

# **INSTRUMENTAÇÃO DE MEDIDA DAS PROPRIADES FÍSICAS DE SOLO**

**[INSTRUMENTATION TO MEASURE  
SOIL PHYSICAL PROPERTIES]**

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Madison, WI, USA

# Estrutura de tópicos da apresentação [Presentation outline]

- **Introdução [Introduction]**
- **Visão geral de métodos antigos [Overview of old methods]**
  - temperatura do solo, teor e potencial (pressão) da água [soil temperature, water content, and potential (pressure)]
- **Penetrômetro de cone, propriedades elétricas (EM38 e outros) e radar de penetração de solo [Cone penetrometer, electrical properties (EM38 others), and ground penetrating radar]**
- **Mapa de solo 3-d e futuras direções [3-D soil map, and future directions]**
- **Conclusões [Conclusions]**

# Introdução [Introduction]

- Caracterização de instrumento em tempo real [Instrument characterization real time]
  - Foco no solo e *in situ* [soil focus, and *in situ*]
  - Chemical, laser e?? análise de tamanho de partículas [laser –chemical and ?? particle size analysis]
- *Medições in situ de solo* [*In situ* soil measurements]
  - medidas de sitio pelo horizonte ou profundidade [site measurements by horizon or depth]
  - Paisagem [Landscape]

# Introdução [Introduction]

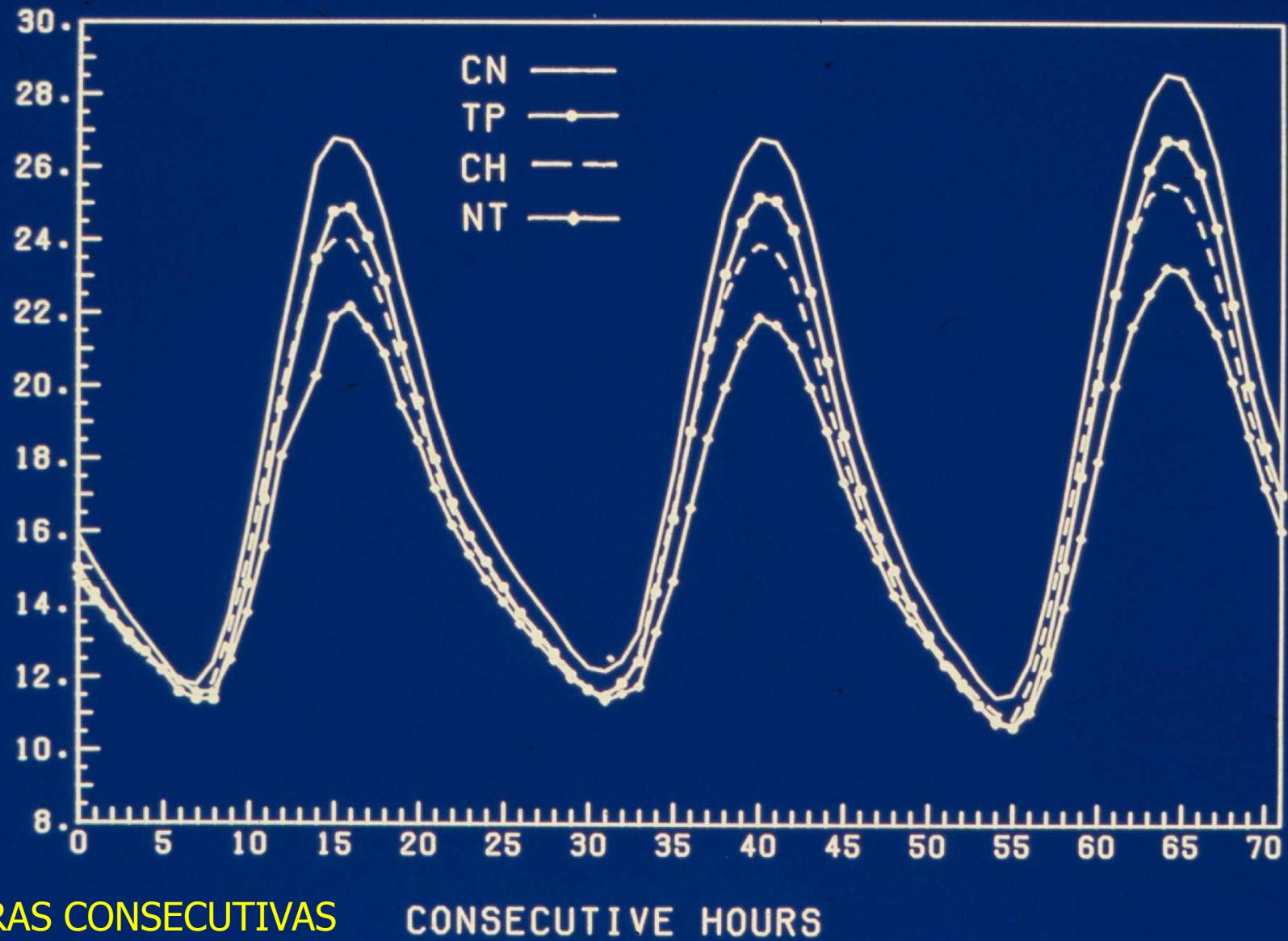
- Investigações de solo em tempo real [Real time soil investigations]
  - temperatura do solo, fluxo de calor, água e evaporação (ET) [soil temperature, heat flux, water, and evaporation (ET)]
  - teor de água do solo e potencial de pressão (água subterrânea) [soil water content, potential, and pressure (groundwater)]
- Fotografias aéreas e observações [Aerial photographs and observations]
- Penetrômetro e solos [Penetrometer and soils]
  - relação de dados de índice de cone (C I) e propriedades físicas [relationship of cone index (C I) data to physical properties]
- Mapeamento de solos –2-D para representação 3D [Soil mapping --2-D to 3-D representation]

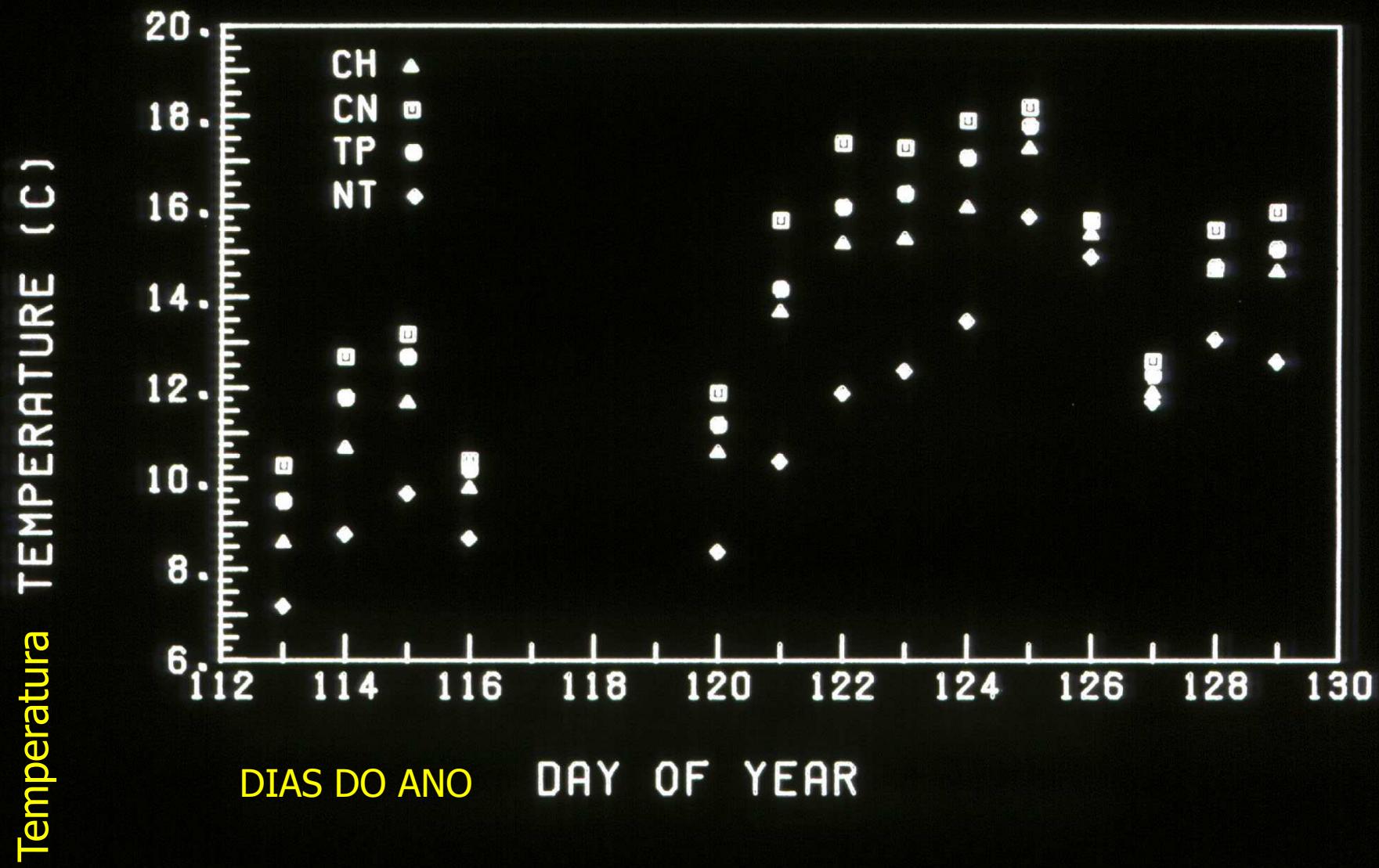


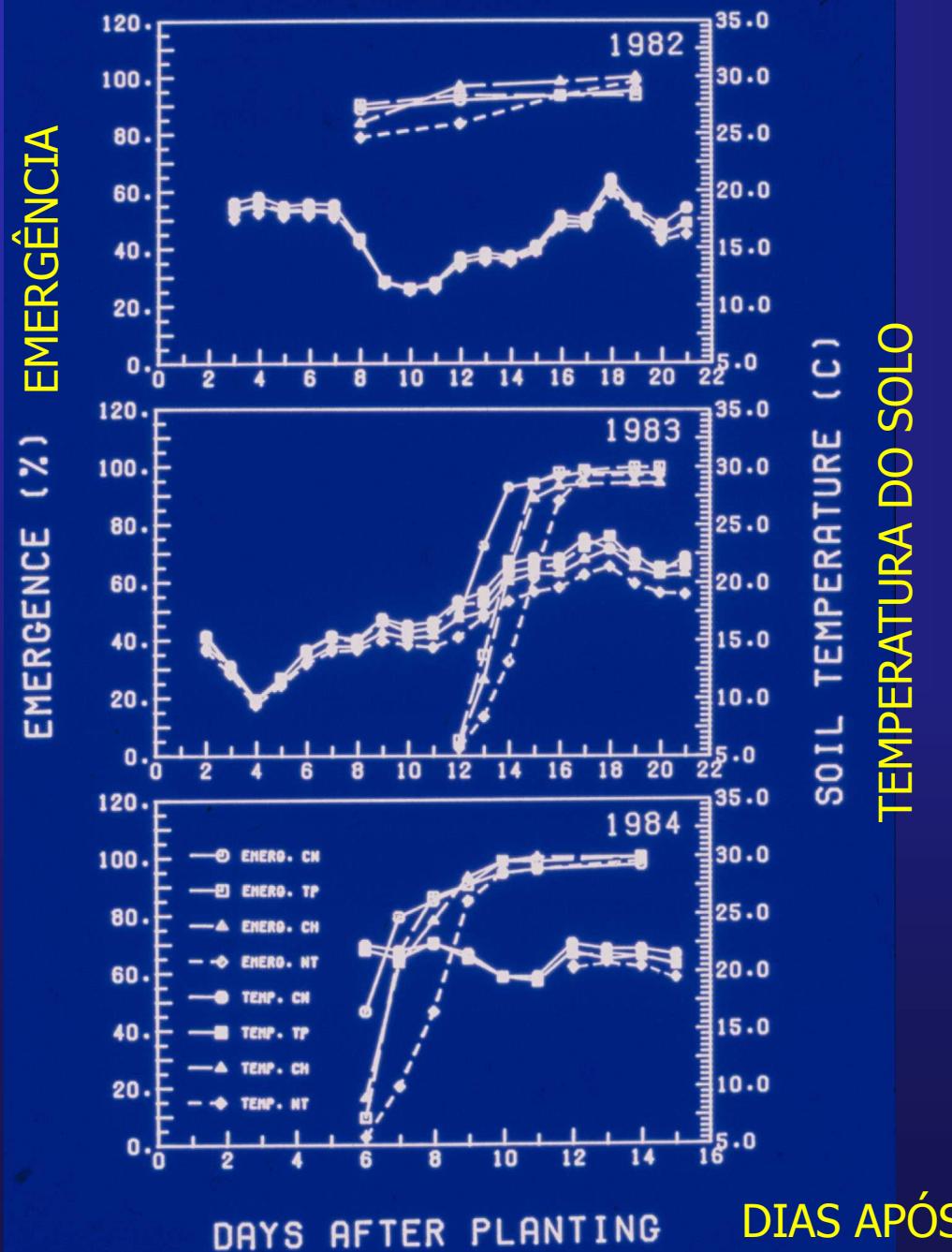
Fotografia  
simples  
tirada de  
avião

[Simple  
photograph  
taken from  
airplane]

TEMPERATURE ( C ) TEMPERATURA

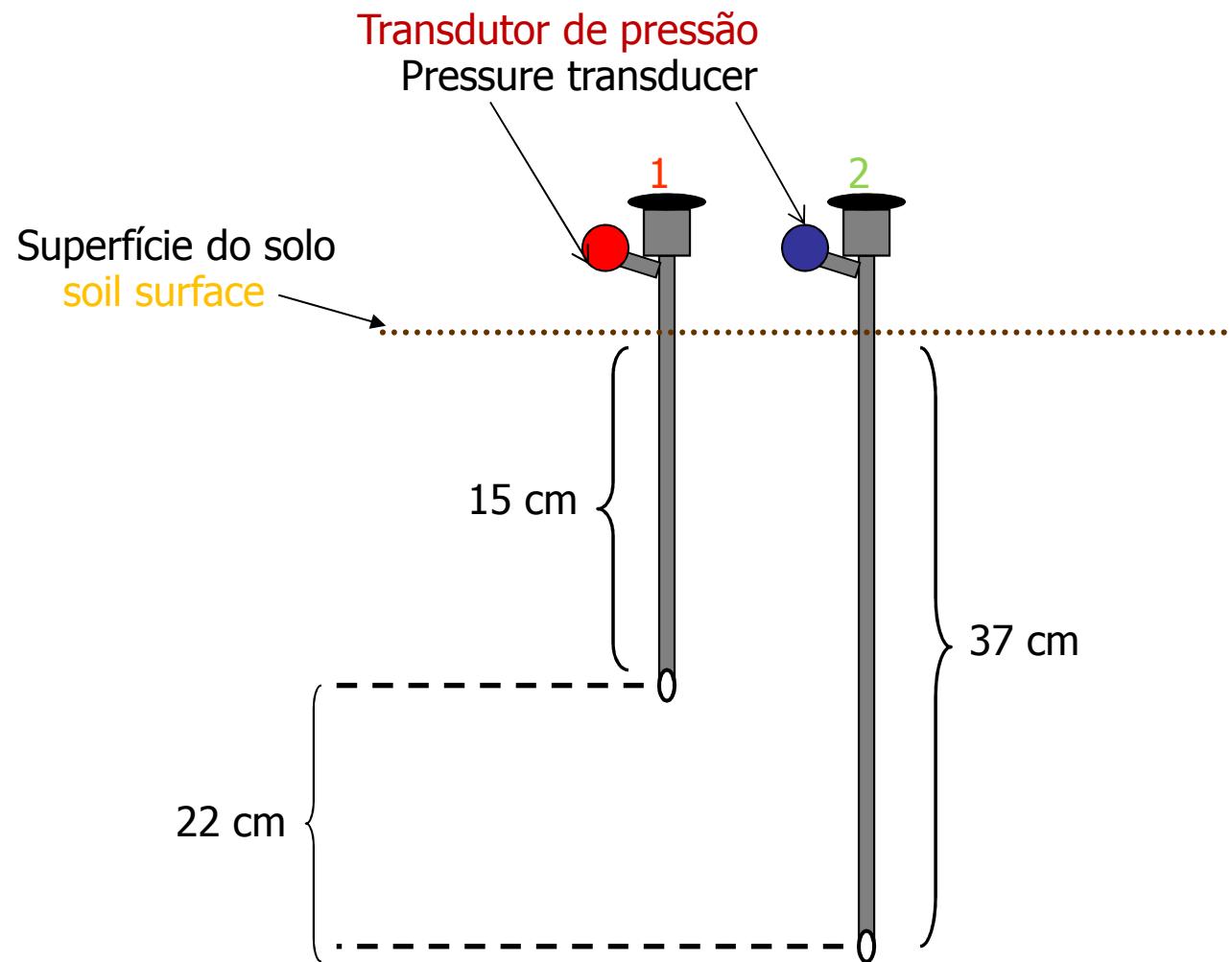






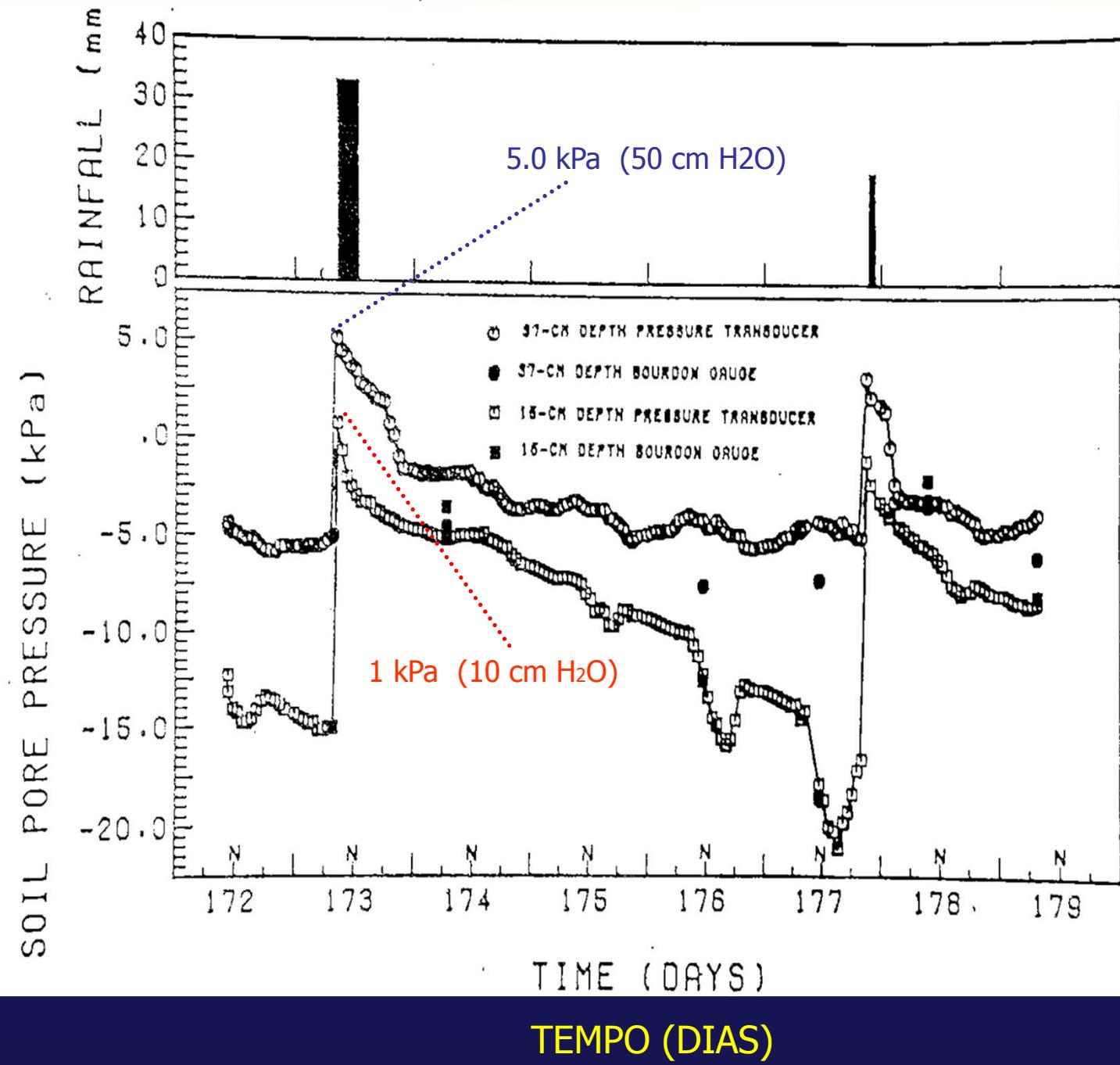
-LVD (deslocamento linear de voltagem) para a taxa de crescimento de tempo real [LVD (linear voltage displacement) for real time growth rate]

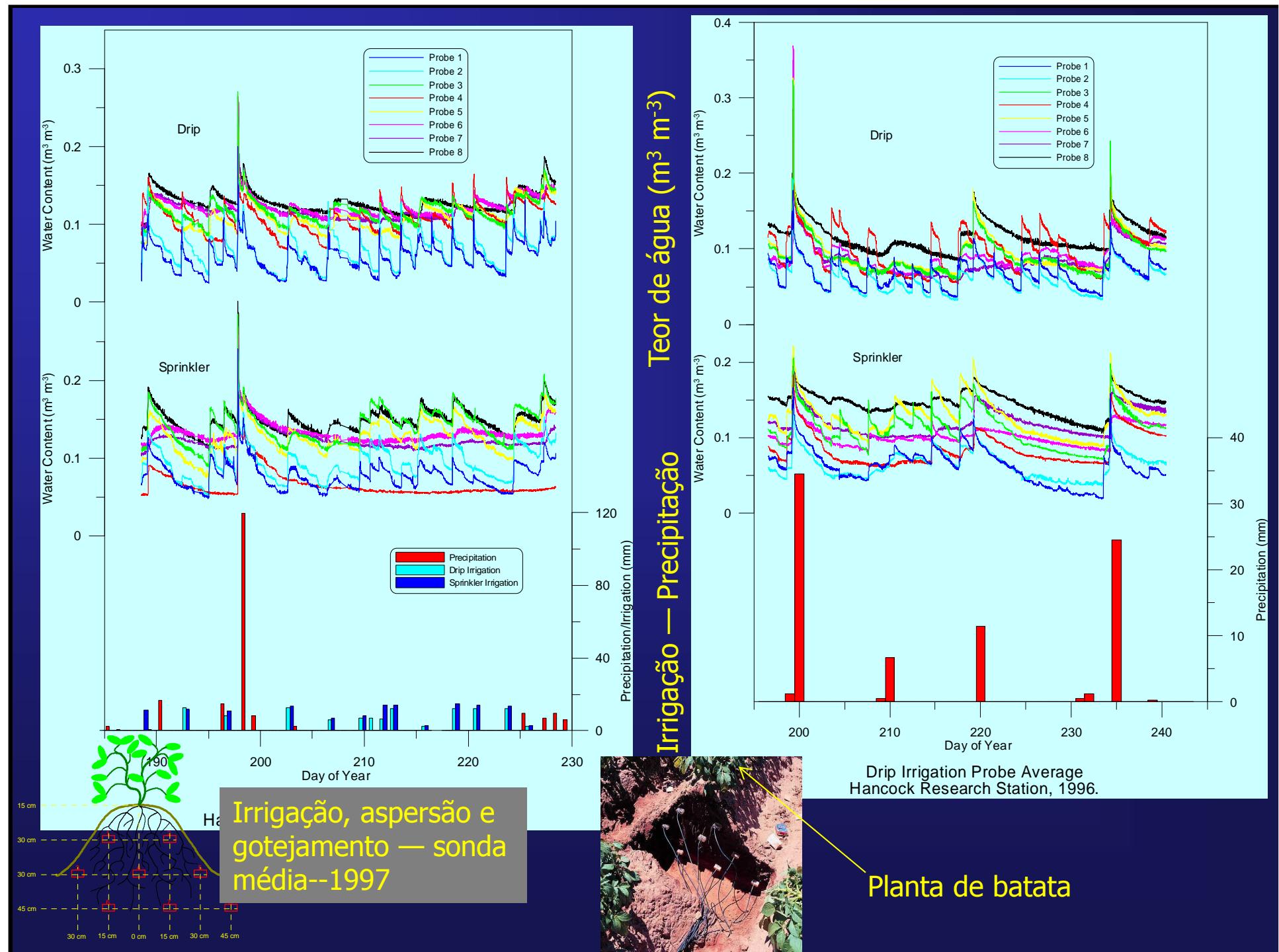
--1982 filmagem continua [1982 continuous filming]



## PRECISÃO DE POROS DO SOLO

## PRECIPITAÇÃO





**Área de estudo  
em planície  
central arenosa**

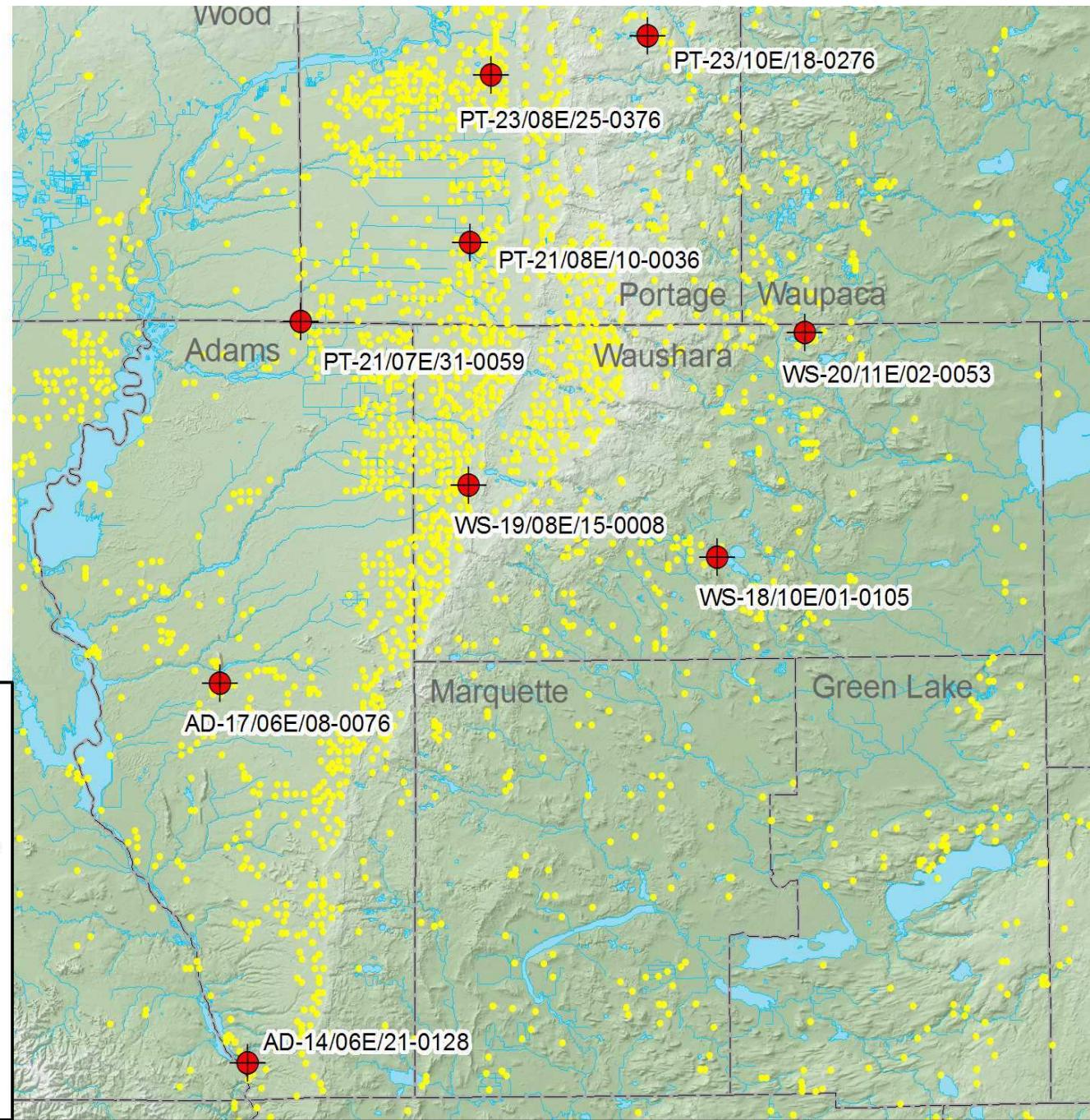
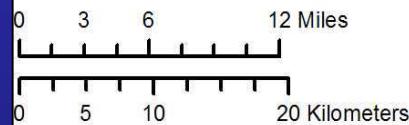
**[Study Area in  
Central Sand  
Plain]**



## A planície central de areia de Wisconsin [The Central Sand Plain of Wisconsin]

USGS Water Level Monitoring Well

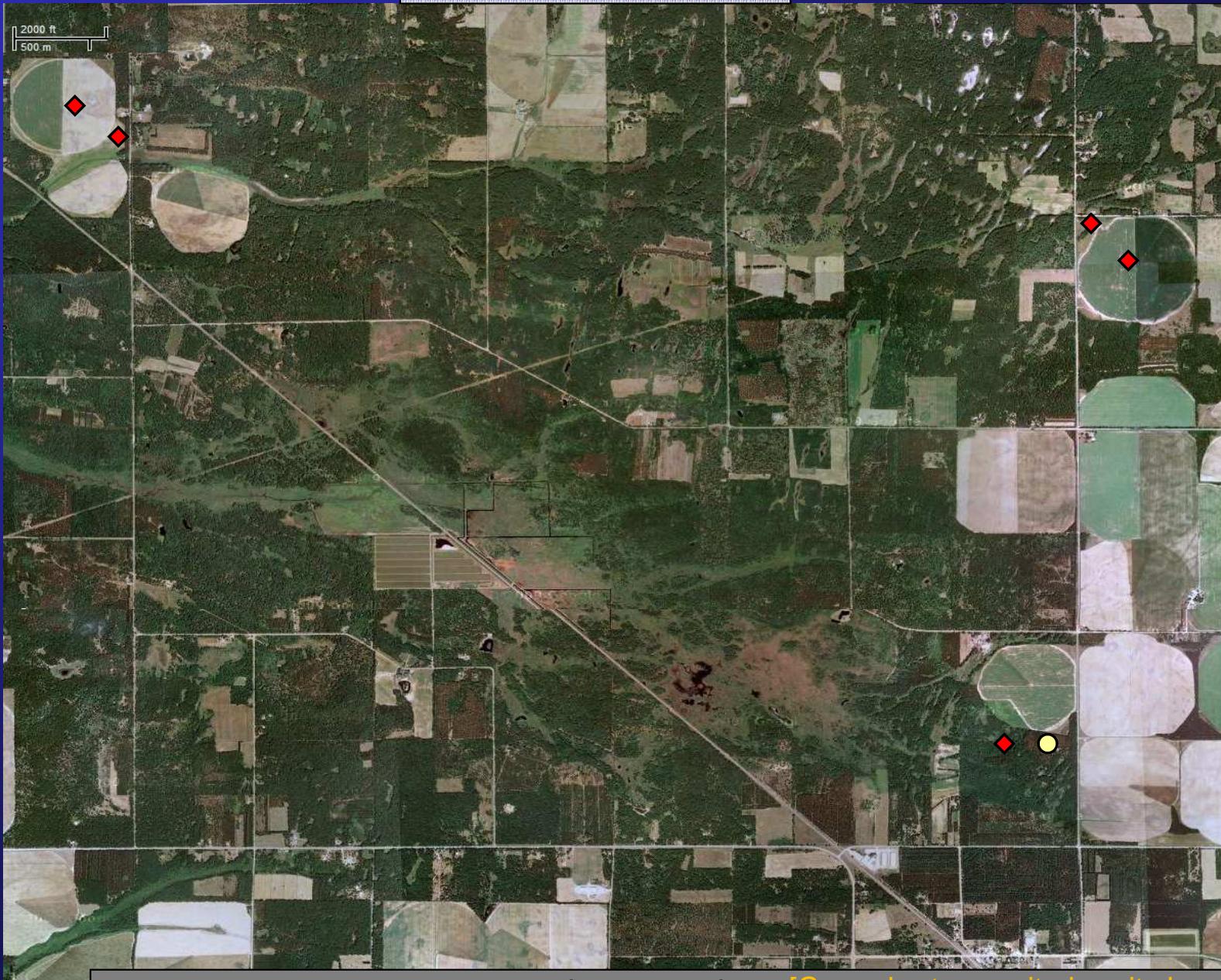
HiCap Well



# Long Lake, Waushara County, WI



## Grand Marsh, WI



- ◆ Local do site de monitoramento das águas subterrâneas [Groundwater monitoring site location]
- Pluviômetro no local de abertura [Rain gauge in opening location]

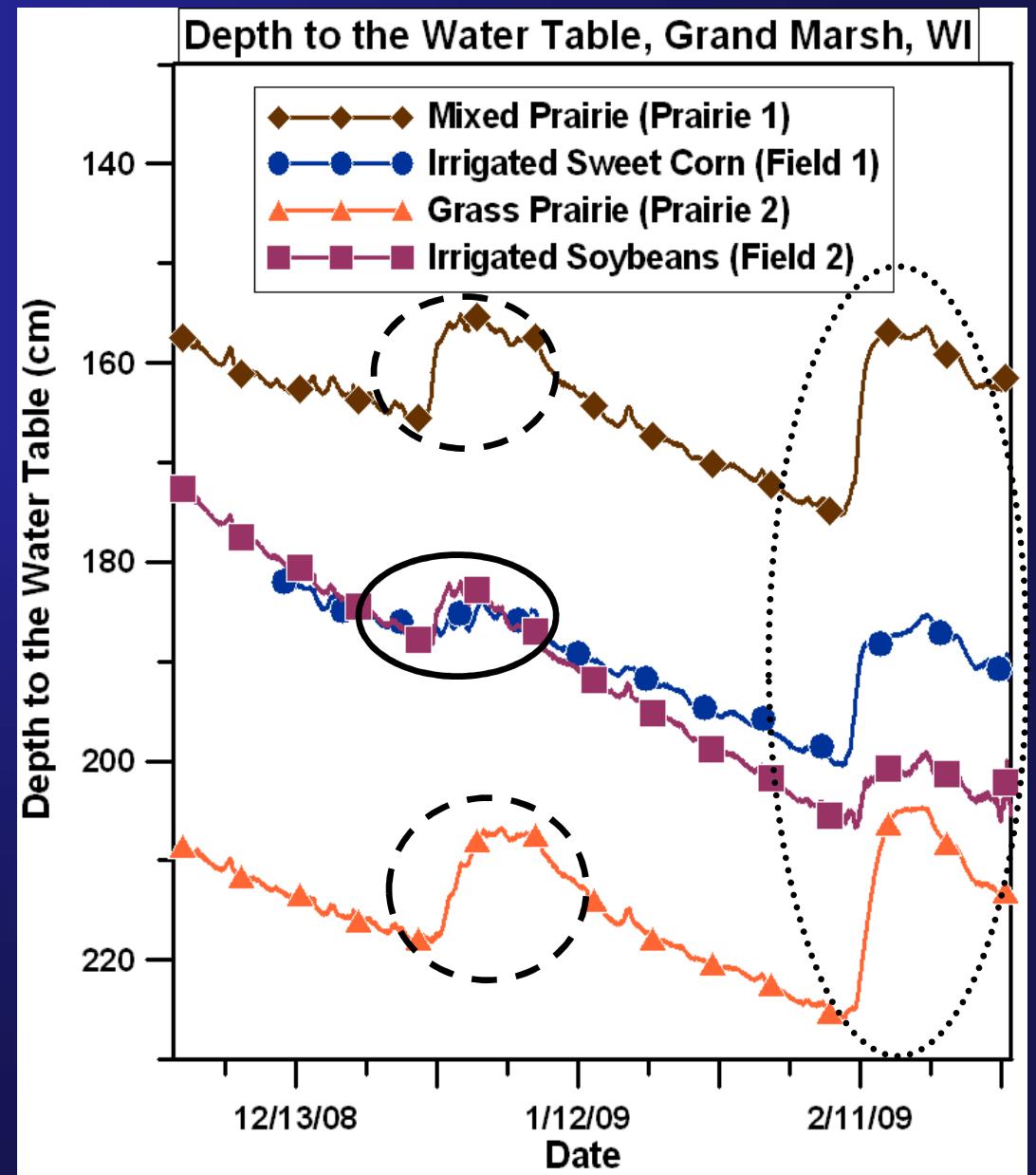


**Quais são as influências da vegetação e do solo congelado na recarga de águas subterrâneas?**

[What are the influences of vegetation and frozen soil on groundwater recharge?]

## Recarregar sob solos congelados [Recharge under frozen soils]

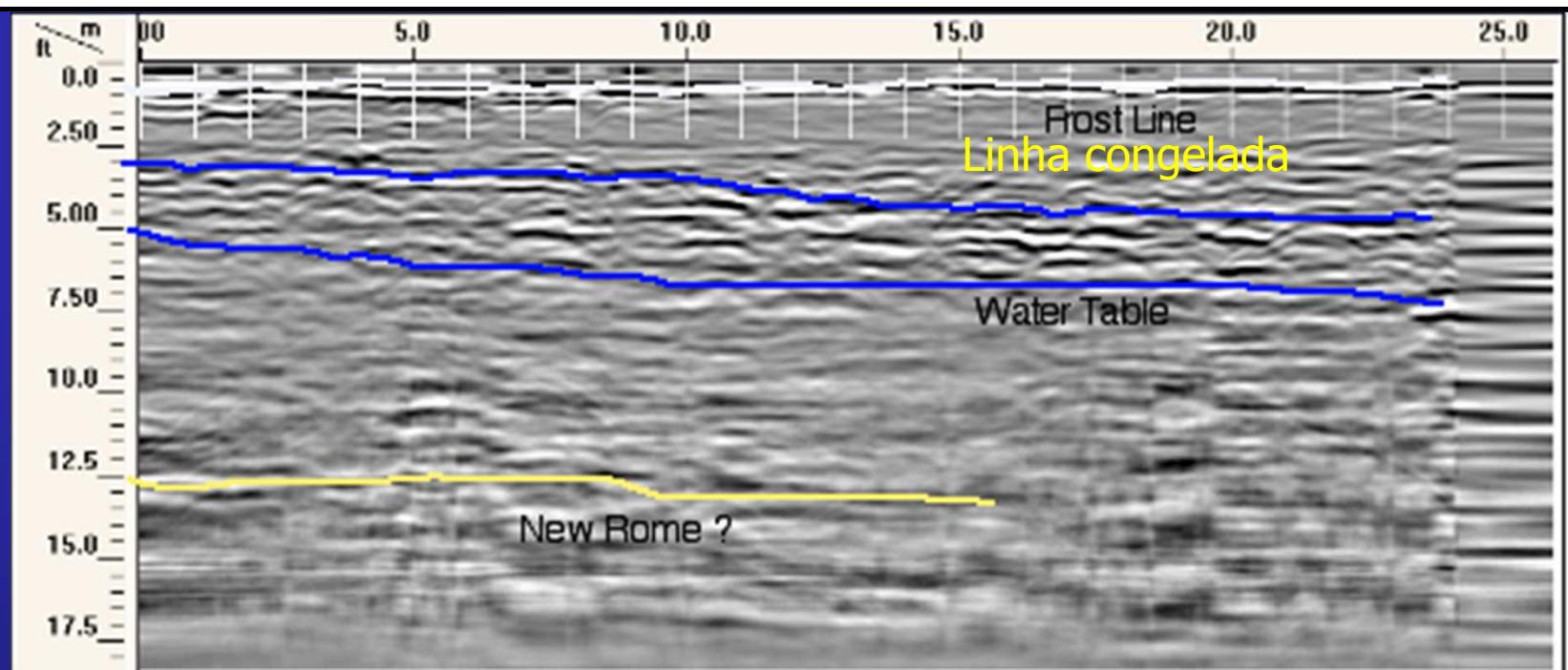
- Ascensão do lençol freático sob vegetação natural vs área de cultura colhida [Water table rise under natural vegetation vs. harvested crop fields]
- Evento 1: Chuva sobre a neve, 27 de dezembro de 2008 [Event 1: Rain on snow December 27, 2008]
- Evento 2: Derretimento da neve ( $10^{\circ}\text{C}/50^{\circ}\text{F}$  + ar temps) 10 de fevereiro de 2009 [Event 2: Snowmelt ( $10^{\circ}\text{C}/50^{\circ}\text{F}$  + air temps) February 10, 2009]



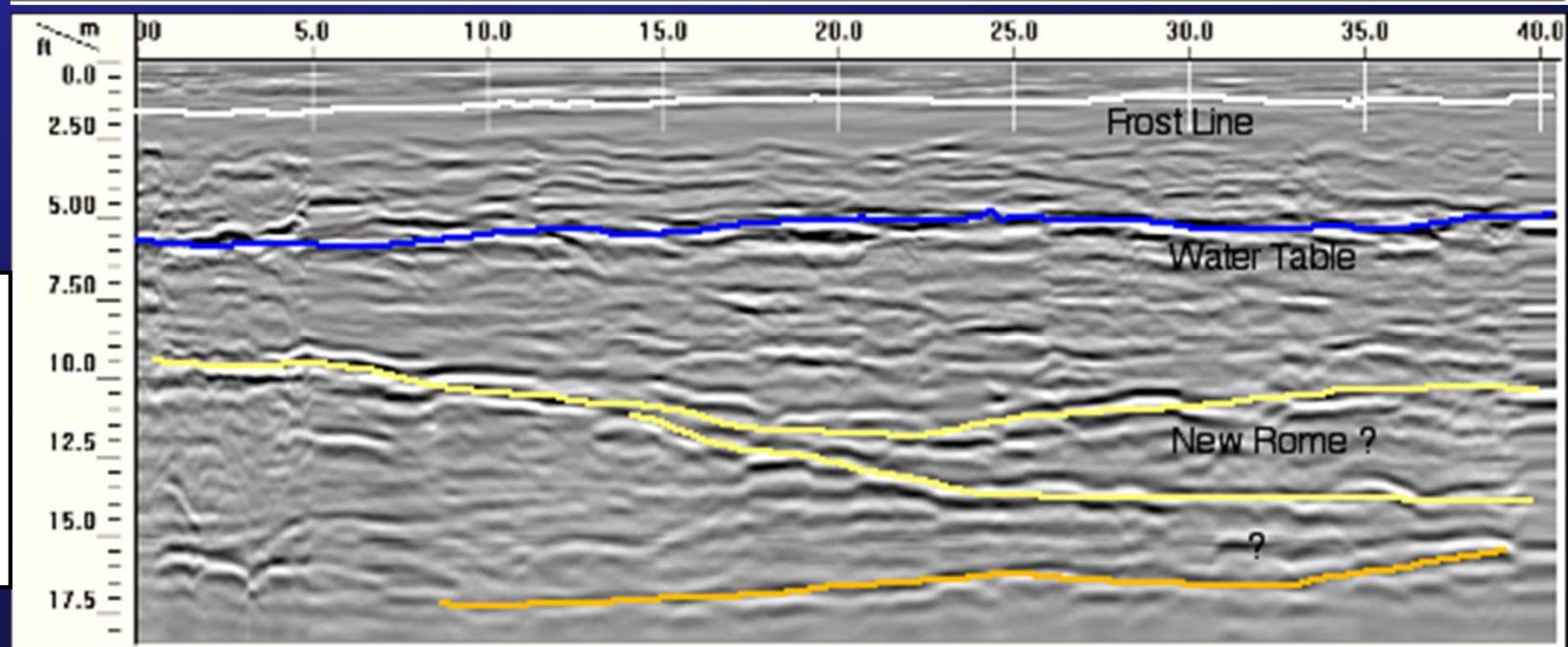
Drs. Dave Hart and Fred  
Madison of Wisconsin  
Geological and Natural  
History Survey



Pradaria  
[Prairie]



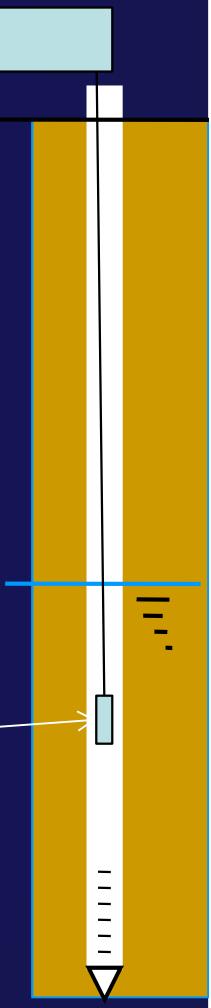
Milho /  
solo  
descoberto  
[Corn /  
bare  
ground]







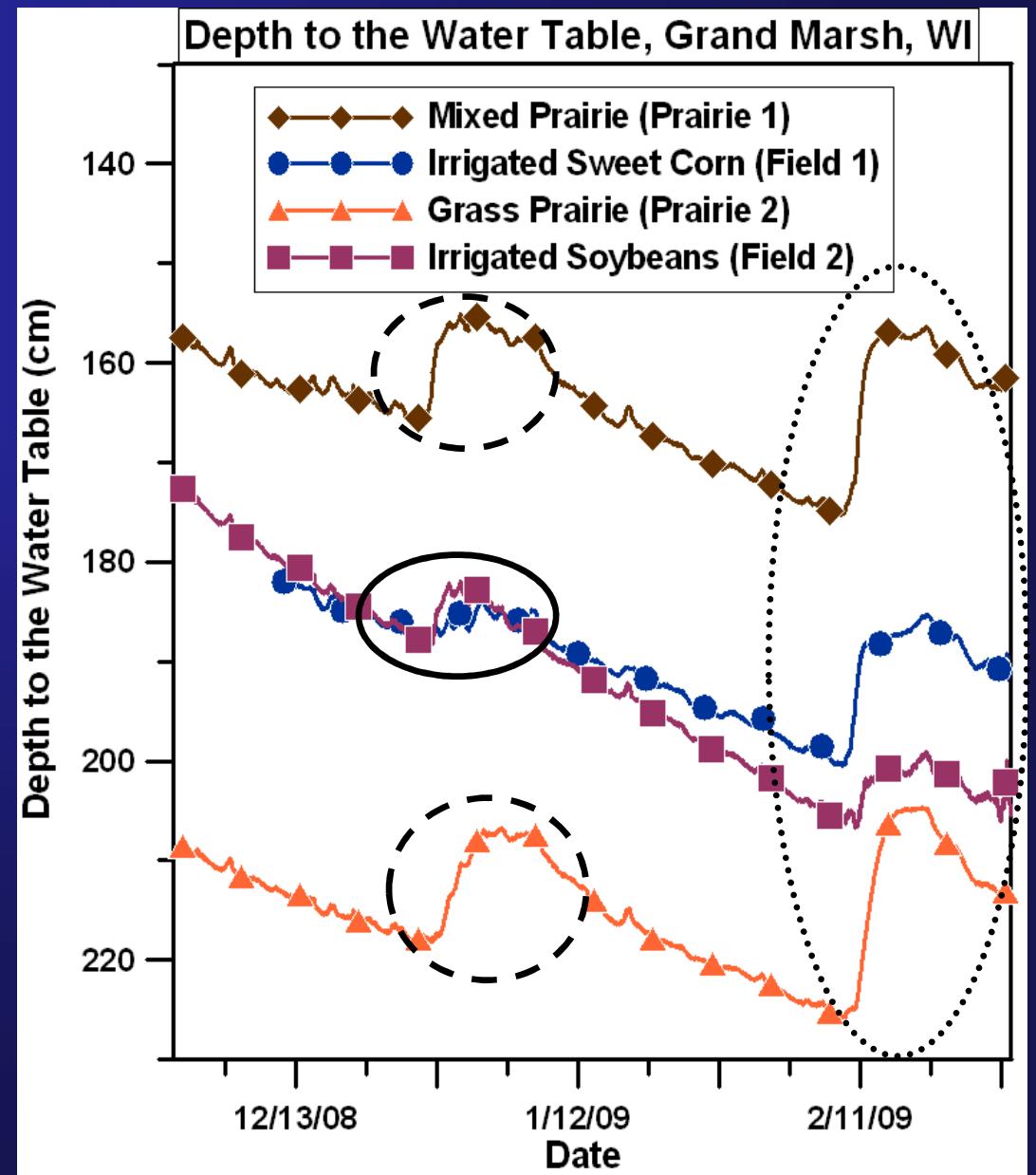
Registrador de  
dados  
[Datalogger]



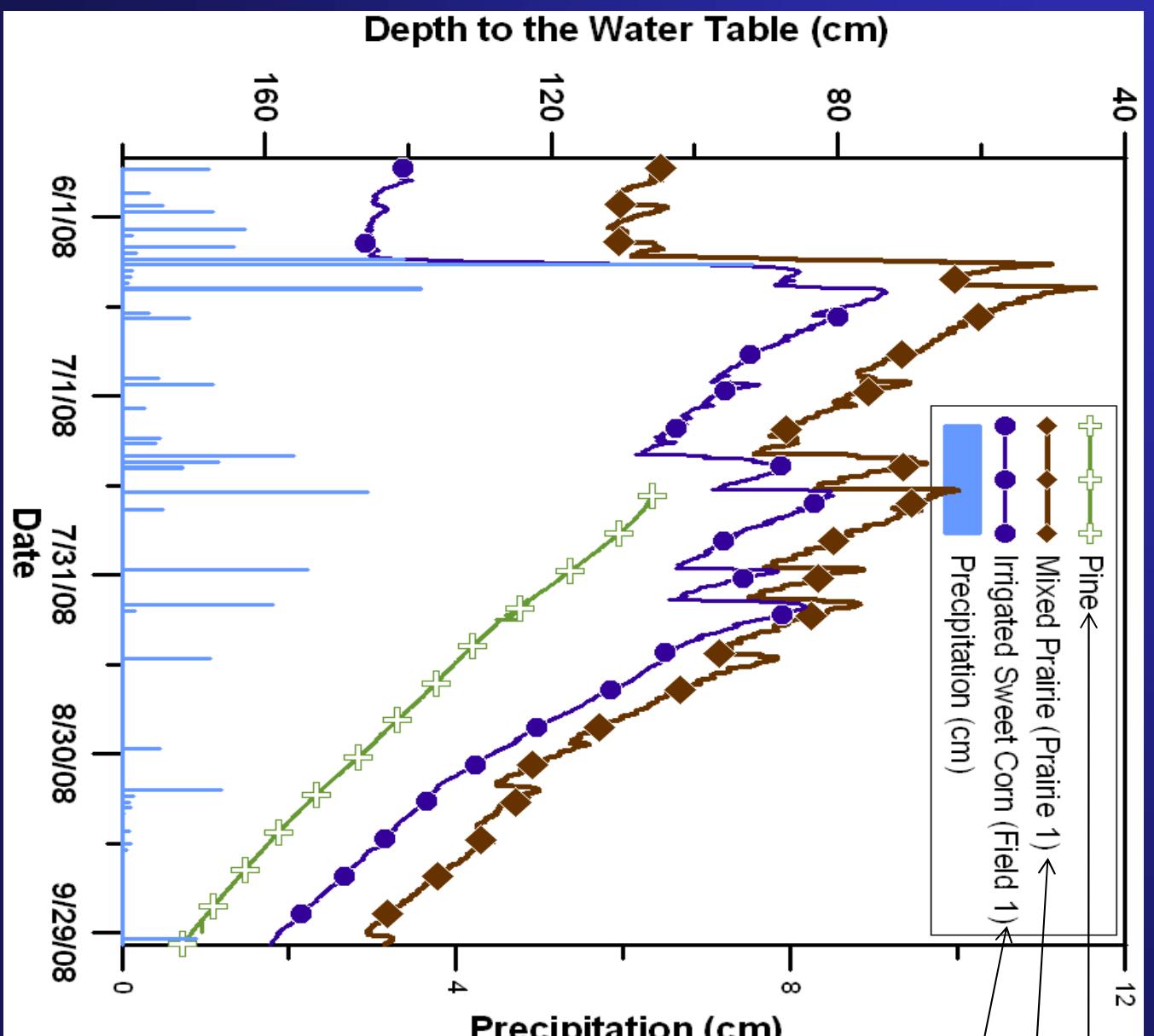
Transdutor de pressão  
[Pressure transducer]

## Recarregar sob solos congelados [Recharge under frozen soils]

- Ascensão do lençol freático sob vegetação natural vs área de cultura colhida [Water table rise under natural vegetation vs. harvested crop fields]
- Evento 1: Chuva sobre a neve, 27 de dezembro de 2008 [Event 1: Rain on snow December 27, 2008]
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## Profundidade de lençol freático



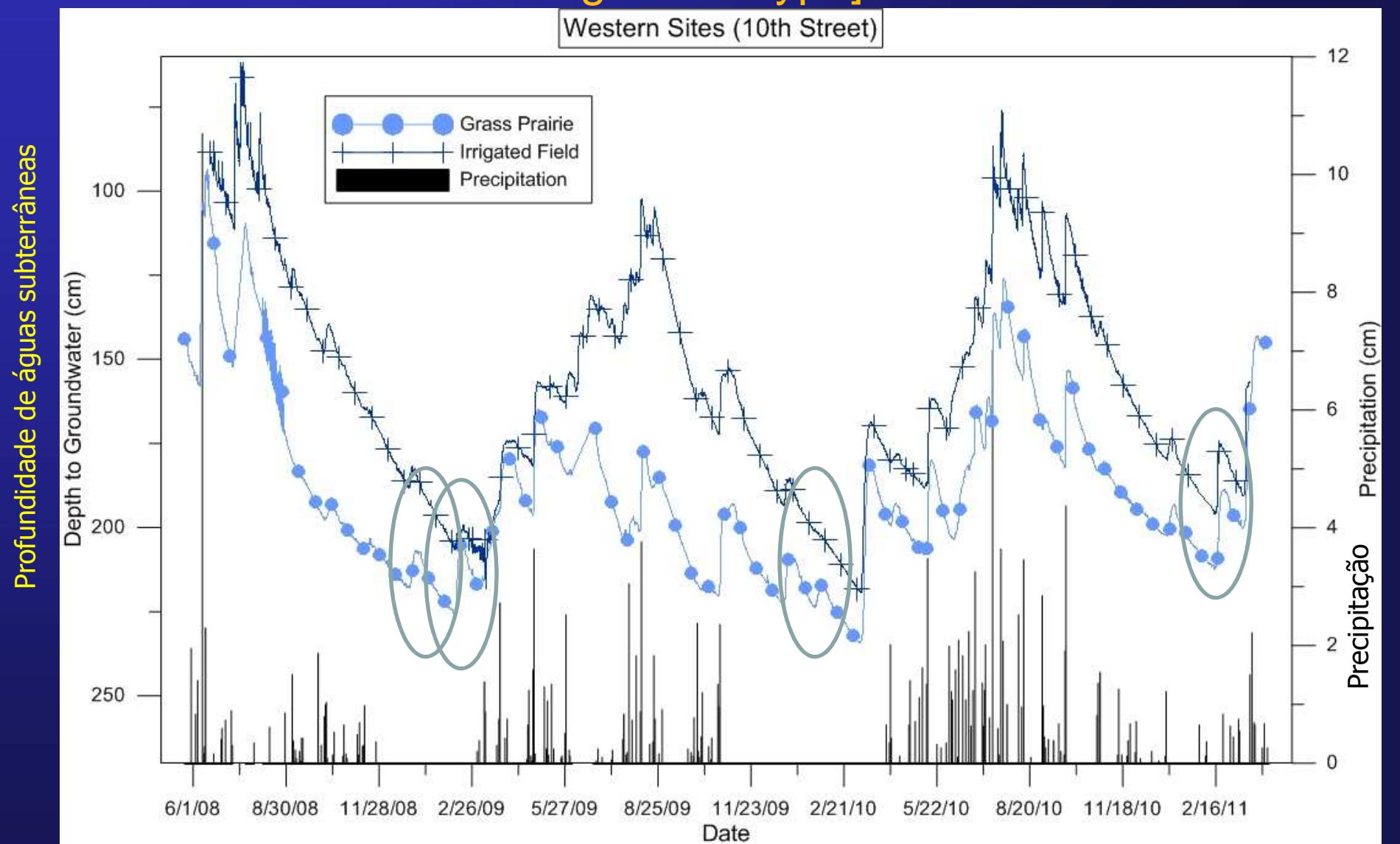
Precipitação

Pinheiro

Pradaria mista

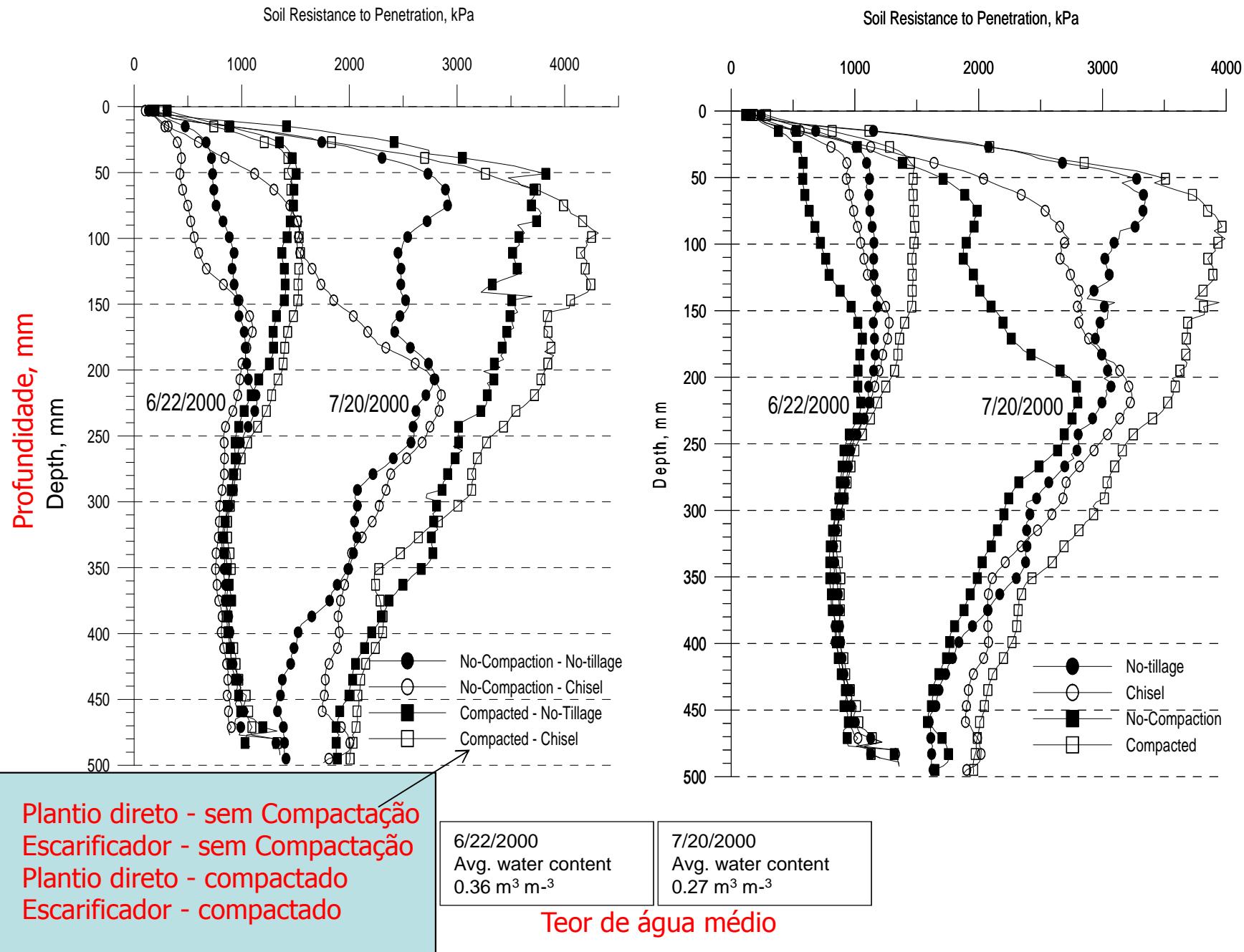
Milho doce irrigado

## Diferenças com base no tipo de vegetação [Differences based on vegetation type]

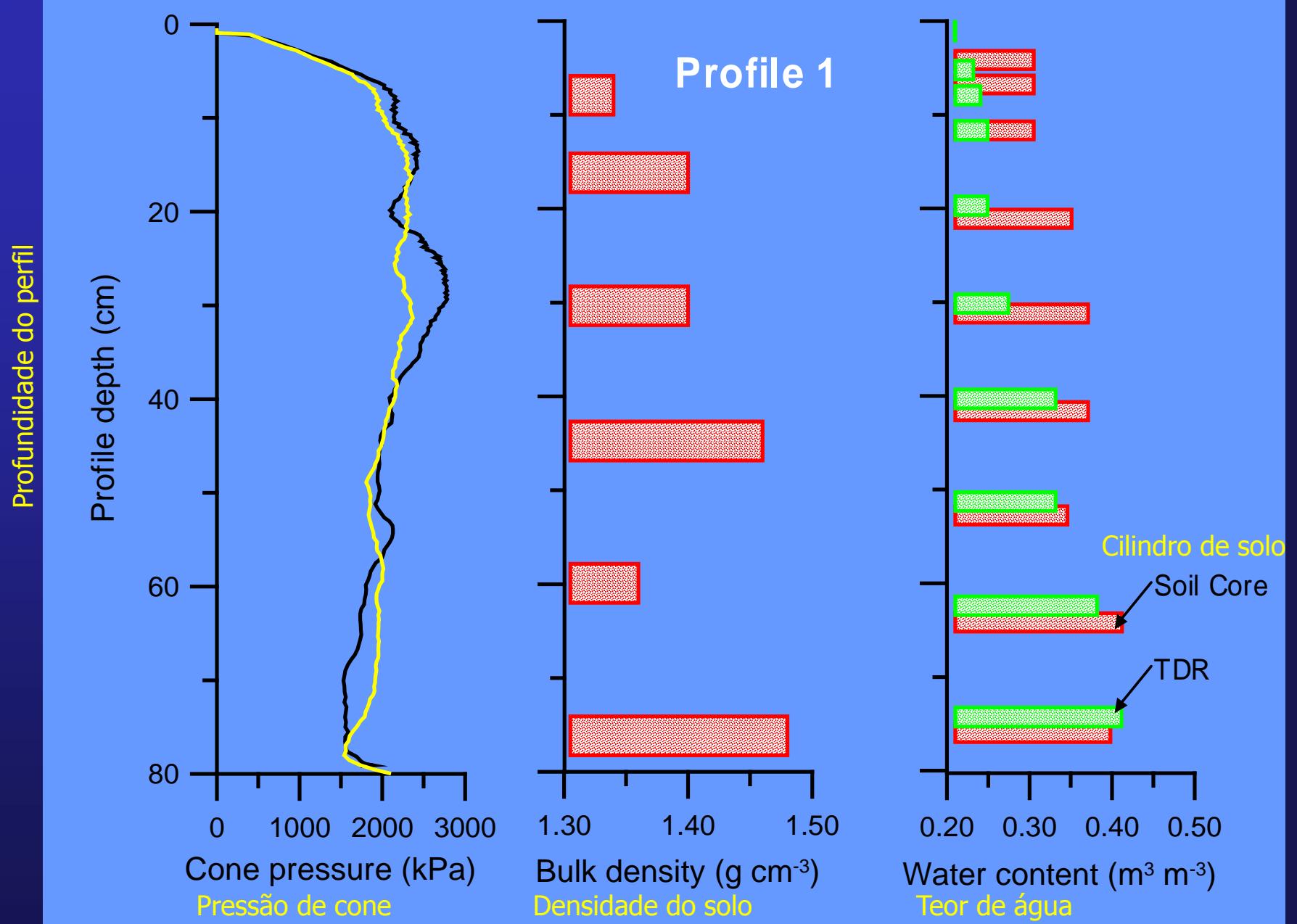


- Recarga no inverno 08/09 e 09/10 [Recharge winters 08/09 and 09/10]
- Menos no outono-primavera-verão [Less in fall-spring-summer]

## Resistência do solo à penetração, kPa







# Usando o penetrômetro cone para mapeamento de solo

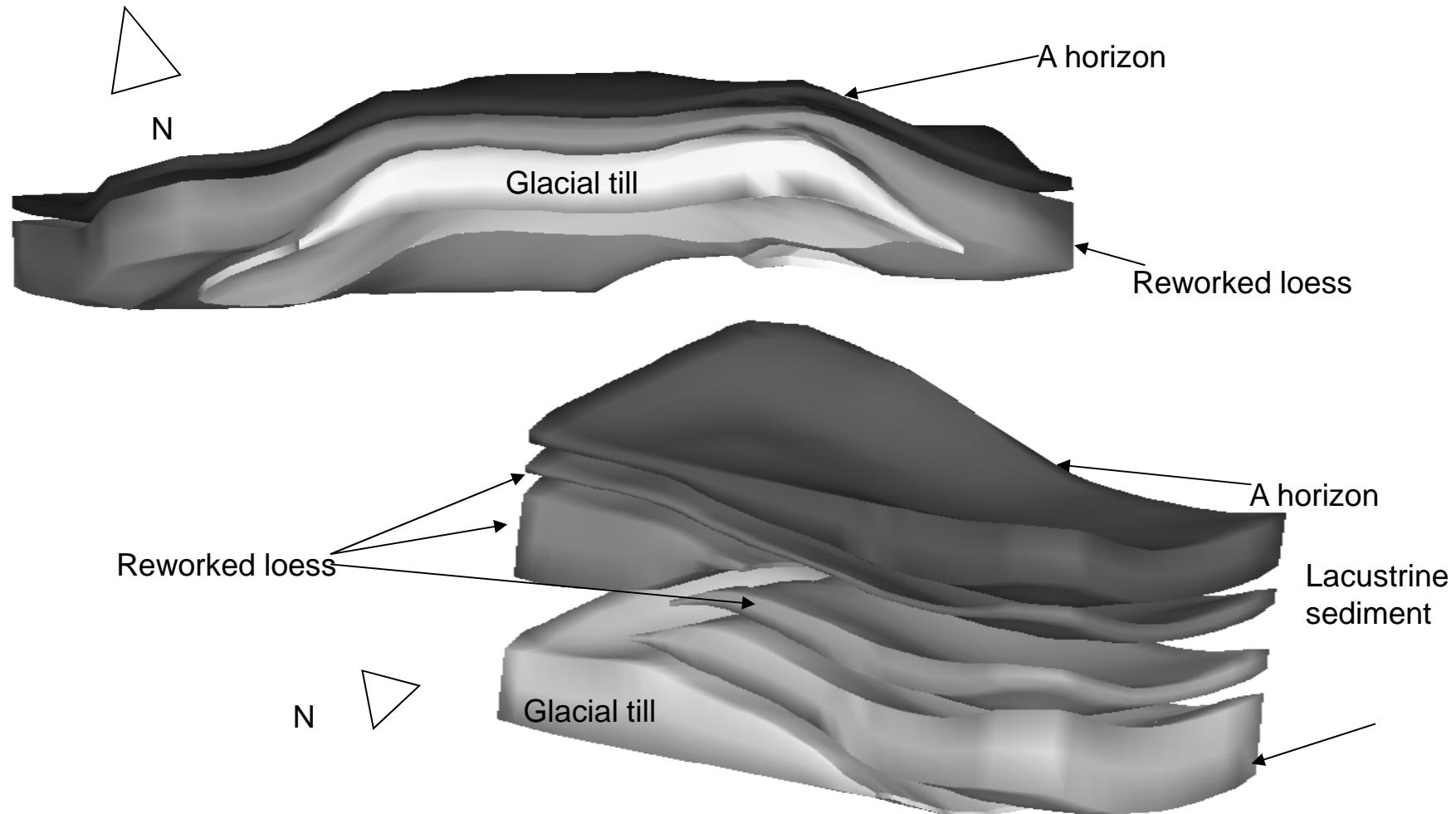
[Using cone penetrometer for soil mapping]

- Objectivo:

Desenvolver o mapa tridimensional do solo com base em dados geostatisticamente analisado de Índice de cone (CI)

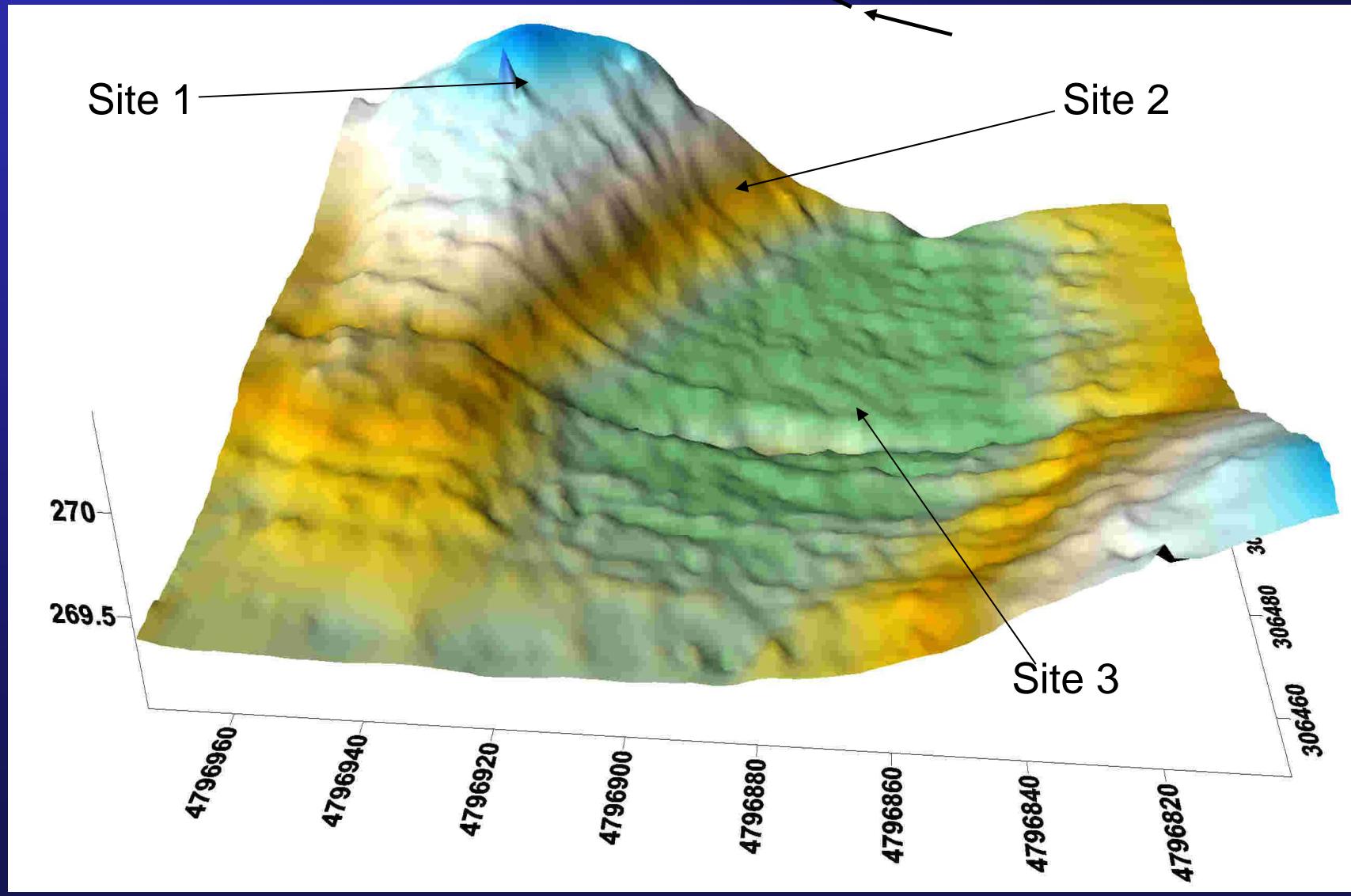
- [Objective:

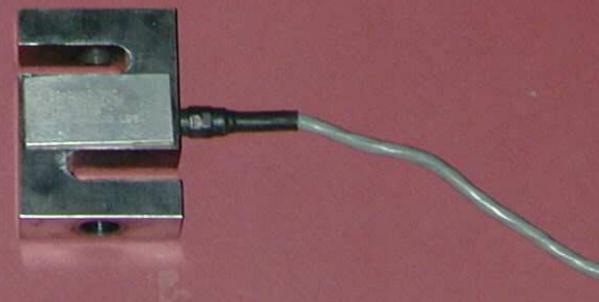
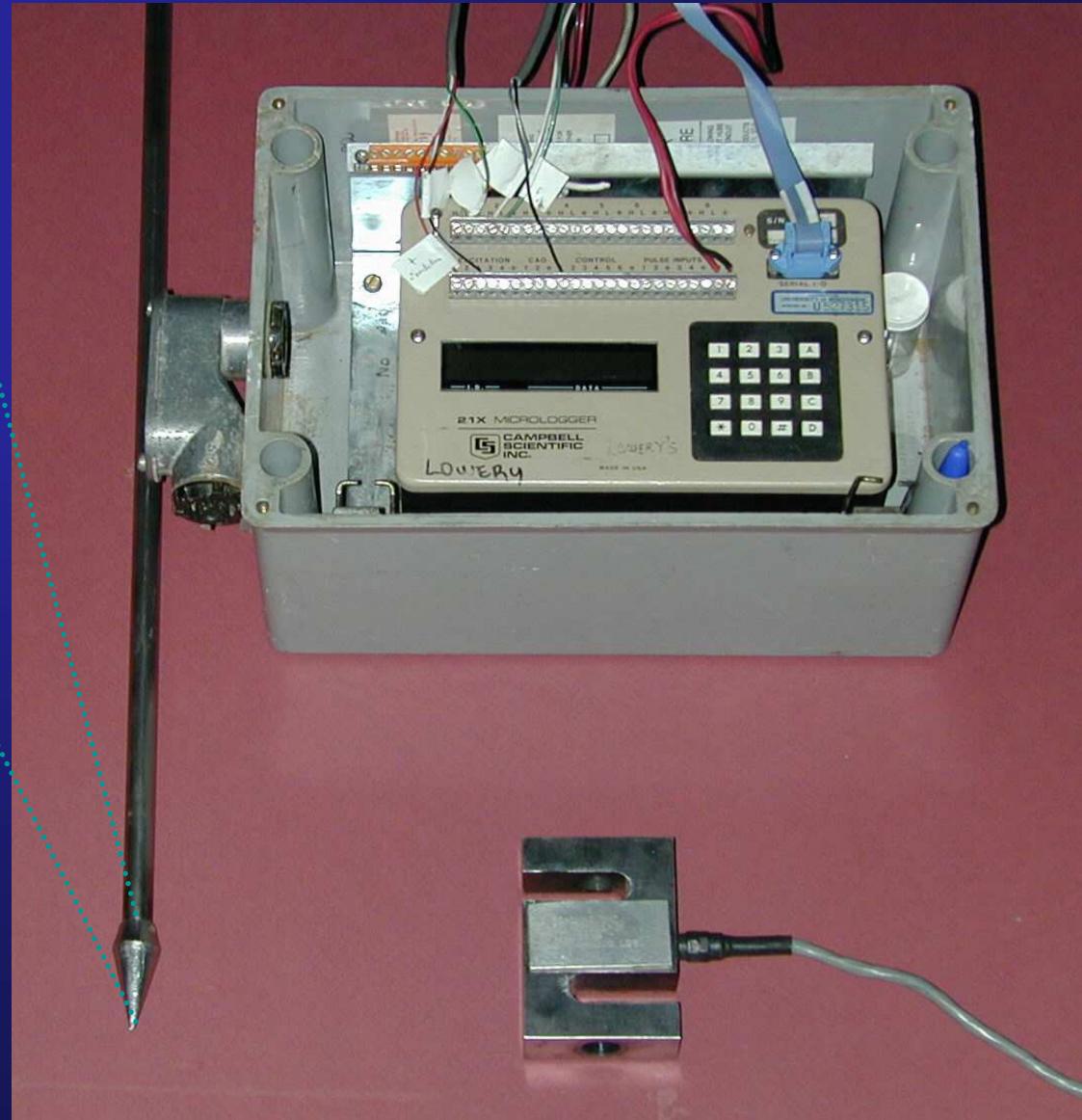
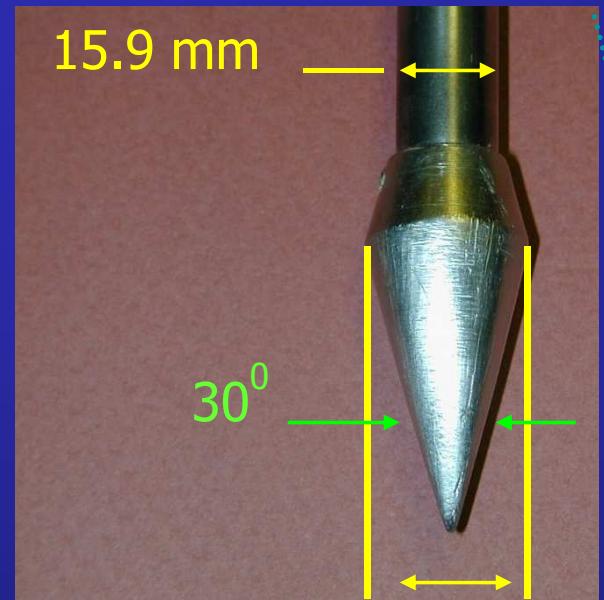
- Develop three-dimensional soil map based on geostatistically analyzed cone index (CI) penetrometer data]

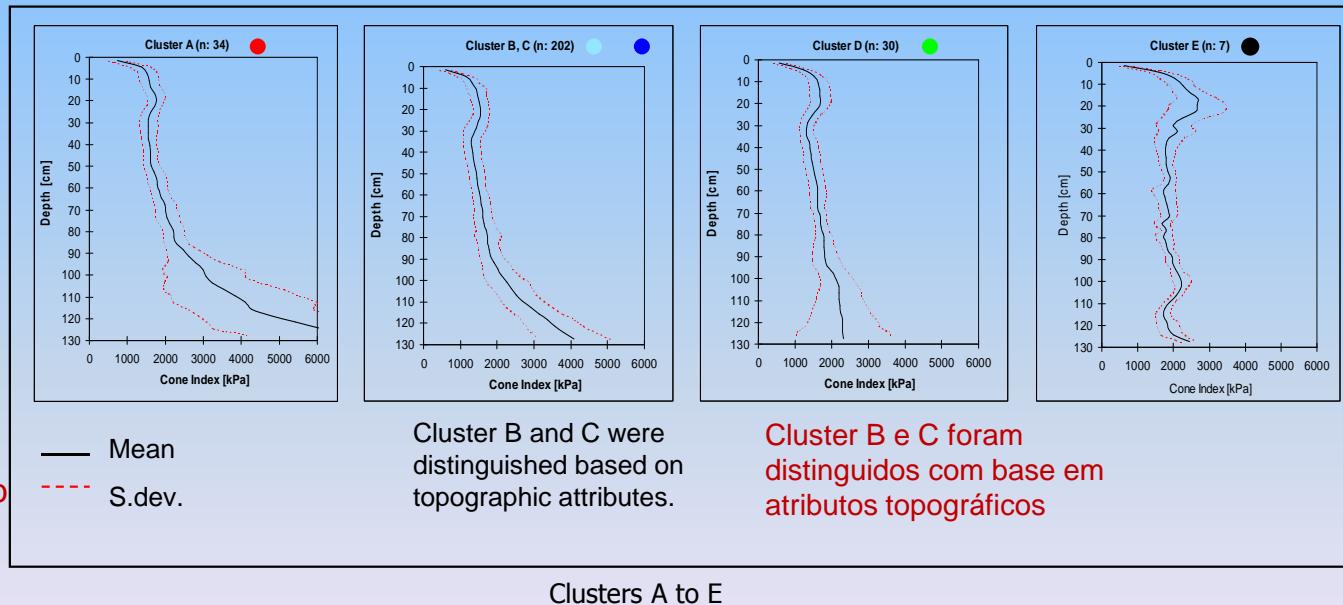
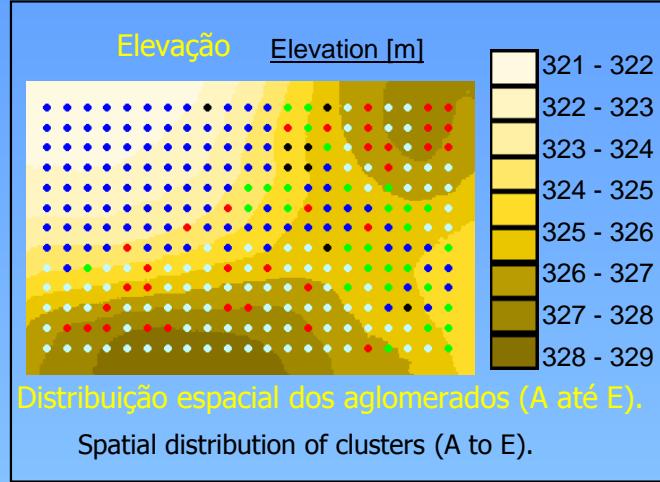


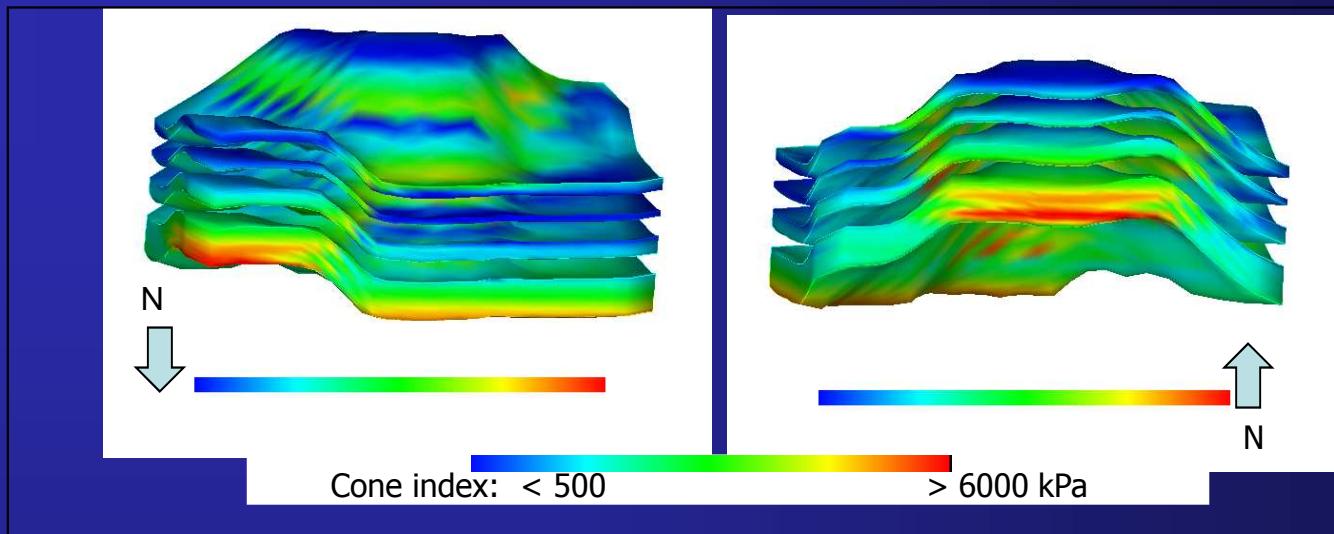
Retrabalhado loess, -sedimentos lacustres, -till glacial, - horizonte A  
[Reworked loess, -glacial till, -lacustrine sediment, -A horizon]

DEM (modelo digital de elevação) diferencial GPS (sistema de posicionamento global) --{[DEM (digital elevation model)  
differential GPS (global positioning system)]}



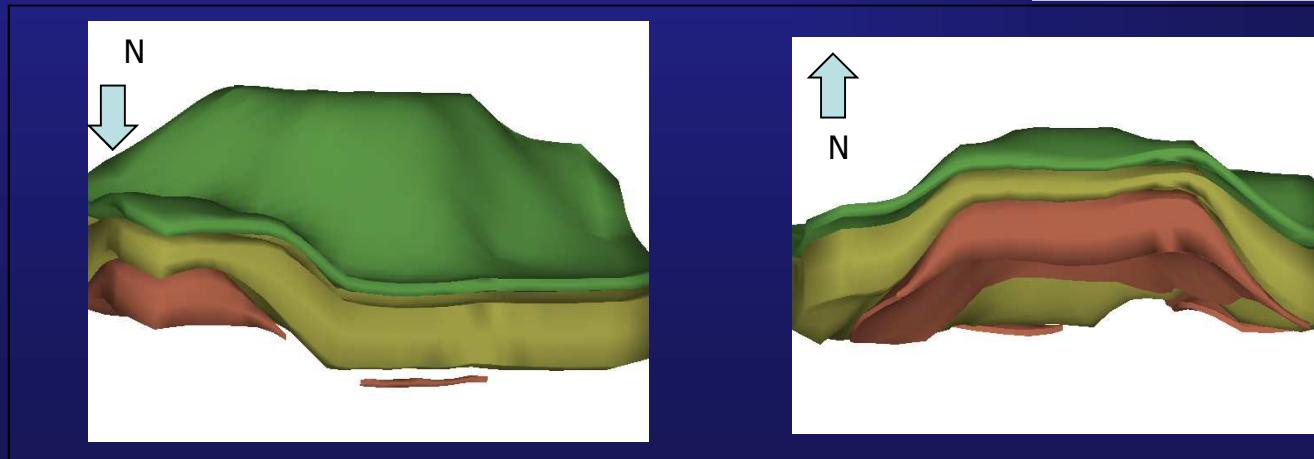






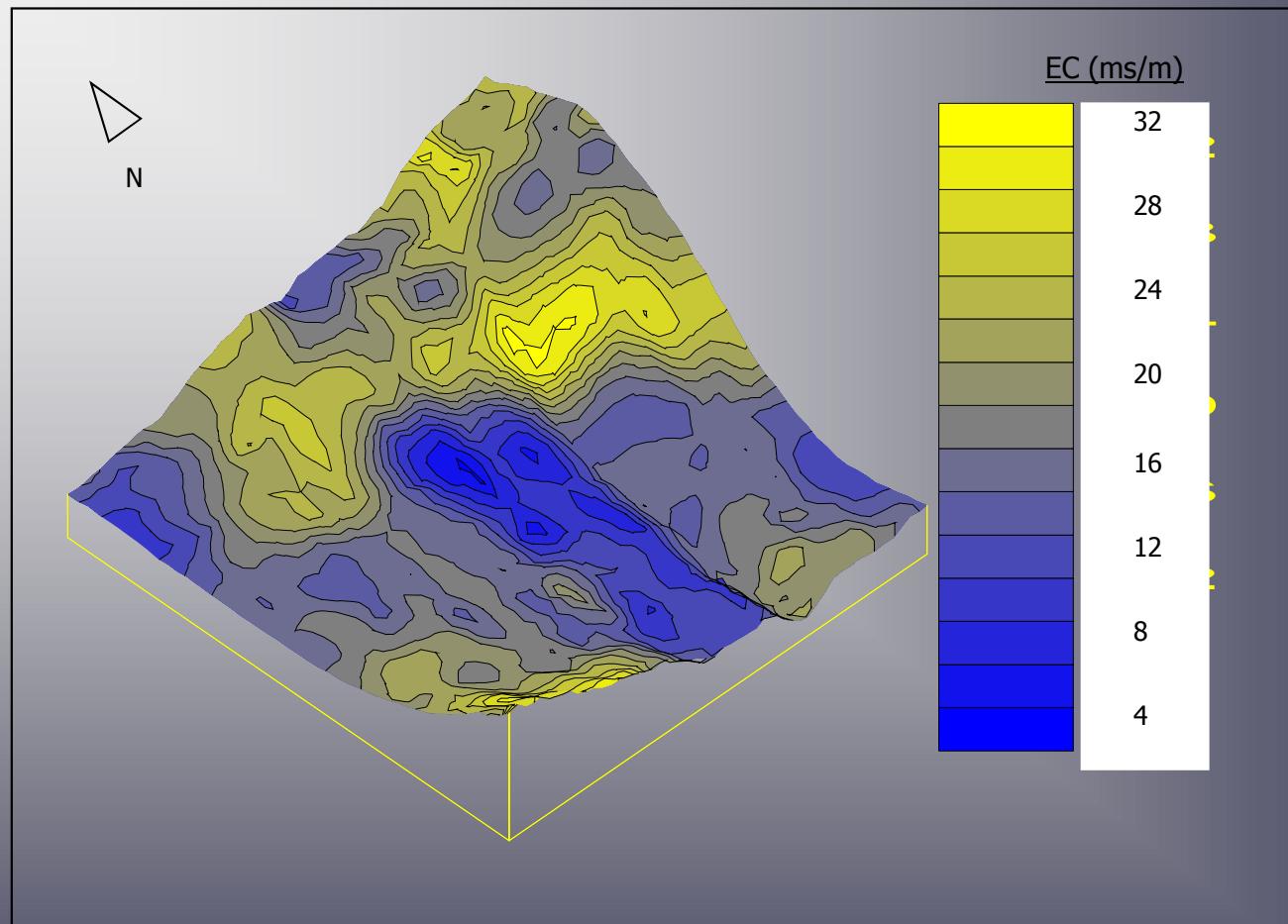
Modelo de paisagem de solo tridimensional mostrando a distribuição de CI.  
[Three-dimensional soil landscape model showing the distribution of CI.]

Site at West Madison Research Station



Distribuição tridimensional das camadas de solo e materiais.  
[Three-dimensional distribution of soil layers and materials.]

## Condutividade elétrica

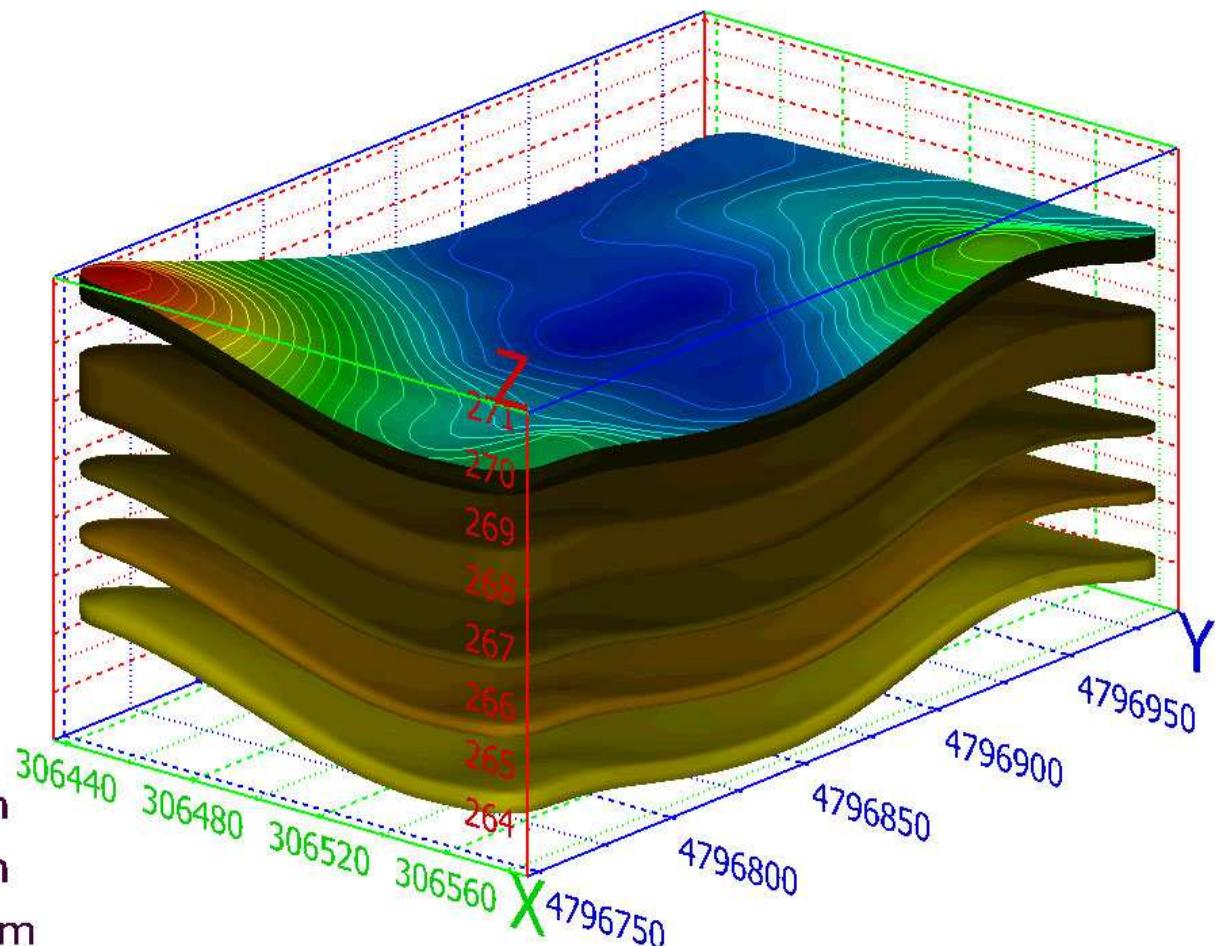


Medições EM38  
[EM38 measurements]

# Mapa 3D do solo Plano série [Soil Survey Plano series 3-D map]

## Horizontes [Horizons]

Ap--	0 to 23 cm
A--	24 to 36 cm
Bt1--	37 to 48 cm
Bt2--	49 to 78 cm
Bt3--	79 to 109 cm
Bt4--	110 to 124 cm
2Bt5--	125 to 135 cm
2BC--	136 to 152 cm
2C--	153 cm



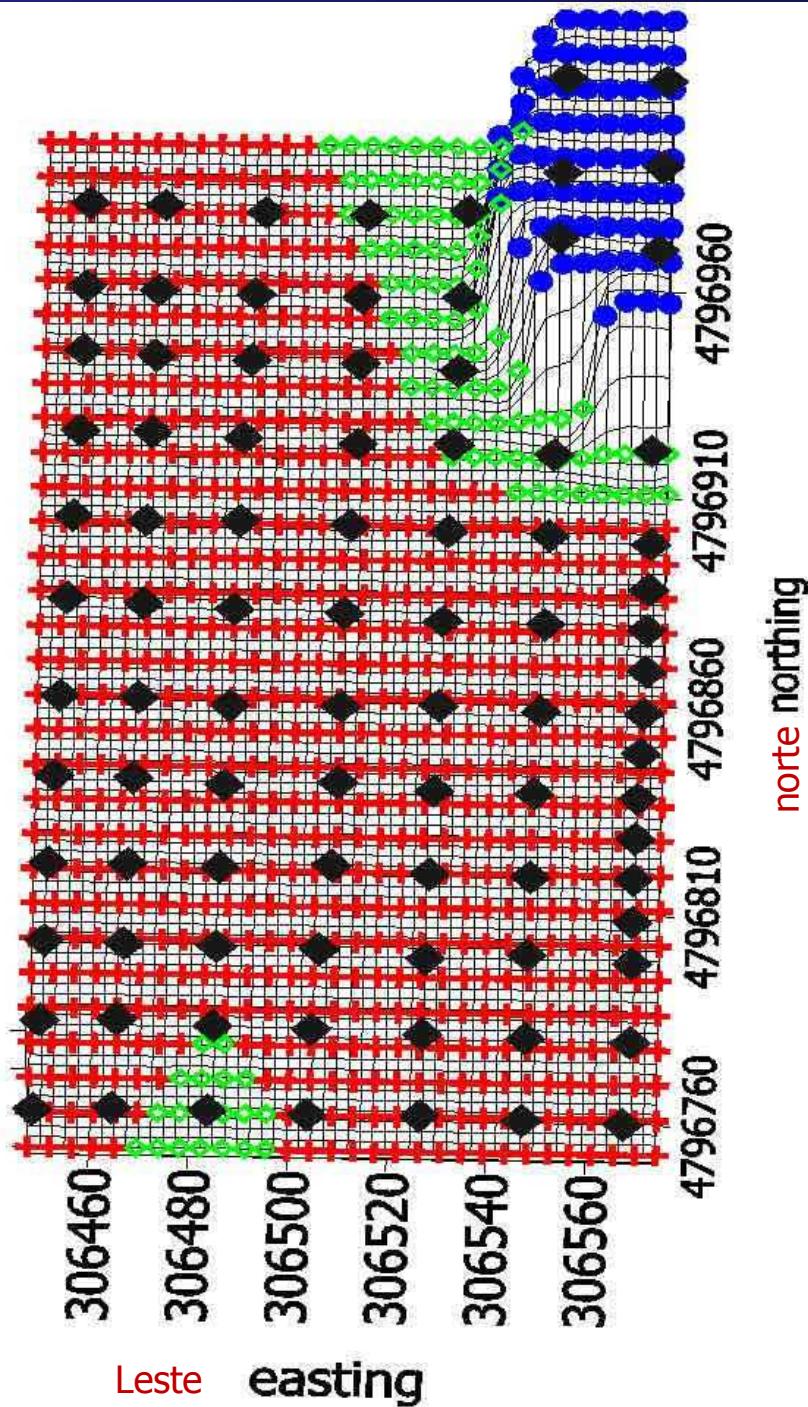
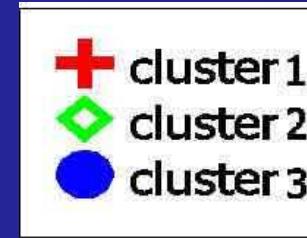
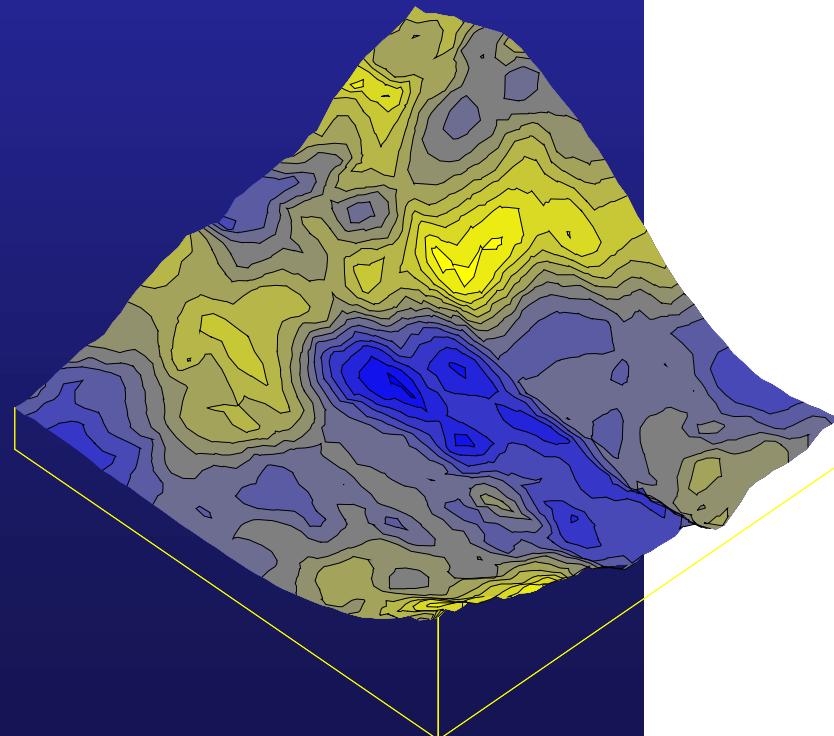
# Tratamento estatístico dos dados de penetrômetro

[Statistical treatment of penetrometer data]

- Profundidade selecionada para análise [Depth selected for analysis]
  - 0 to 1.14-m
- Dados Kriged [Kriged data]
  - valores estimados entre valores medidos
  - [estimated values between measured values]
- Dados de kriged de cluster [Clustering kriged data]
  - grupos de leituras de CI semelhantes
  - [groups of similar CI readings]

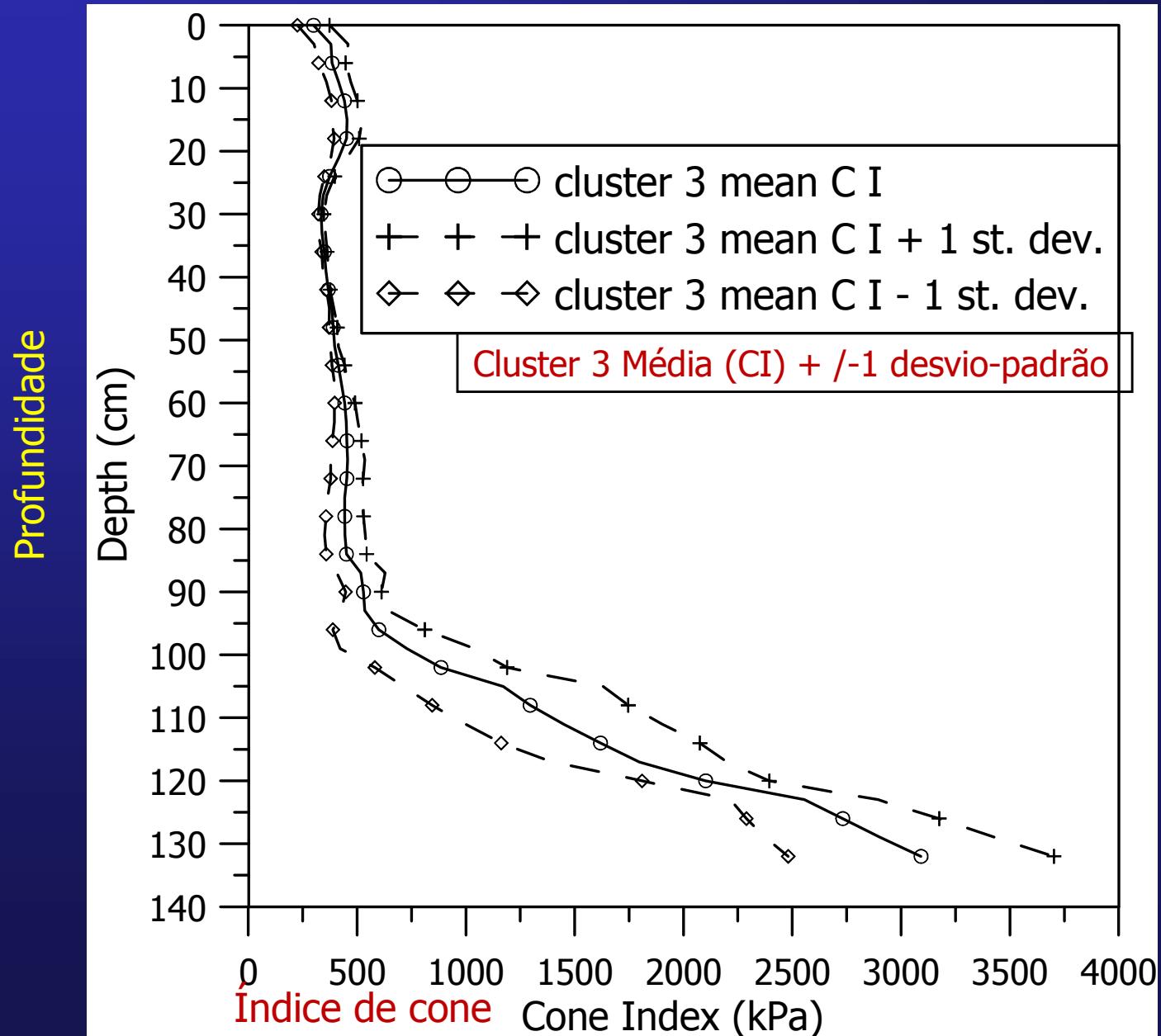
# Resultados do penetrómetro por agrupamento

[Penetrometer clustering results]

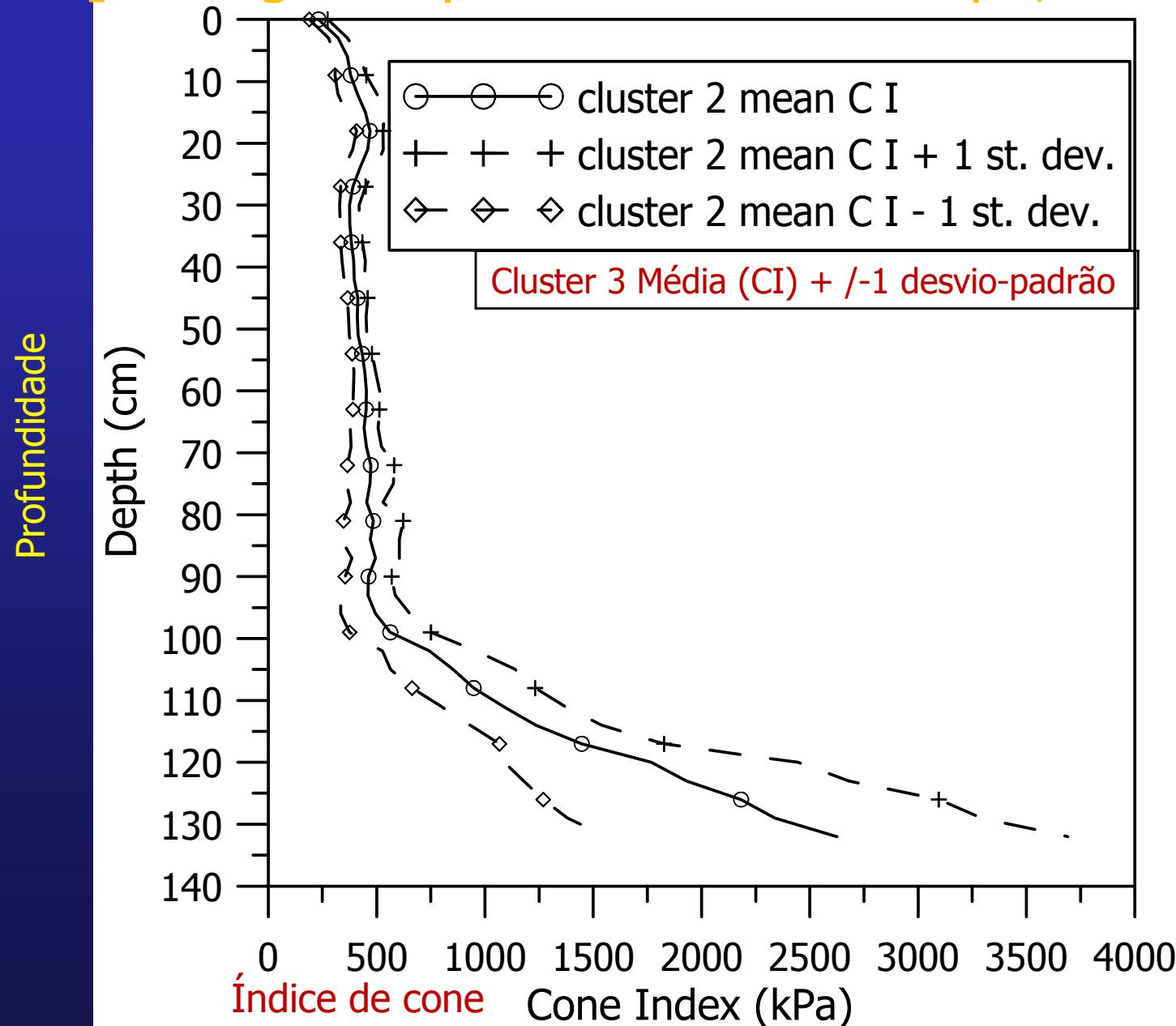


# Média CI perfil cluster 3: topo da colina, n = 6

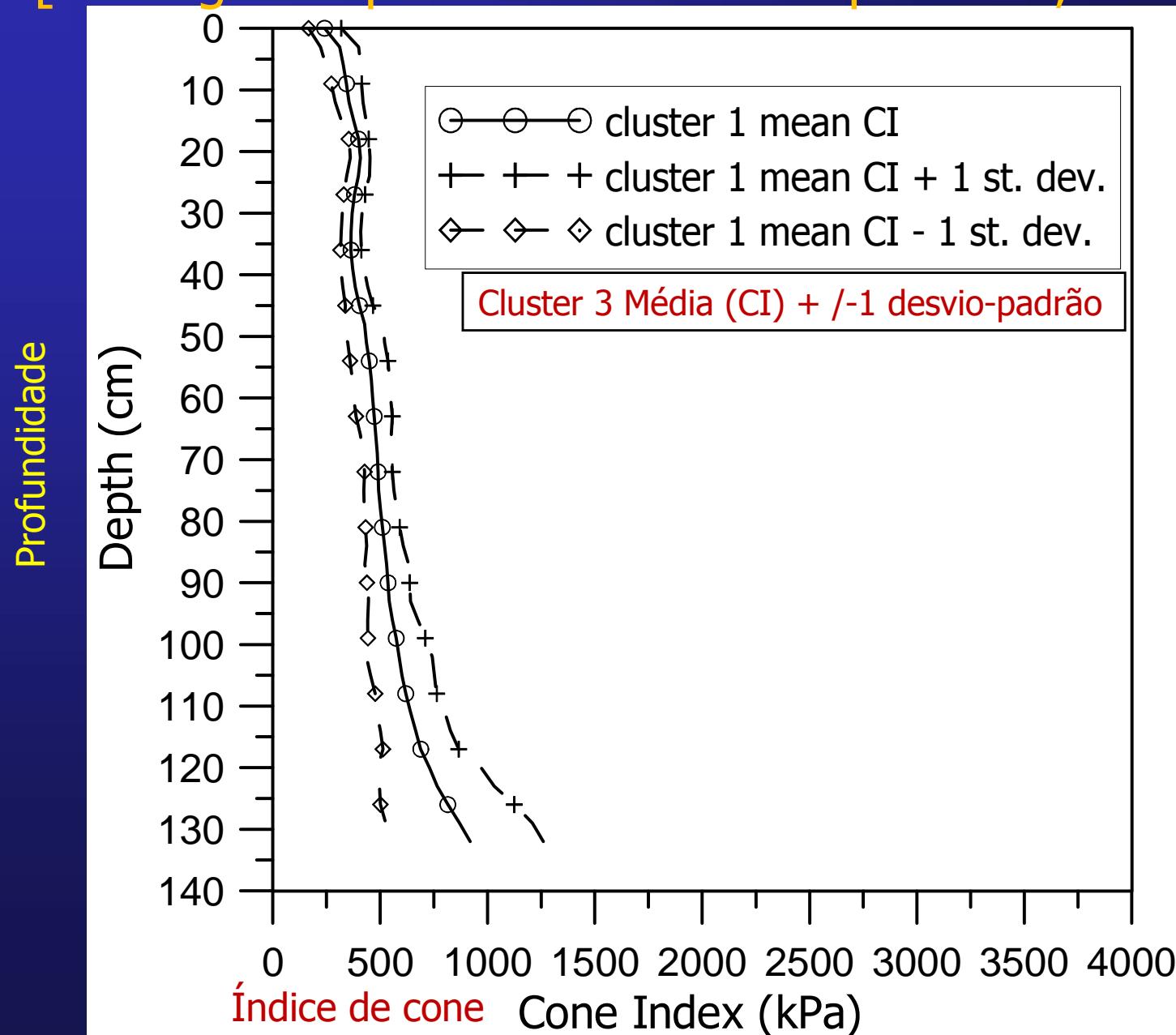
[Average C I profile cluster 3: hilltop, n=6]



# Média C I perfil cluster 2: inclinação, n = 7 [Average C I profile cluster 2: slope, n=7]



Média C I perfil cluster 1: depressão, n = 75  
[Average C I profile cluster 1: depression, n=75]

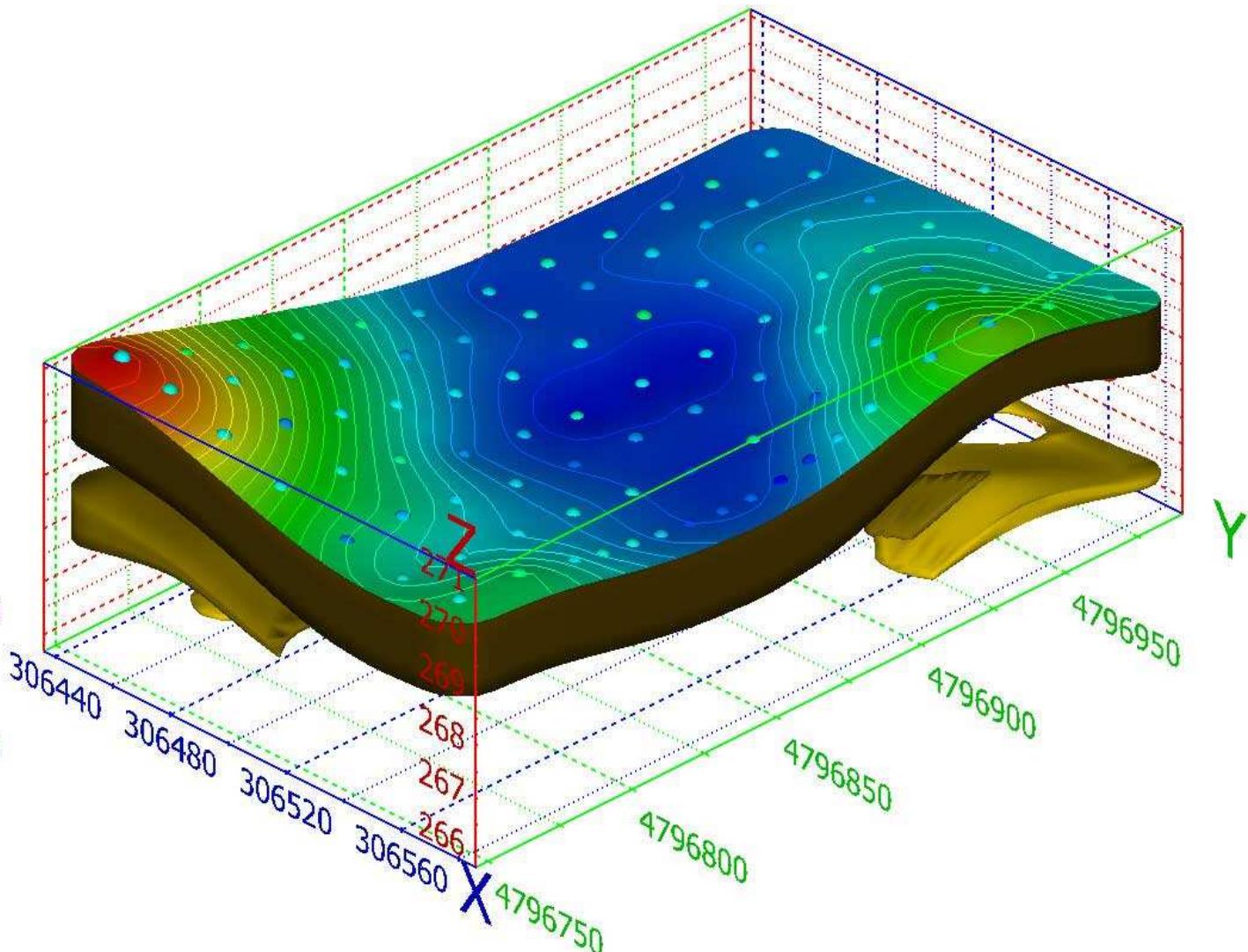
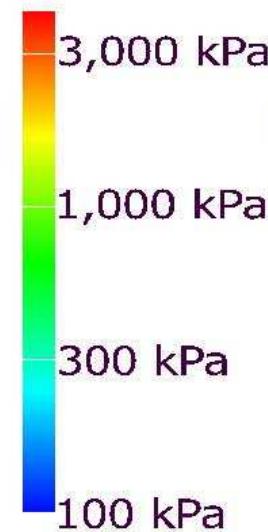


# Imagens 3-d [3-D images]

- Geo-camadas [Geolayers]
  - Camada superior [Top layer]
    - profundidades onde  $C\ I < 1000\ kPa$
    - [depths where  $C\ I < 1000\ kPa$ ]
  - Camada média [Middle layer]
    - profundidades onde  $1000\ kPa < C\ I < 1500\ kPa$
    - [depths where  $1000\ kPa < C\ I < 1500\ kPa$ ]
  - Camada inferior [Bottom layer]
    - profundidades onde  $C\ I > 1500\ kPa$
    - [depths where  $C\ I > 1500\ kPa$ ]

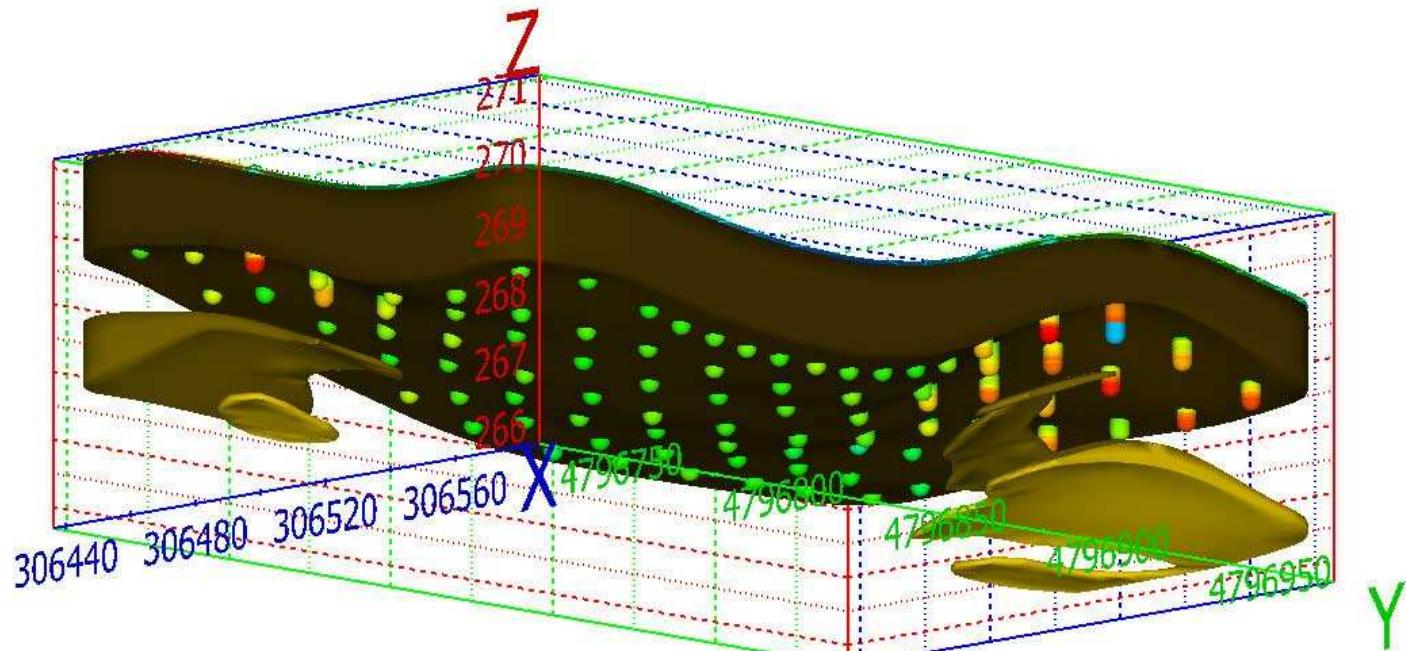
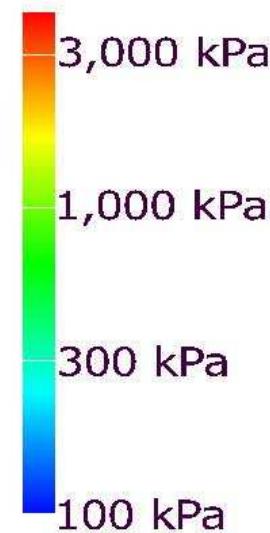
# 3 Geocamadas [3 geolayers]

Legenda  
de esfera  
encaixado  
[Imbedded  
Sphere  
Legend]



# 3 Geocamadas [3 geolayers]

Legenda  
de esfera  
encaixado  
[Imbedded  
Sphere  
Legend]



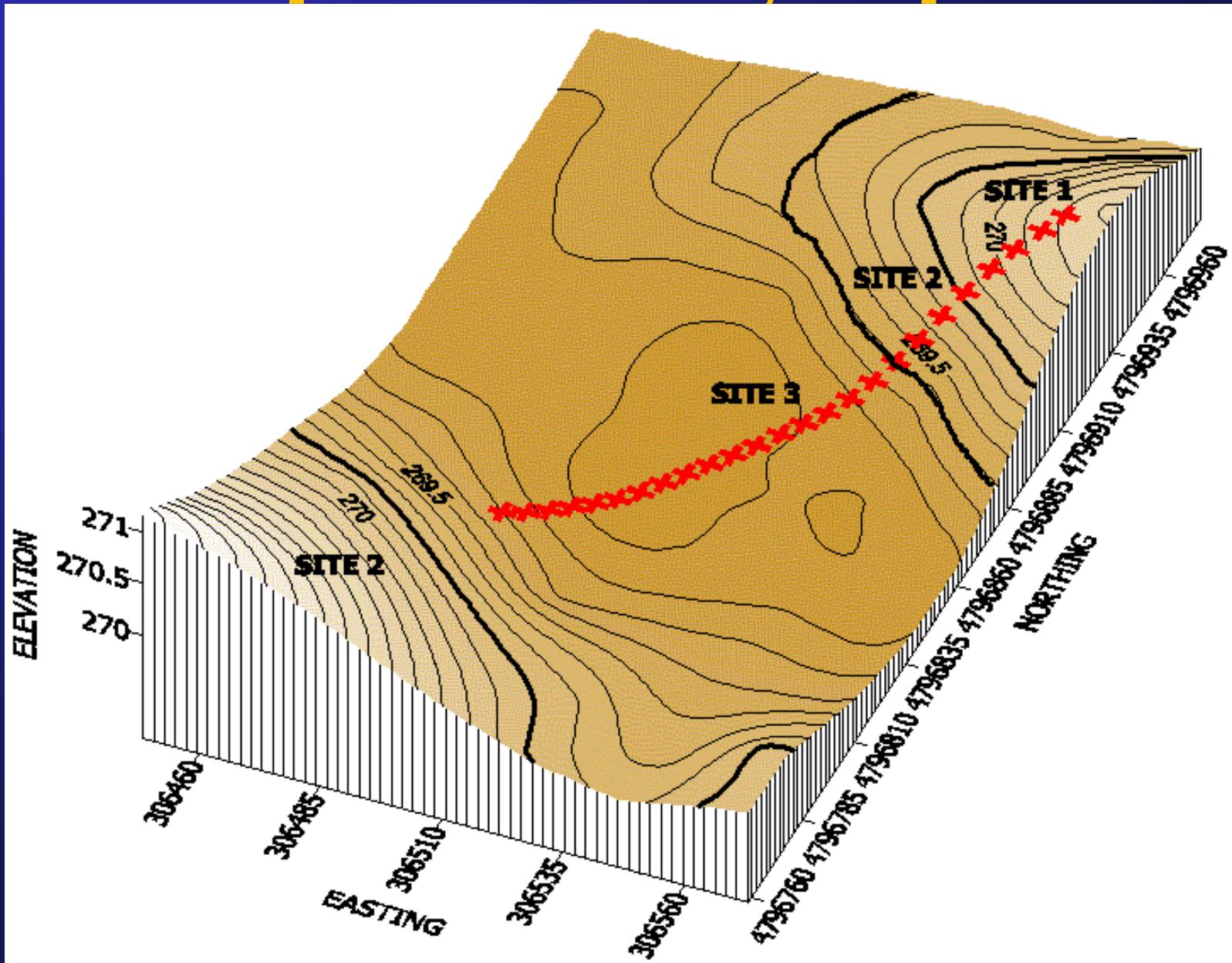
## Conclusões [Conclusions]

- Método estatístico dá classificação robusta com fronteiras definidas entre as localidades de cluster
  - [Statistical method gives robust classification with defined borders between cluster locations]
- Representações 3D [3-D depictions ]
  - não-uniformidade espacial de CI valores
  - [spatial non-uniformity of CI values]
  - aumento abrupto em leituras de penetrómetro de cone corresponde a area erodida do solo.
  - [abrupt increases in cone penetrometer readings matches Soil Survey eroded area]

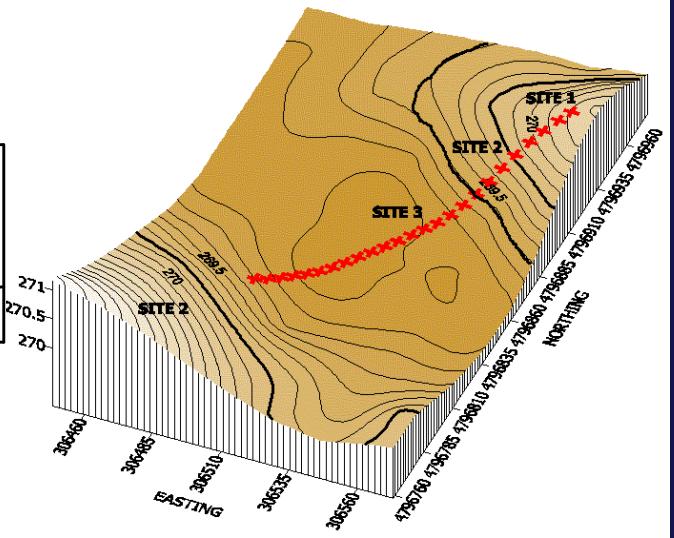
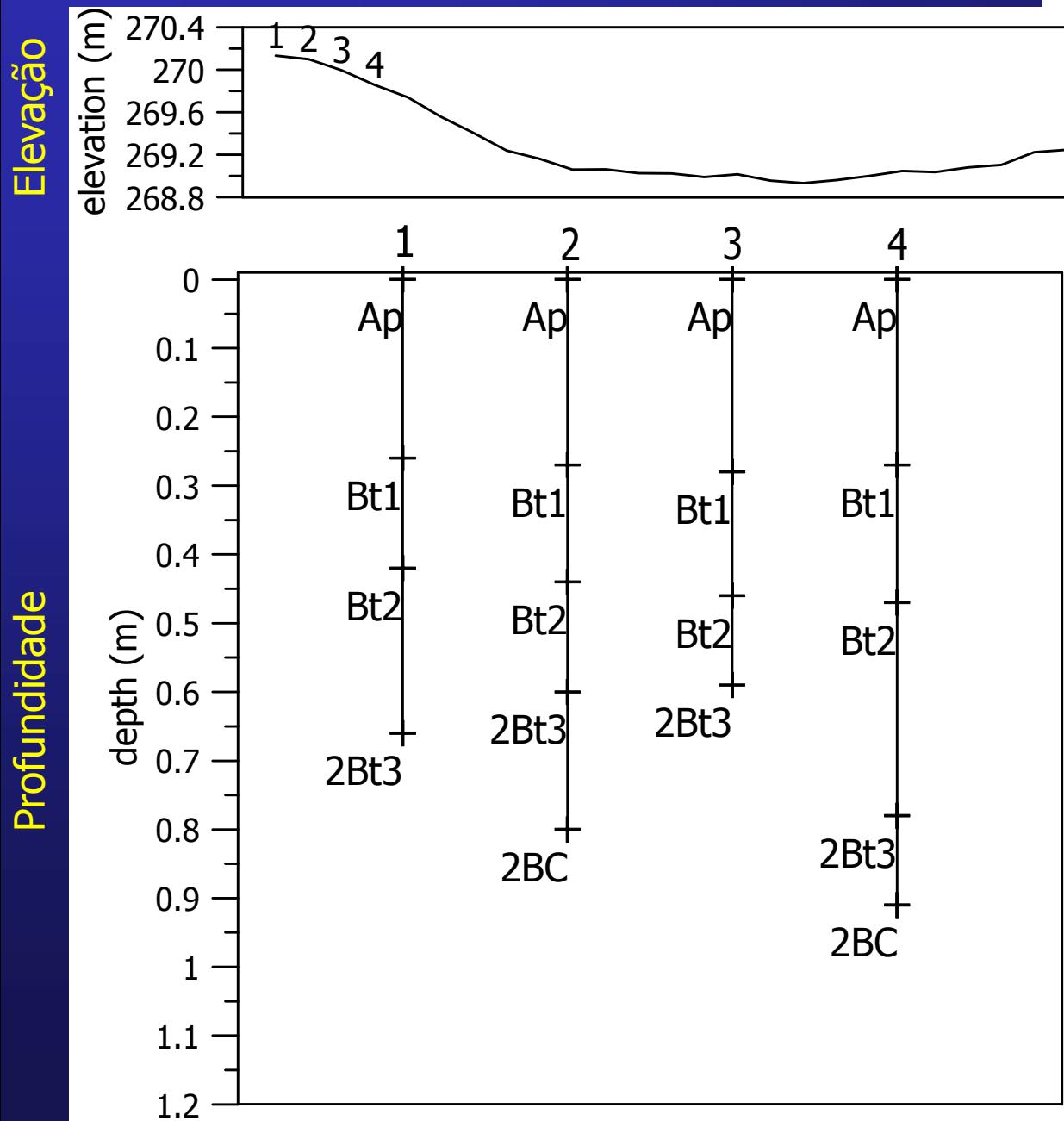
# Caracterização do site usando linha transecto [Site characterization using line transect]

- Objectivo [Objective]
  - Caracterização de site usando extrações de cilindros do solo ao longo da linha de três sitios
  - [Site characterization using soil core extractions along line transecting three sites]
    - designação de horizonte [horizon designation]
    - determinação de tamanho de partícula [particle size determination]
    - relacionamento de dados penetrómetro às propriedades do solo [relationship of penetrometer data to soil properties]

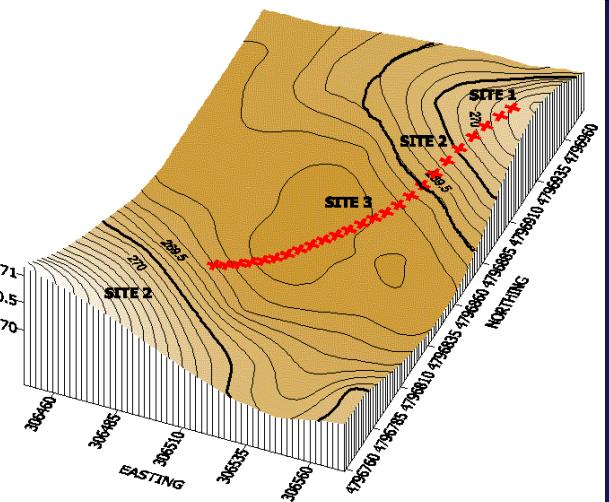
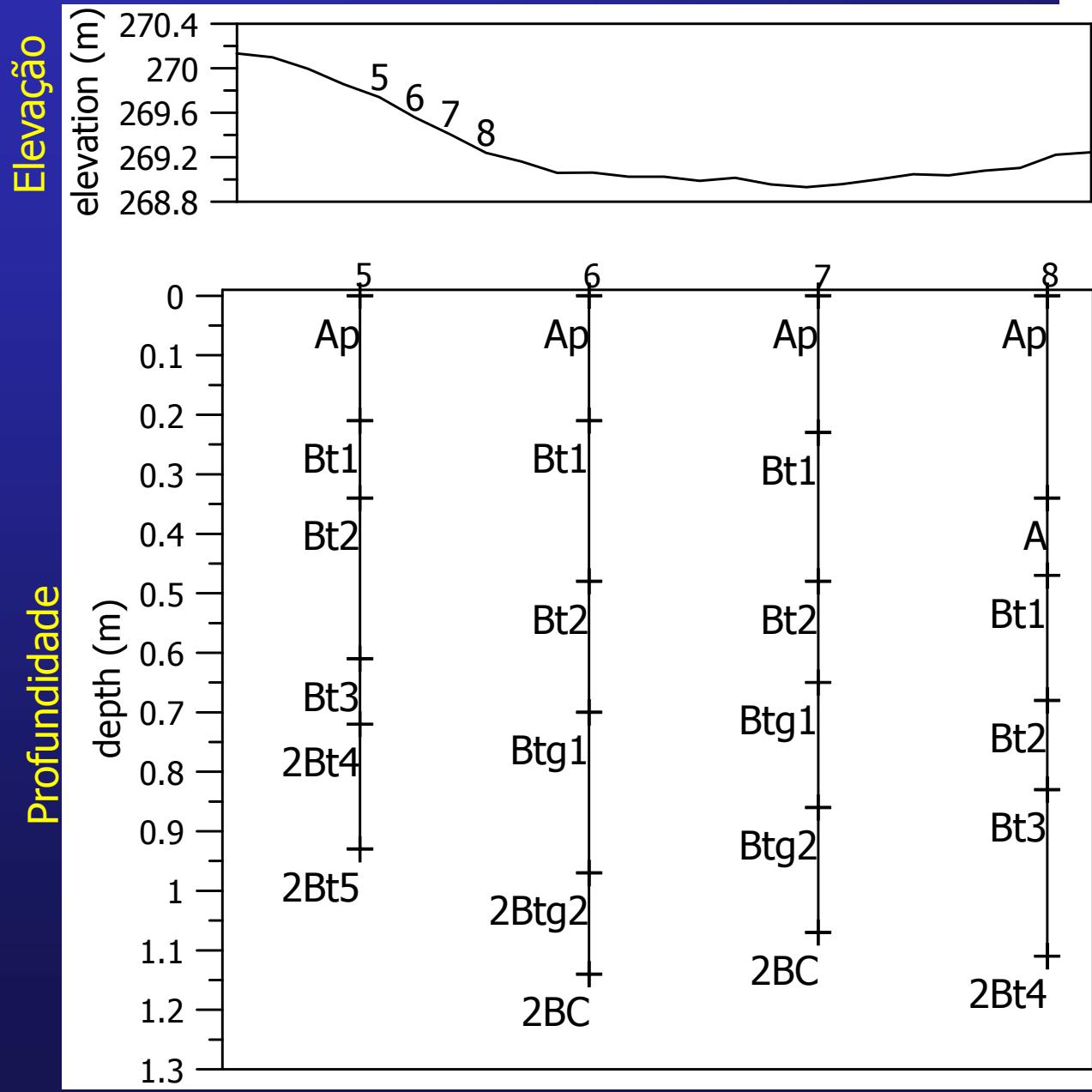
# Linha transecto de área de estudo [Line transect study area]



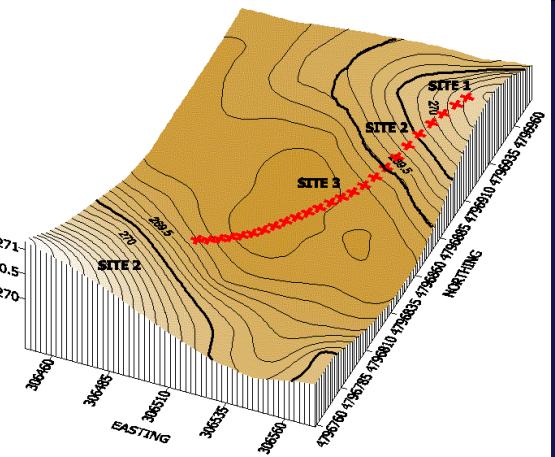
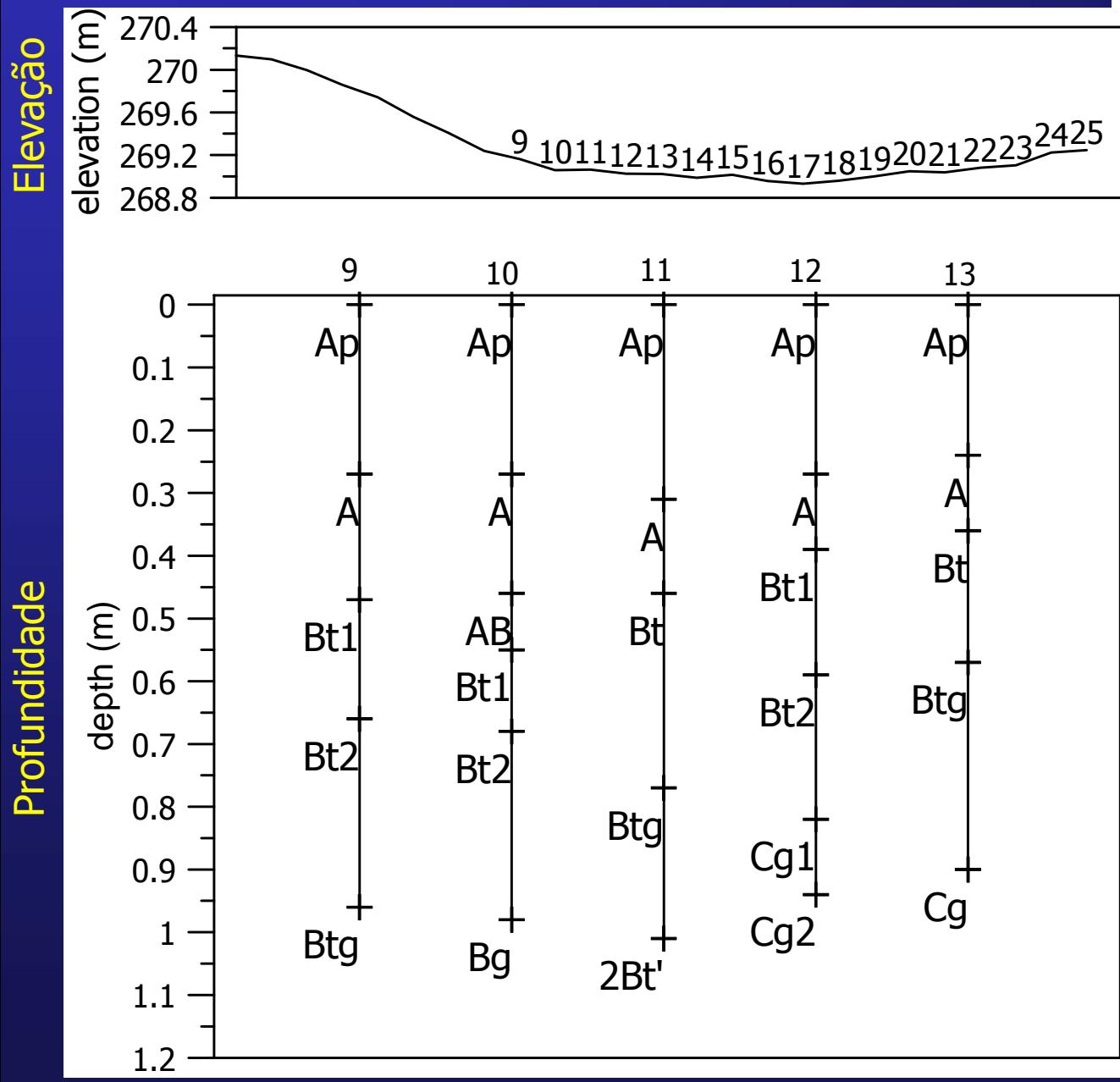
# Site 1



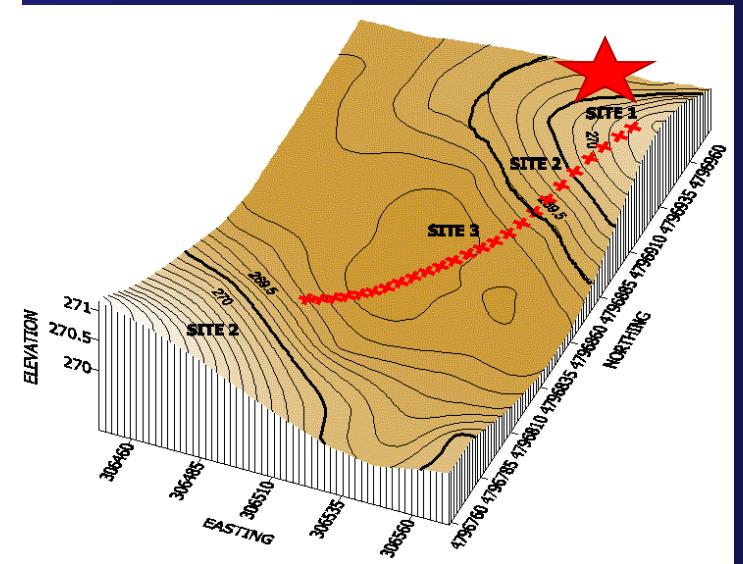
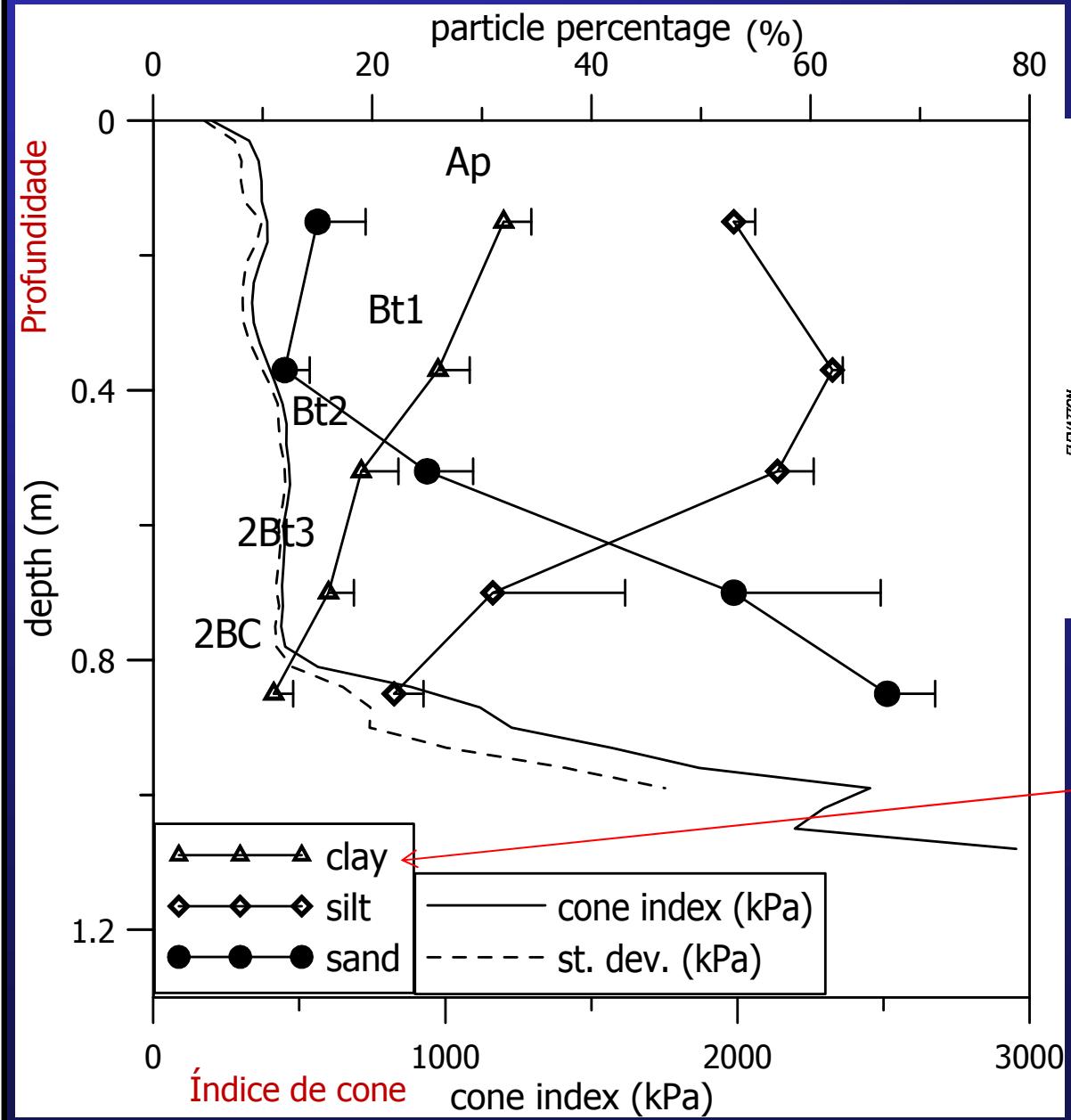
# Site 2



# Site 3



Site 1: frações de tamanho médio da partícula e dados de CI do topo da colina  
 [hilltop average particle size fractions and CI data]

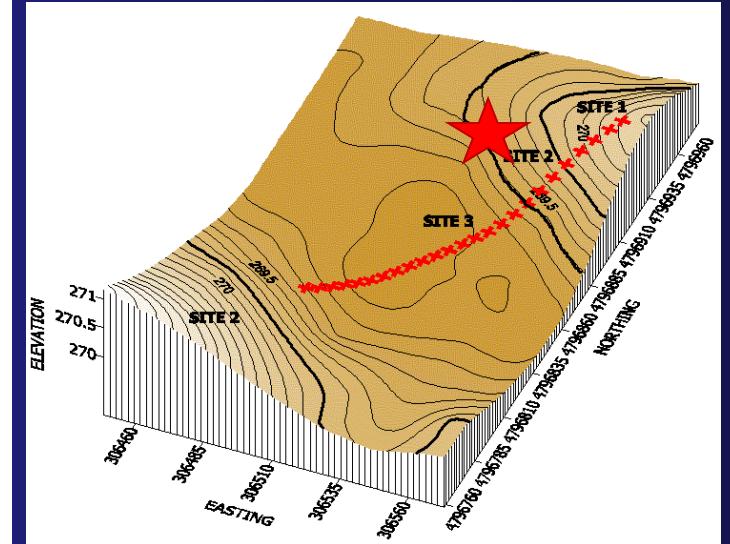
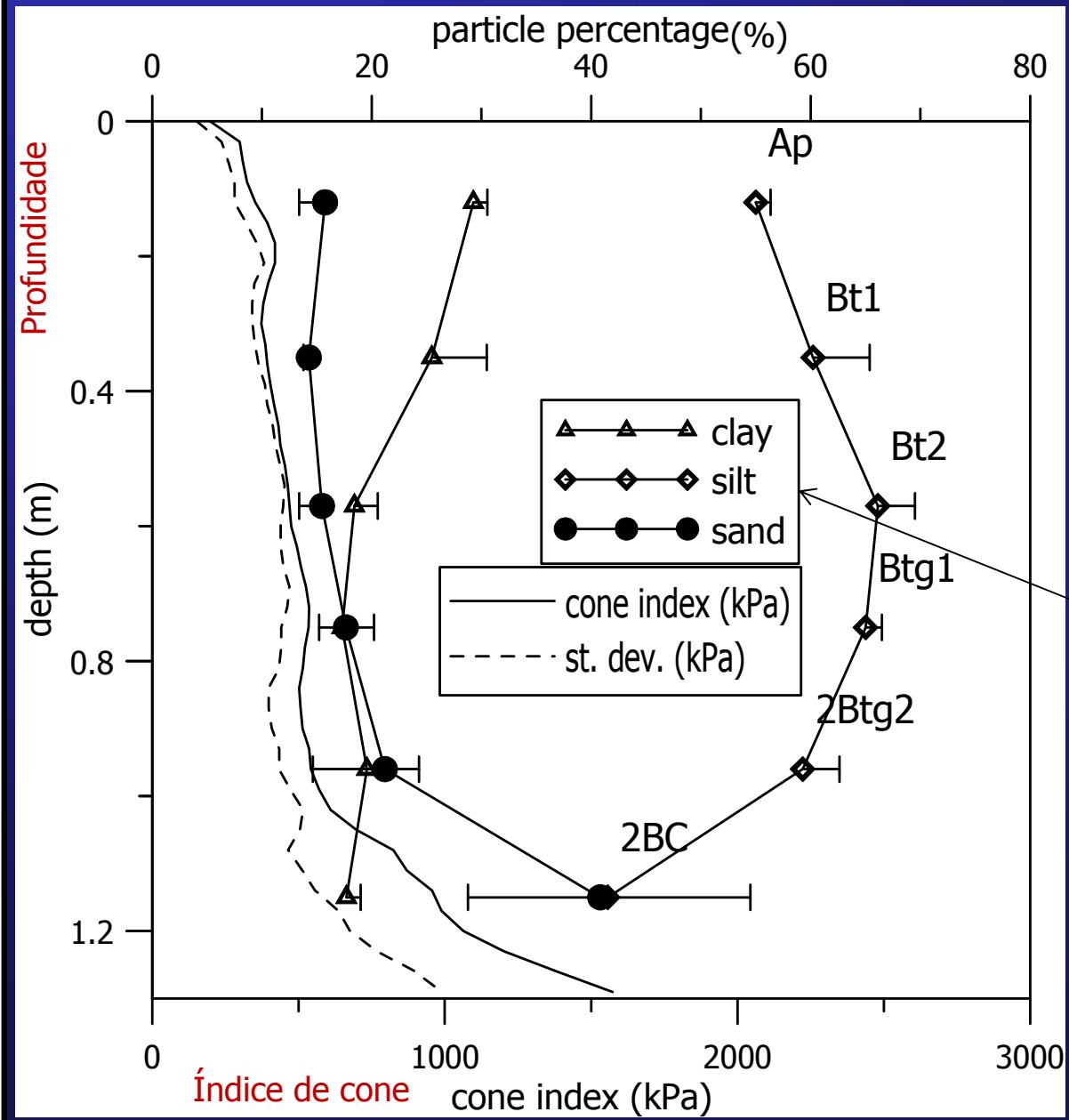


Argila  
 Silte  
 Areia



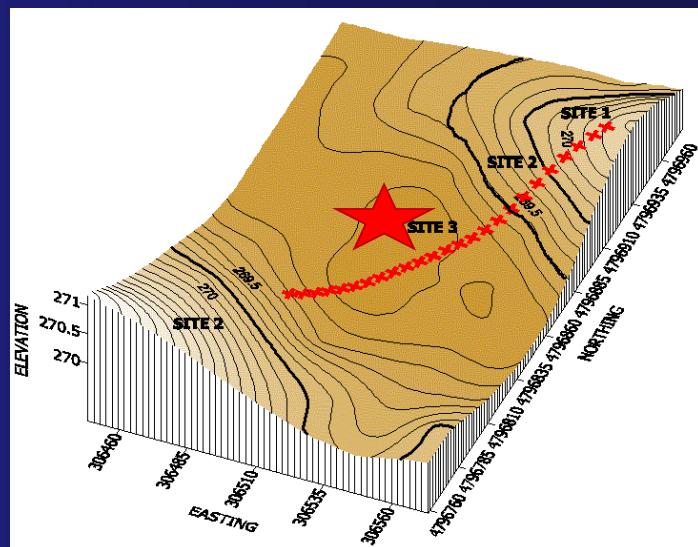
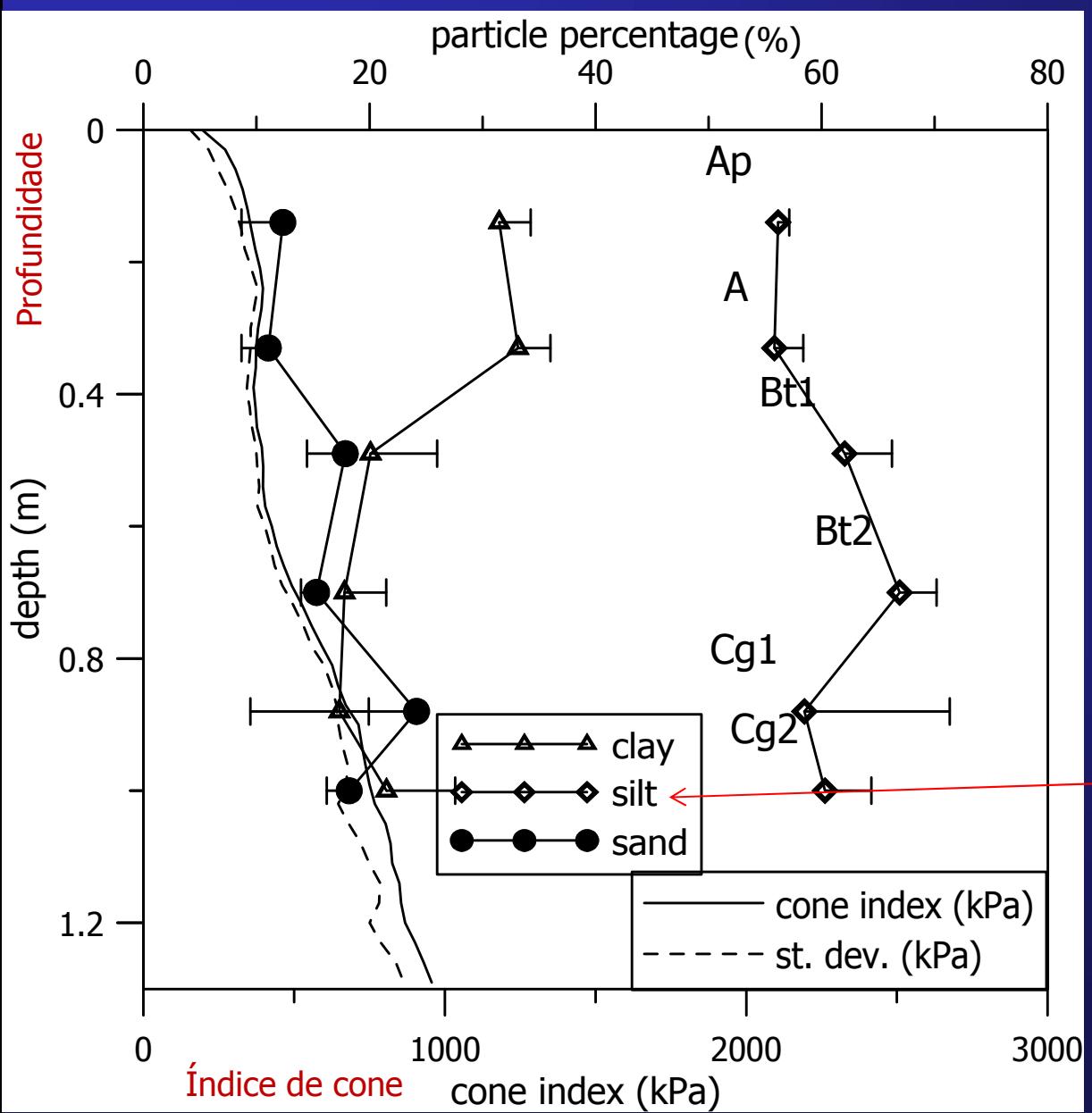
Laser para análises de tamanho de partícula  
[Laser for particle size analyses]

## Site 2: frações de tamanho médio da partícula e dados de CI da inclinação [slope average particle size fractions and CI data]



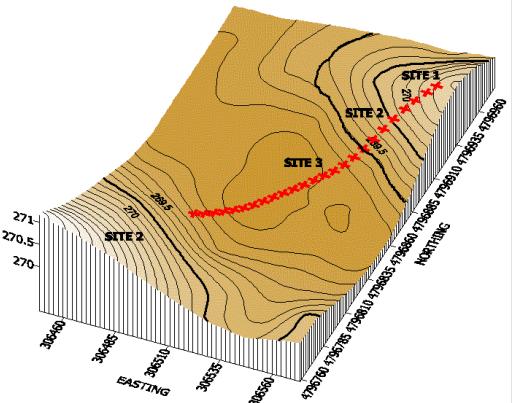
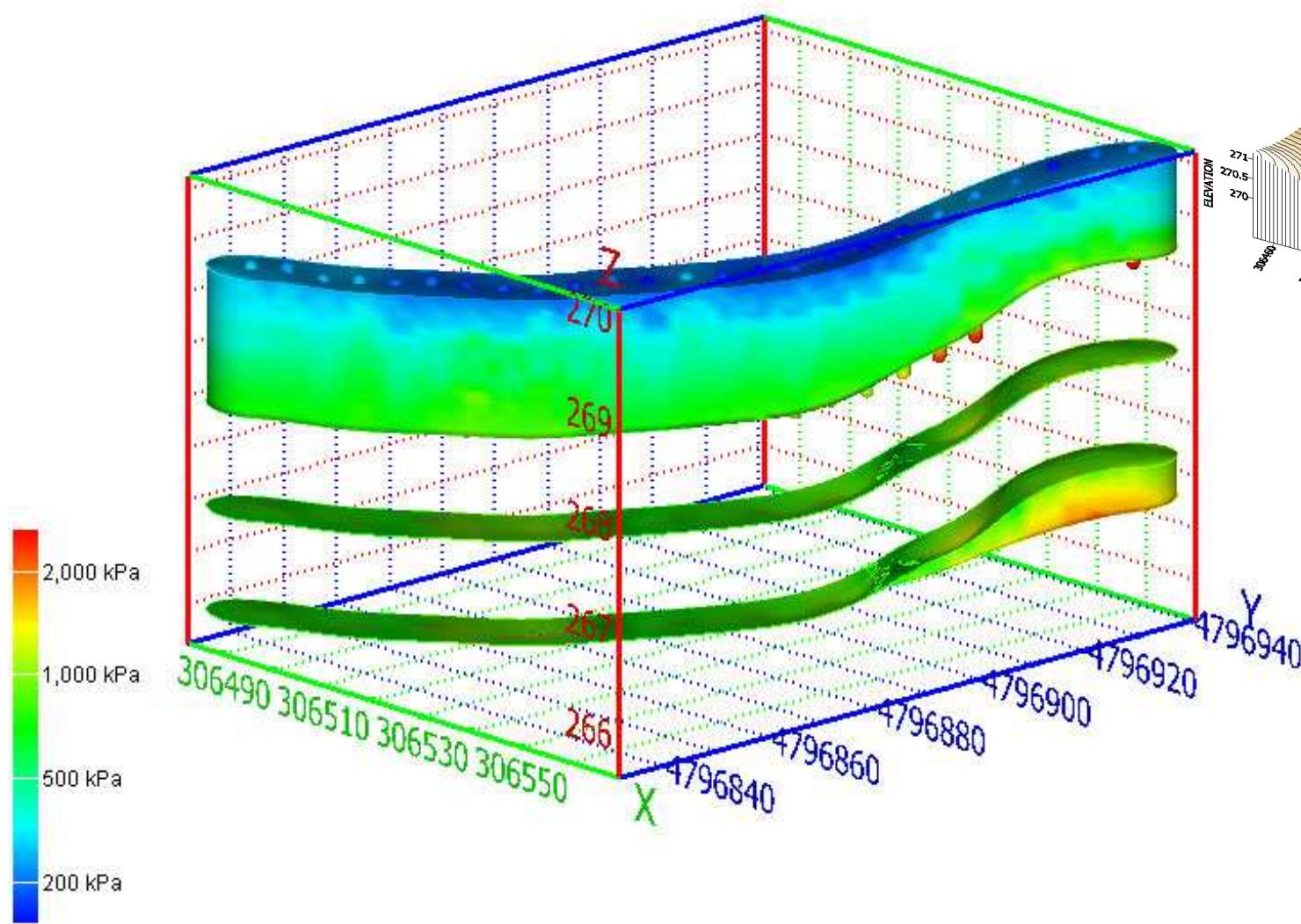
Argila  
Silte  
Areia

## Site 3: frações de tamanho de partícula médio e de dados do CI da depressão [depression average particle size fractions and CI data]

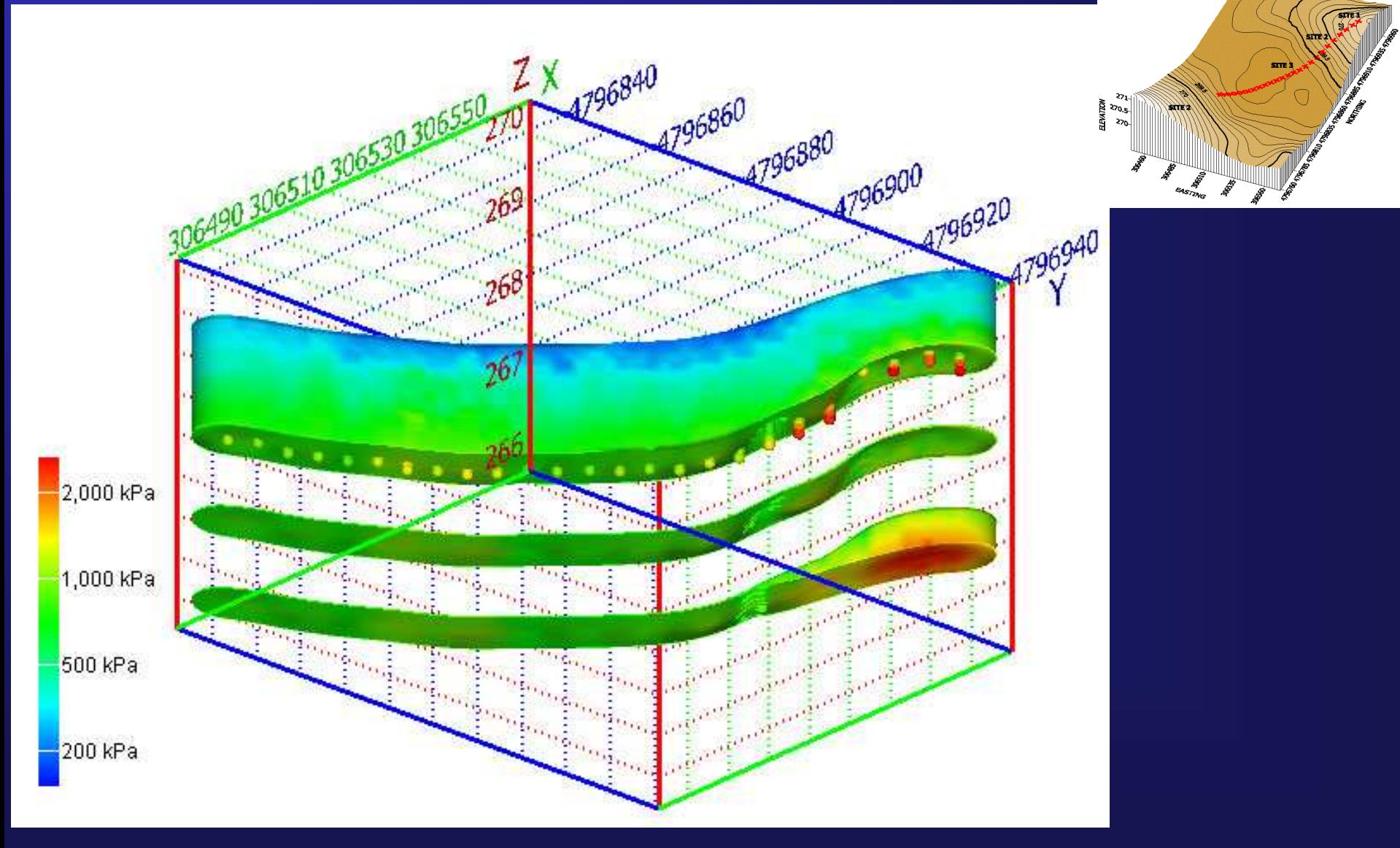


Argila  
Silte  
Areia

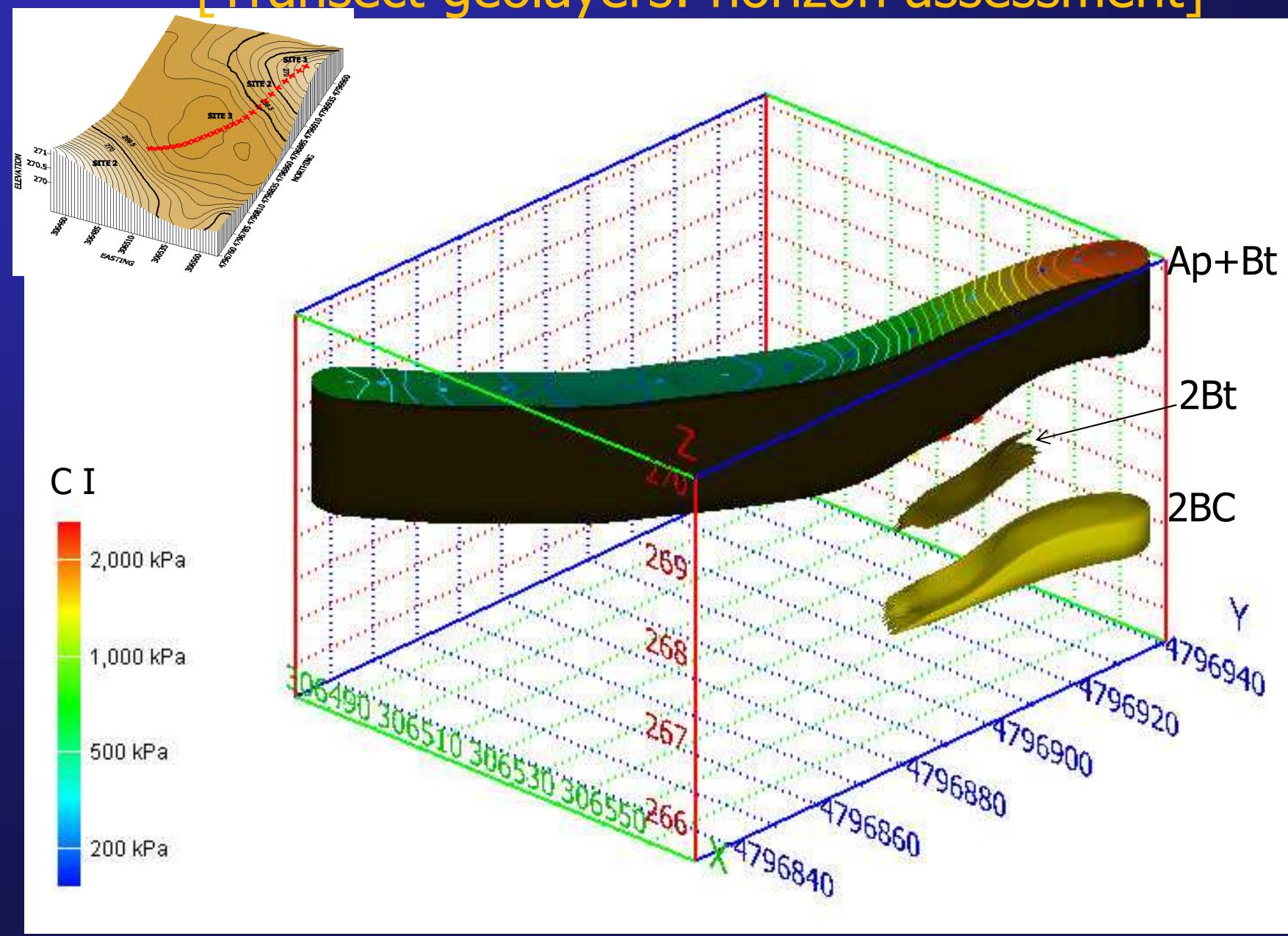
# Diagrama de blocos: transecto de penetrómetro de cone [Block diagram: Cone penetrometer transect]



# Diagrama de blocos: transecto de penetrómetro de cone [Block diagram: Cone penetrometer transect]



# Transecto de geocamadas: avaliação de horizonte [Transect geolayers: horizon assessment]

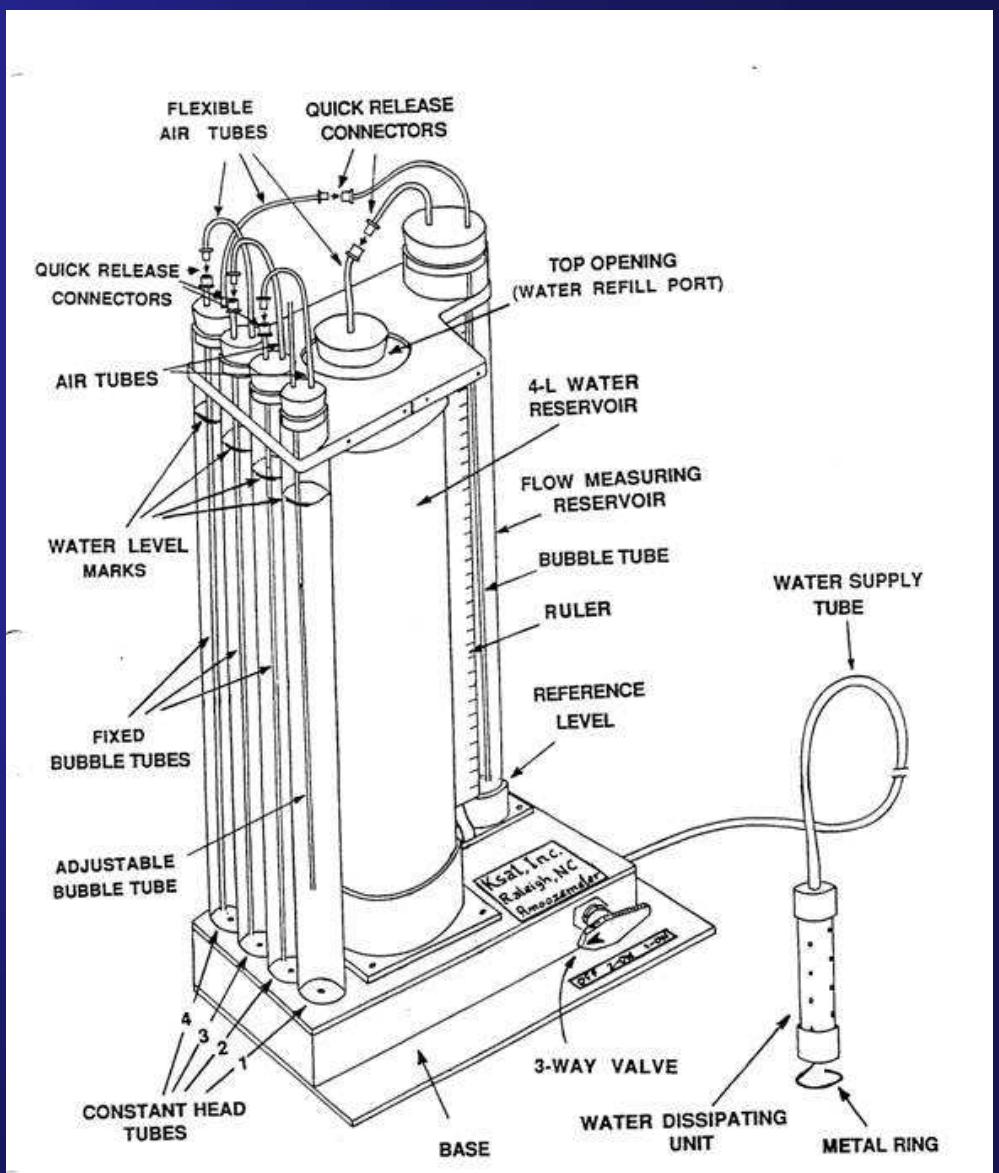
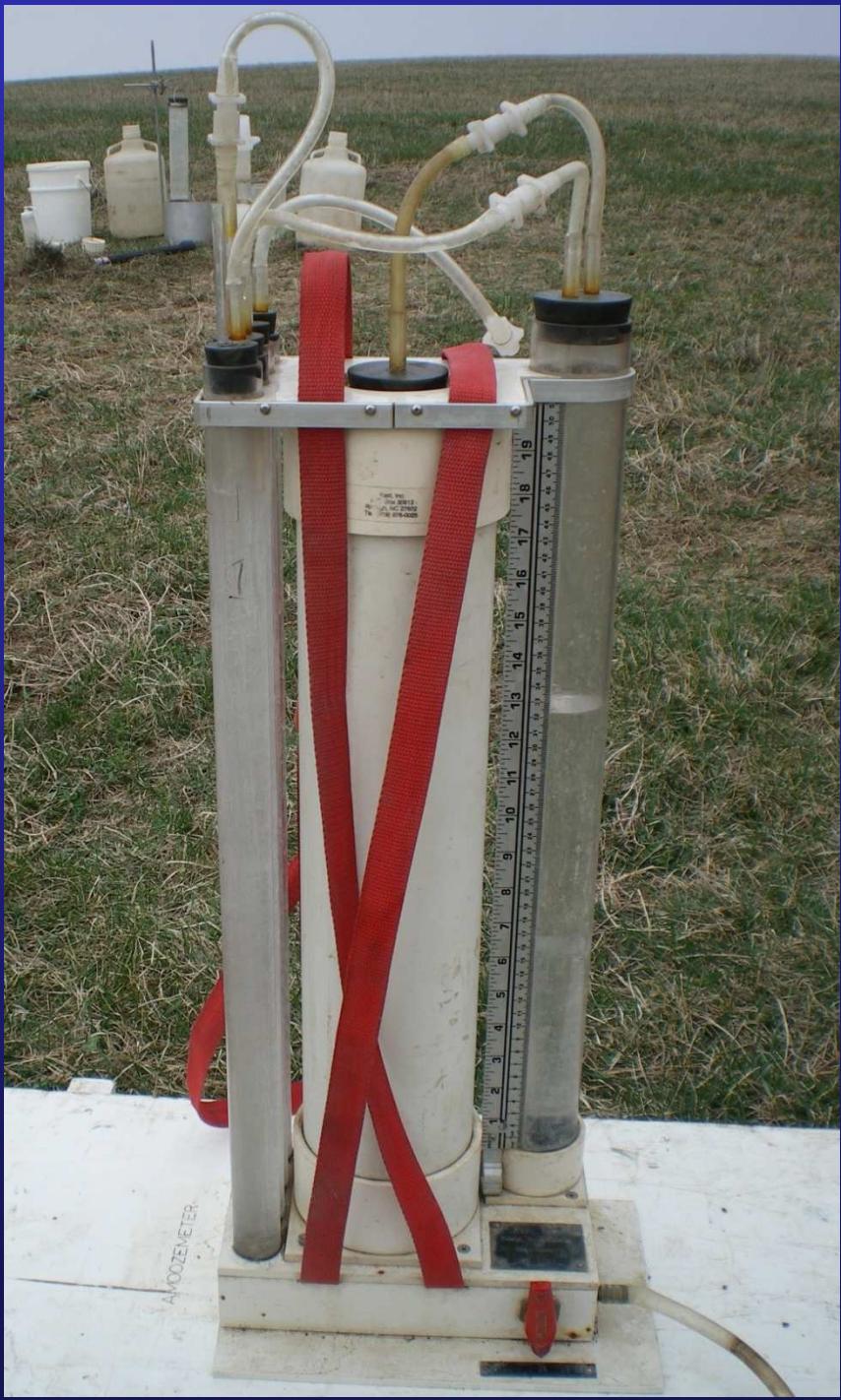


# Conclusões de caracterização do sítio [characterization conclusions]

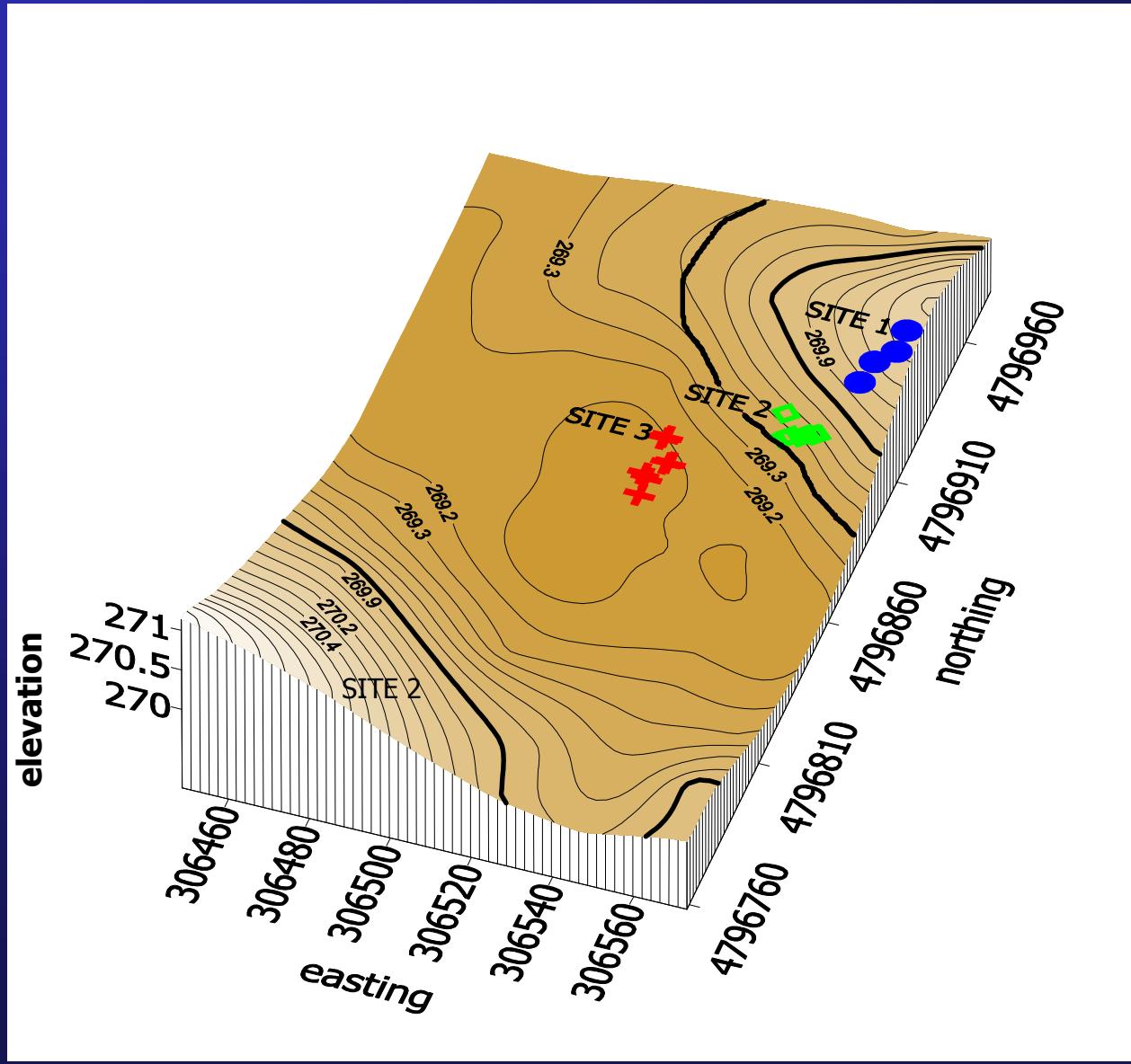
- Análise de laser [Laser analysis ]
  - fração areia: bom [sand fraction: good]
  - fração argila: estimado abaixo [clay fraction: underestimated]
  - fração silte: superestimado [silt fraction: overestimated]
- Penetrómetro identificado [Penetrometer identified]
  - localização de horizonte 2BC [2BC horizon location]
  - conteúdo de areia: aumento abrupto [sand content: abrupt increase]

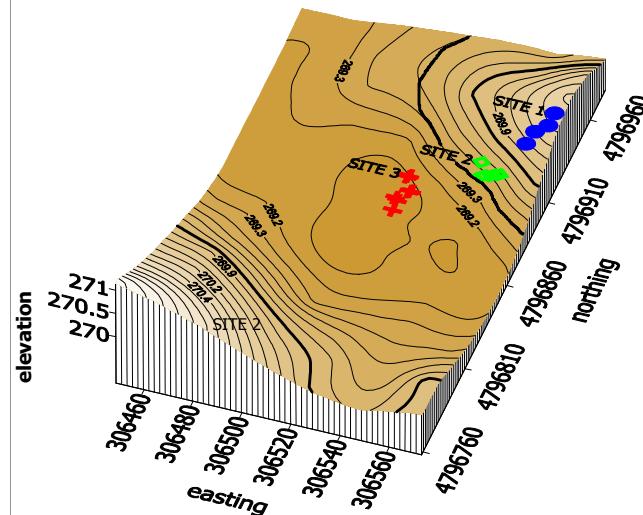
## Condutividade hidráulica medida por horizonte Hydraulic conductivity measured by horizon

- Objectivo [Objective]
  - Permeameter de carga constante usado para medir a condutividade hidráulica do horizonte *in situ* saturado ( $K_{sat}$ ) para áreas de diferentes propriedades do solo.
  - [Compact constant head permeameter used to measure by horizon *in situ* saturated hydraulic conductivity ( $K_{sat}$ ) for areas of different soil properties.]

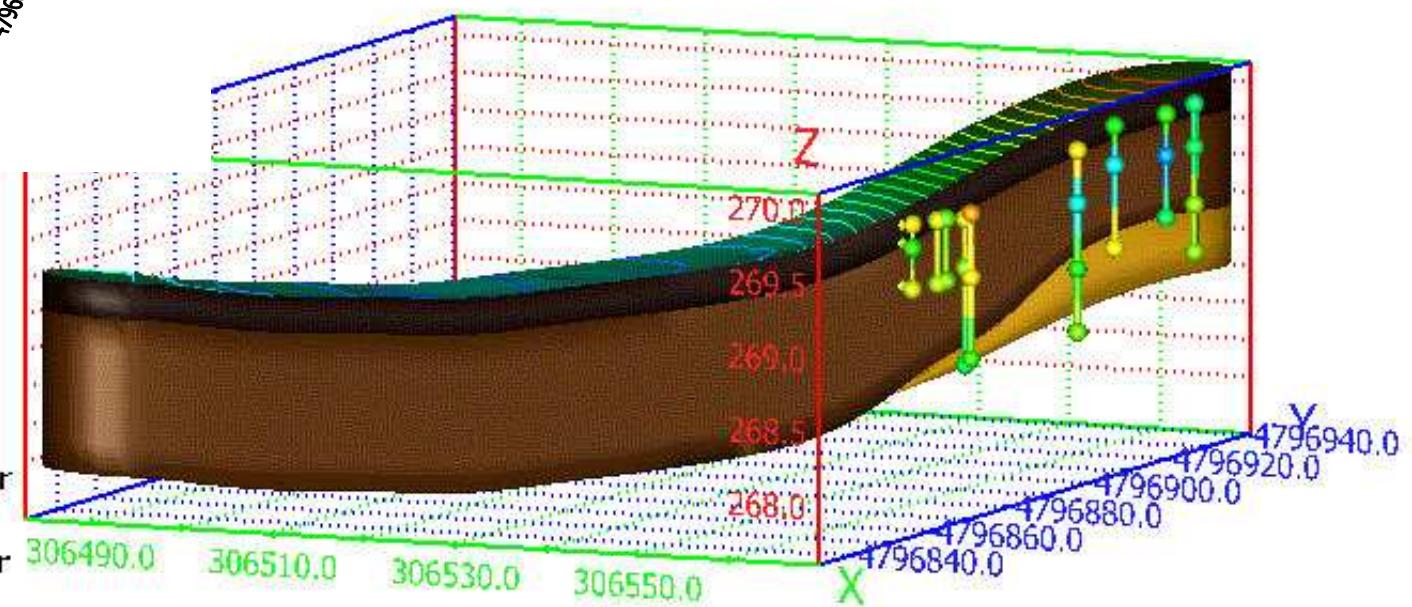


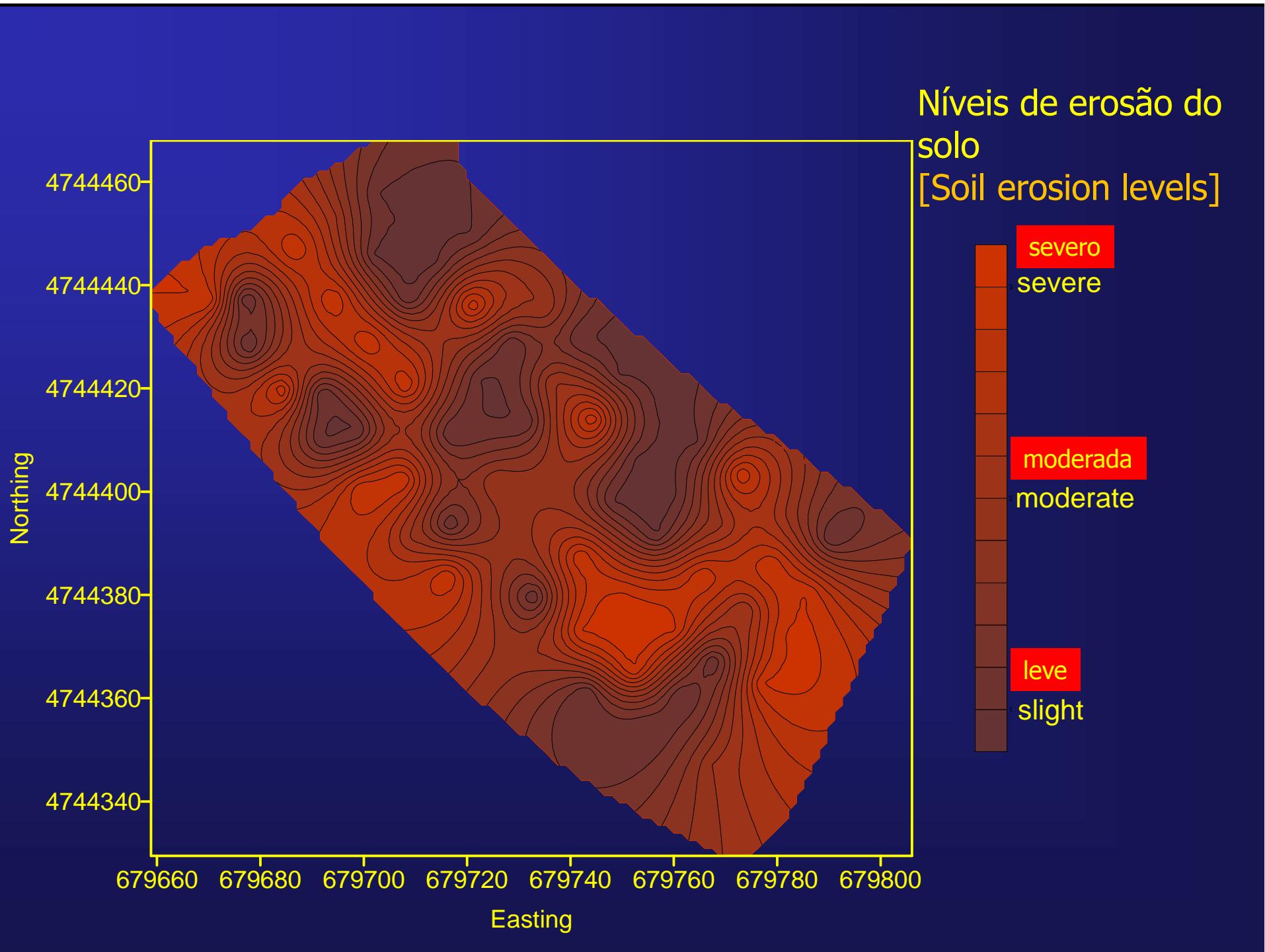
# Locais de medição da condutividade hidráulica [Hydraulic conductivity measurement locations]

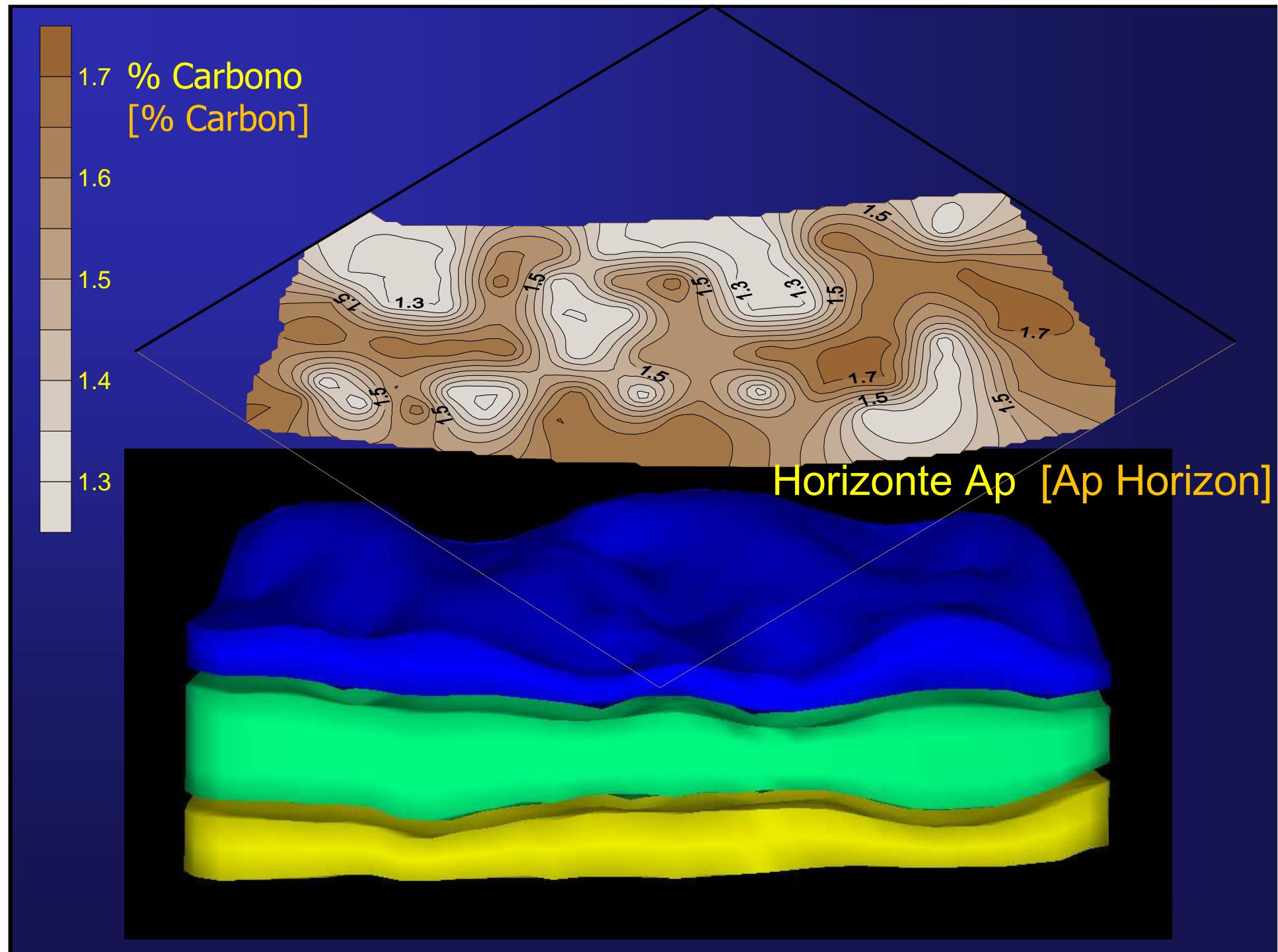




# Valores de condutividade hidráulica Hydraulic conductivity values







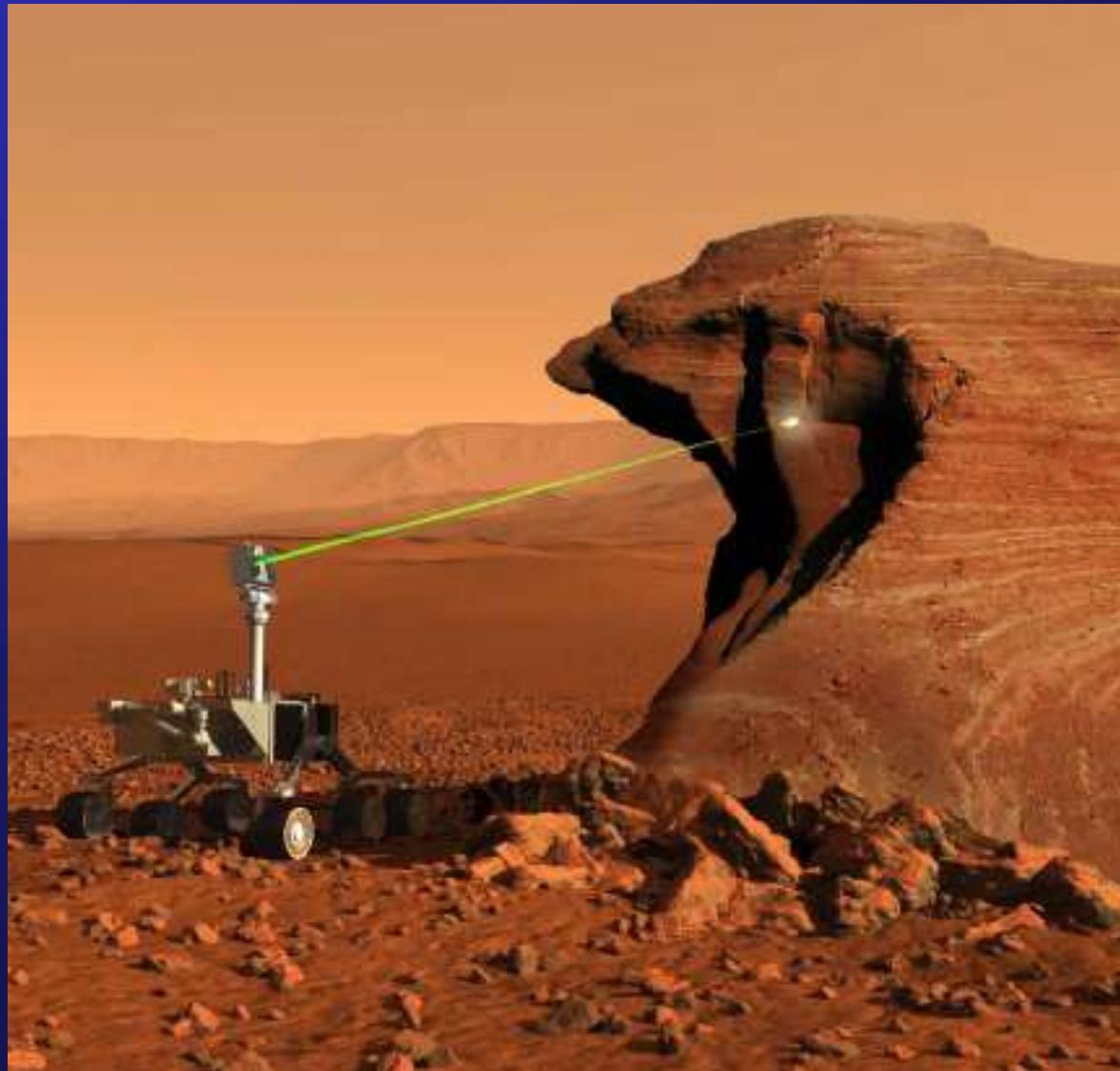
## Conclusões e oportunidades futuras

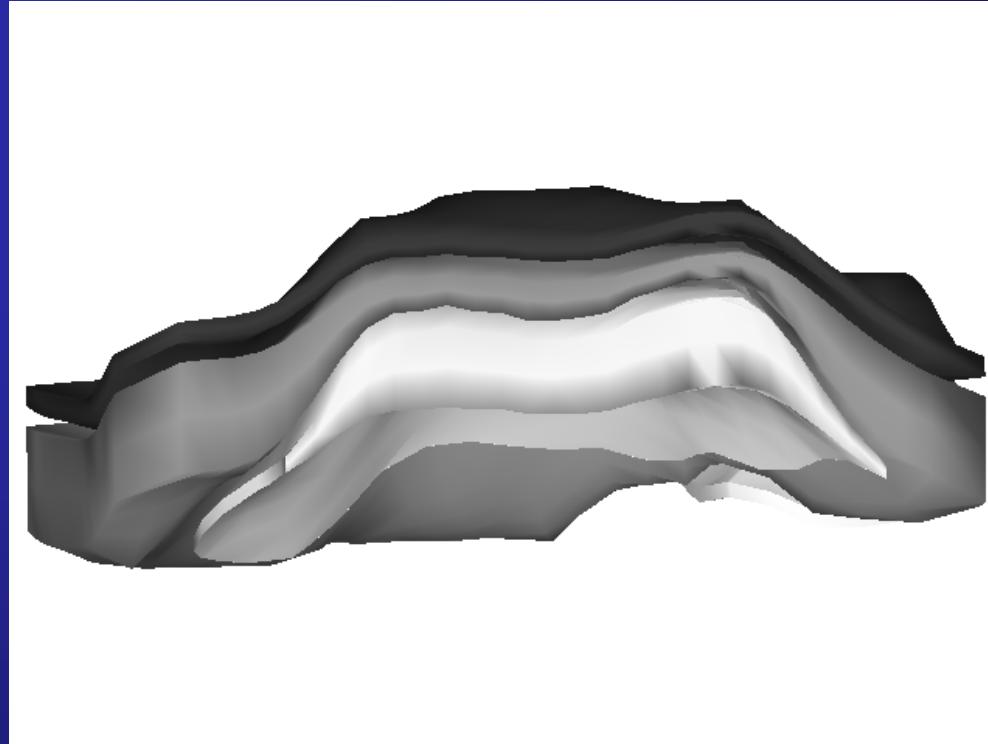
- Medições rápidas - laser de tamanho de partícula do solo
- Medições em tempo real
- Laser análises químicas de solos, laboratório e *in situ*

## [Conclusions and Future Opportunities

- Rapid measurements --laser of soil particle size
- Real time measurements
- Laser soil chemical analyses, lab and *in situ*]

Mars Rover to Fire Rock-Zapping Laser -- See more at:  
<http://www.space.com/17164-mars-rover-curiosity-laser-big-drive.html#sthash.QBgXHDEG.dpuf>





Perguntas ??  
(Questions ??)