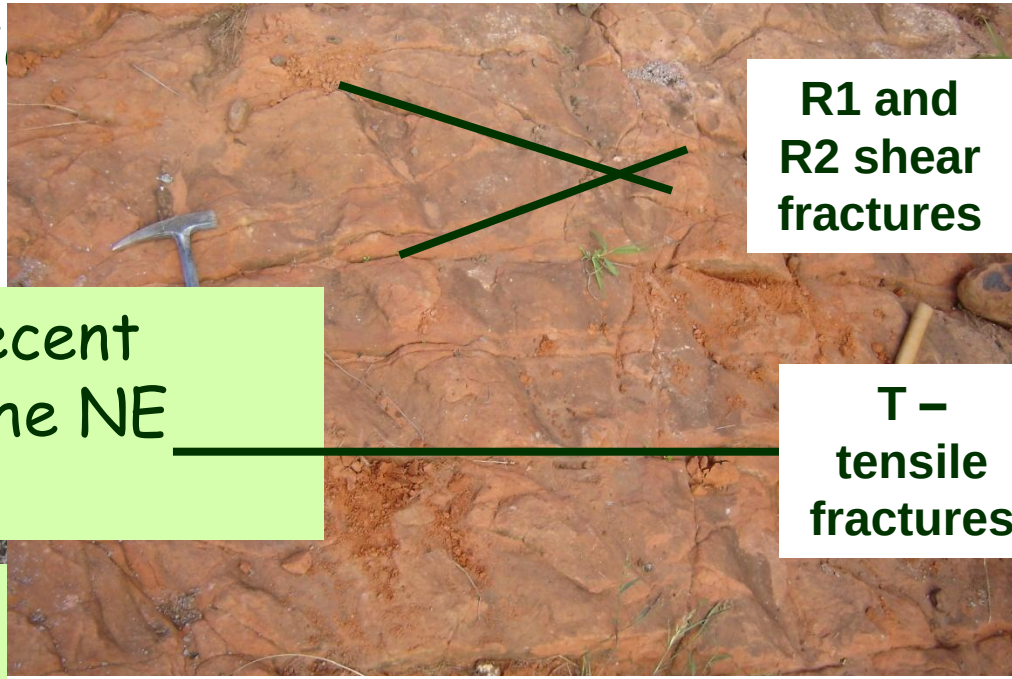
TRANSMISSIVE SUBHORIZONTAL FRACTURES

B2 – 15 to 26 m deep





WHAT ABOUT THE TECTONIC SUBVERTI



Intertrappe sandstones - NS to N40E

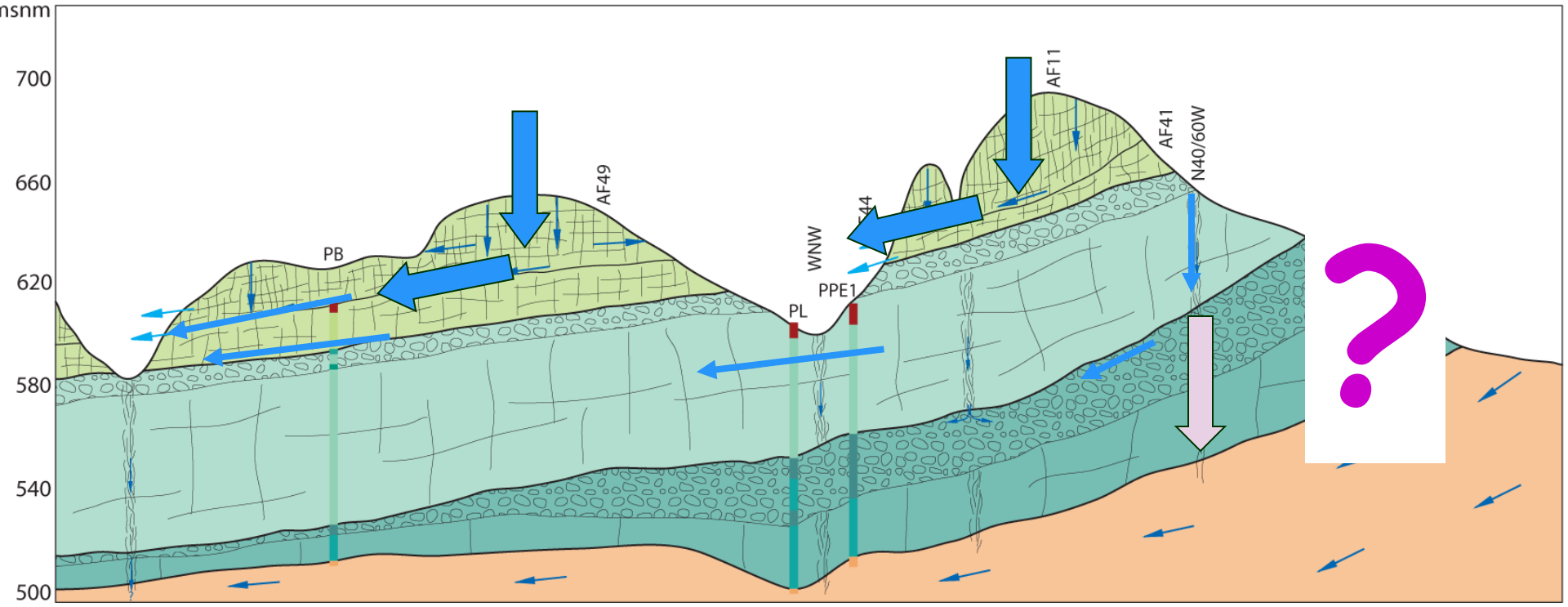
There is indication of recent preferential flow along the NE direction

Do the NE fractures cut through all the basalt stack?

B3 - N50E and N40W shear fractures

B1 - N60E shear fractures

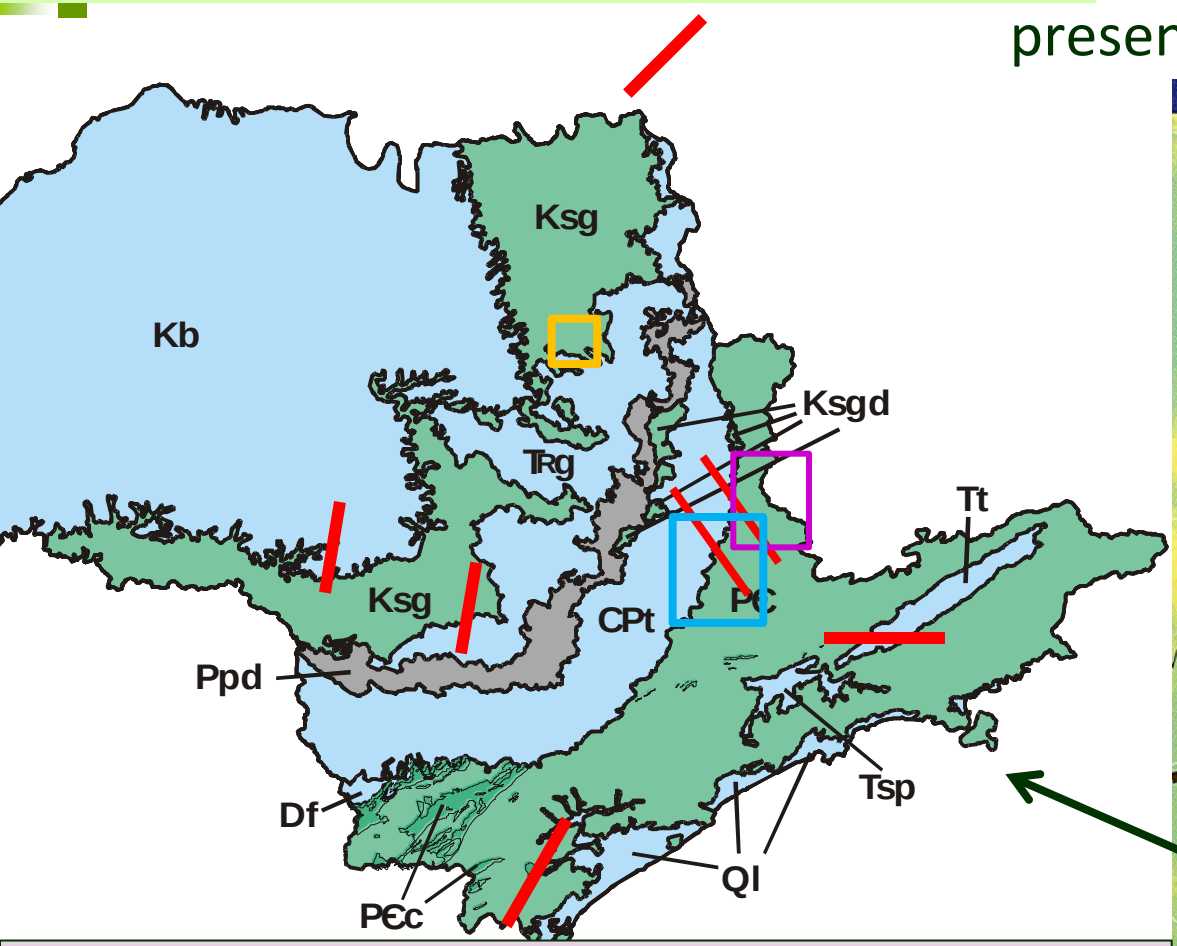
CONCEPTUAL MODEL



Is there vertical recharge through the basalt?

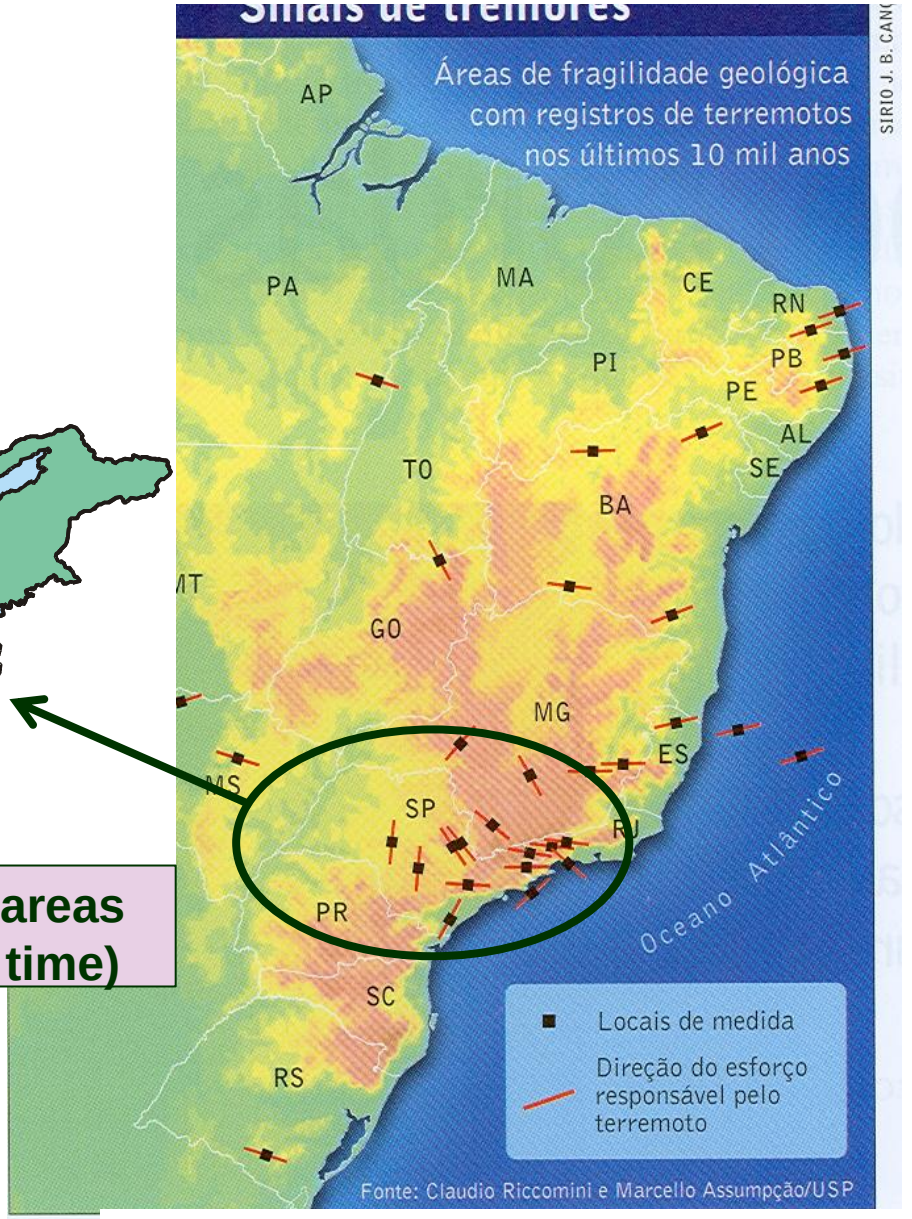
It remains a question, but the NE trending fractures may be the ones that control the flow at the present time

São Paulo State (study areas and SHmax) sil: direction of the SHmax at th present time (earthquackes)



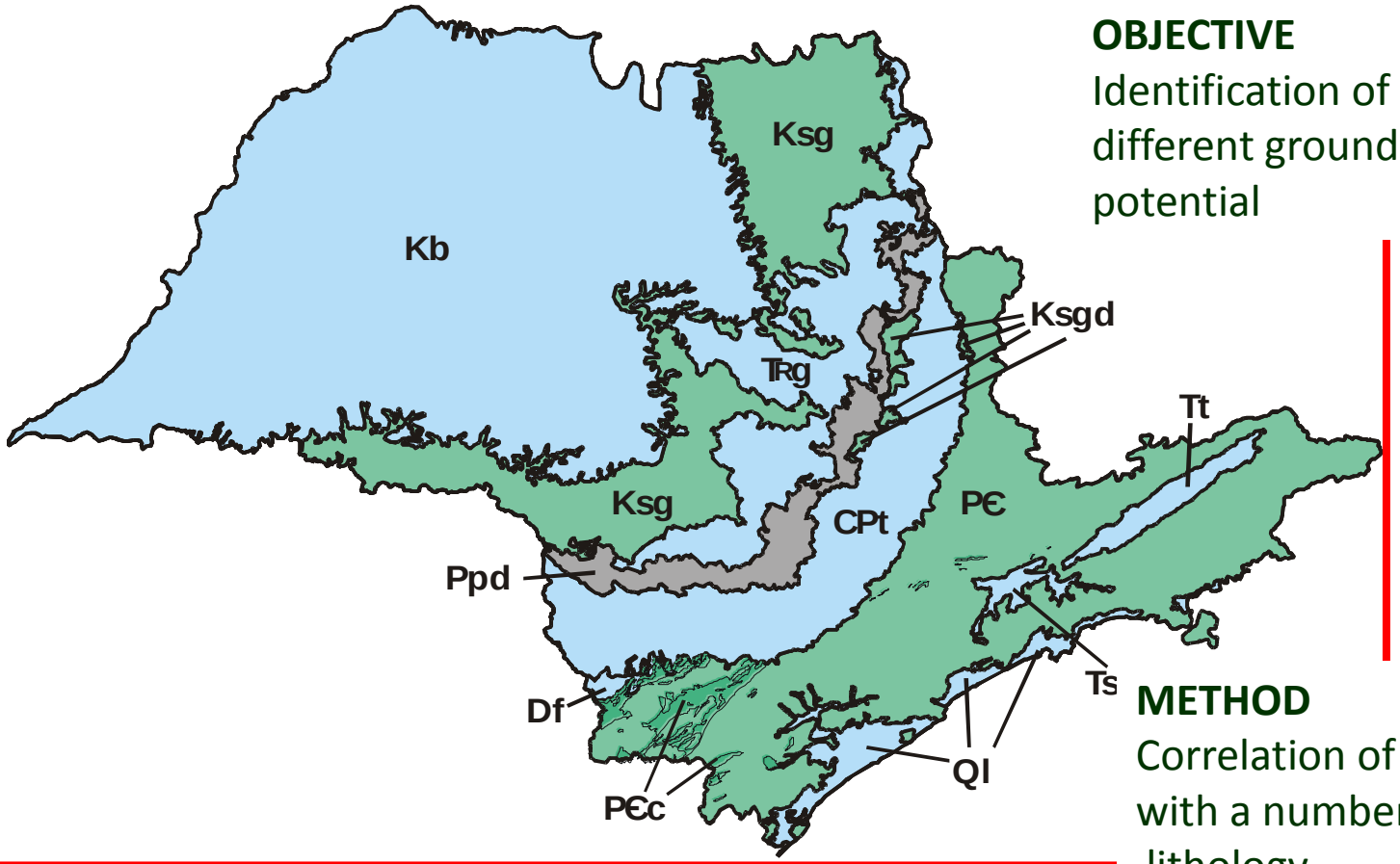
Direction of preferential flow in the study areas (fractures under extension at the present time)

- Campinas = 30-60W and NE
- Lindoia = NE
- Ribeirão Preto = NE



Revista da Fapesp (pag 57, julho, 2002)

STATE OF SÃO PAULO STUDY CASE



OBJECTIVE

Identification of areas with a different groundwater exploitation potential

METHOD

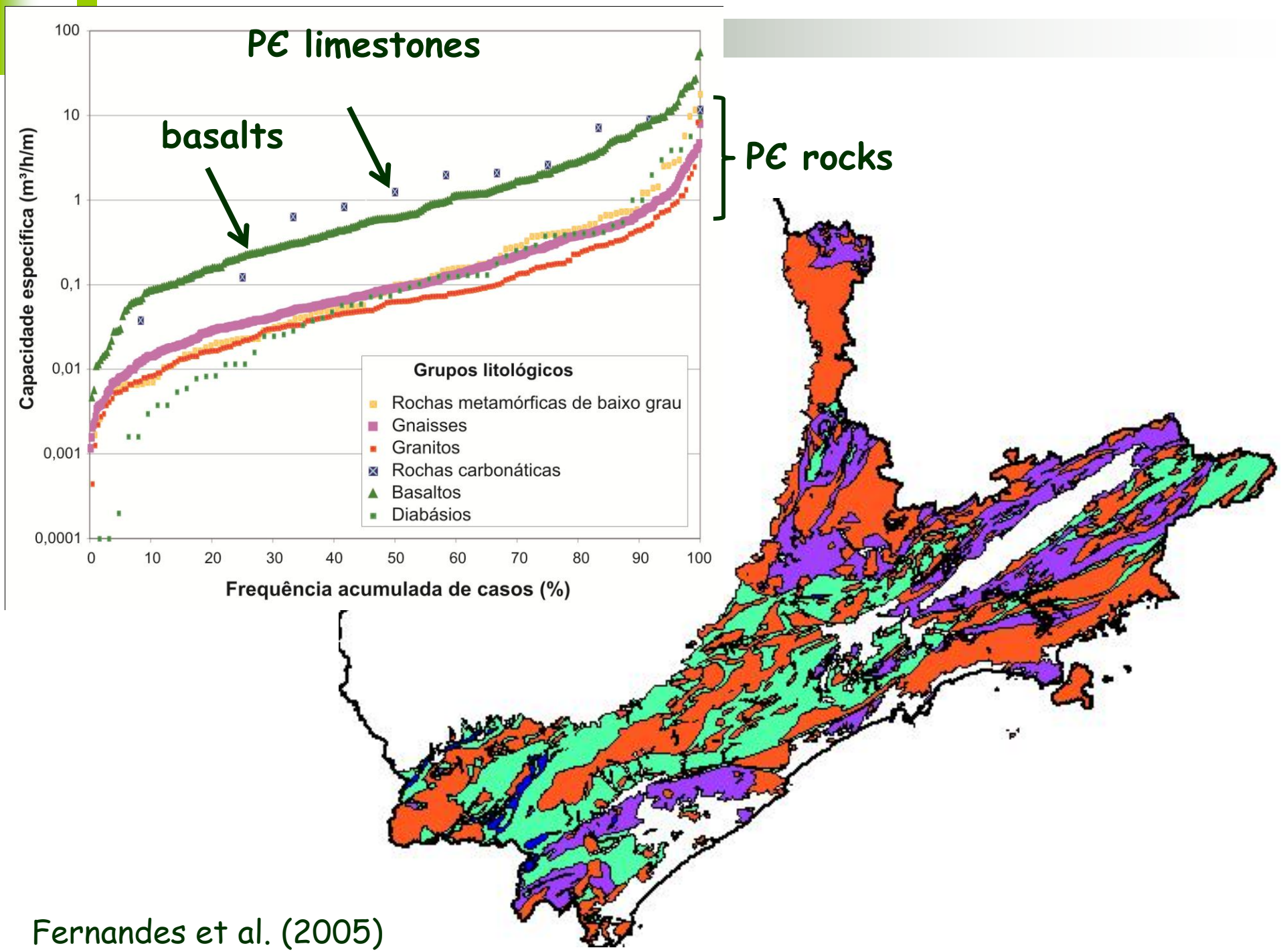
Correlation of well specific capacity with a number or factors:

lithology,

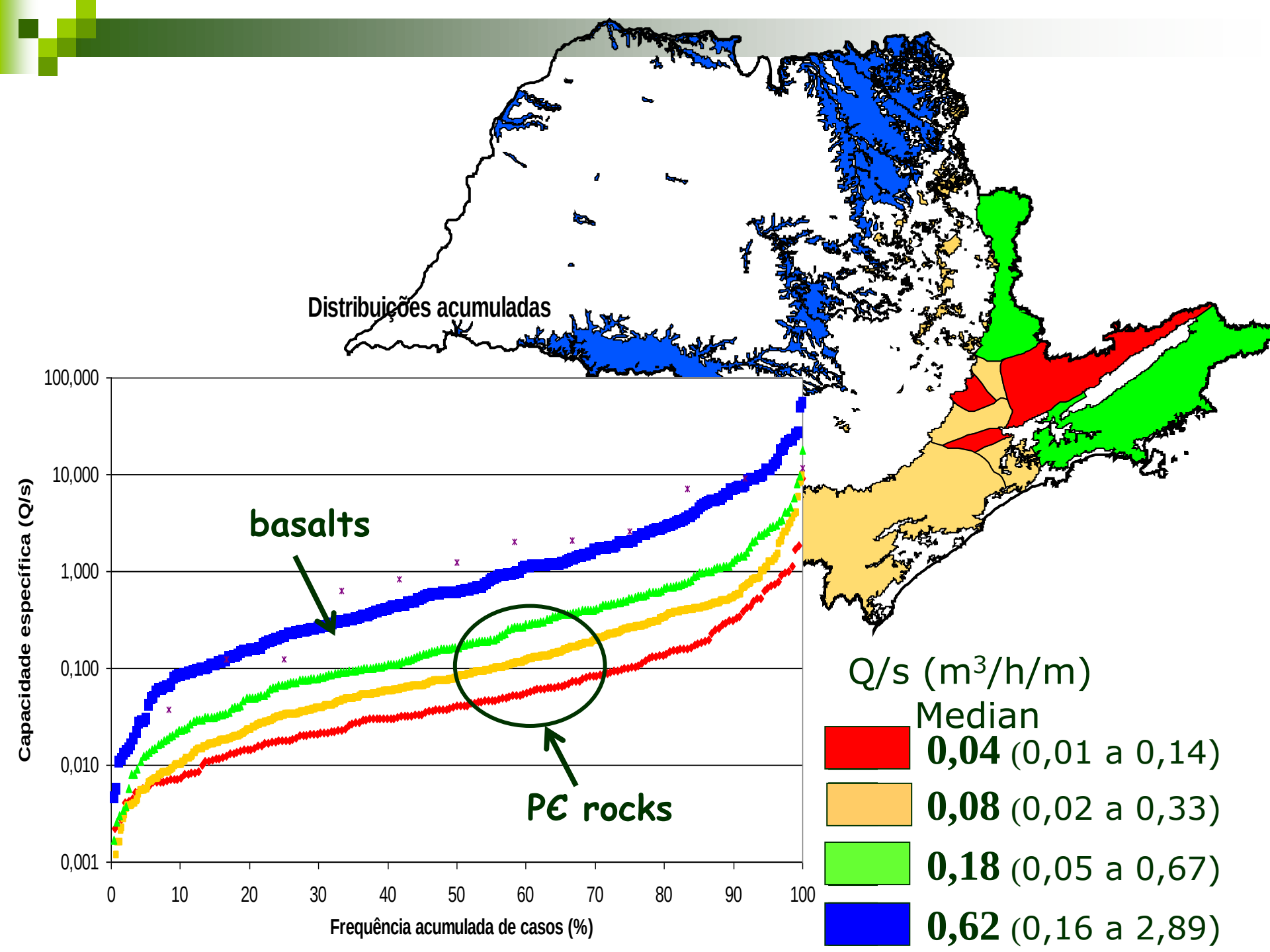
- lineament densities and directions,
- lineament intersections,
- thickness of unconsolidated cover,
- geological blocks delimitated by significant descontinuities

REGIONAL SCALE

- 1:750.000 or less



Fernandes et al. (2005)


Distribuições acumuladas
basalts
PЄ rocks
Capacidade específica (Q/s)
100,000
10,000
1,000
0,100
0,010
0,001
0
10
20
30
40
50
60
70
80
90
100
Frequência acumulada de casos (%)
Q/s (m³/h/m)
Median
0,04 (0,01 a 0,14)
0,08 (0,02 a 0,33)
0,18 (0,05 a 0,67)
0,62 (0,16 a 2,89)

Geological blocks = Tectonic domains?

More productive bolcks = Domains undergoing expansion?

Less productive domains = Domains undergoing compression?

CONCLUSIONS

- Quaternary stress fields control the prefential flow of groundwater in the NW and NE directions

- Quaternary stress fields are not homogeneously distributed in the State SP

- São Paulo State: there may be areas under extension (with a greater potential for groundwater production) and areas under compression (smaller potential)