Role of Earthworms on Preferential Transport through Soils

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Students and Collaborators

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- John Moncrief, John Nieber, Ed. Berry, Nyle Wollenhaupt, Udai Singh.

Reasons for Preferential Flow

- Differences in fluid properties (relevant in non-agricultural settings)
- Discontinuities in soil horizons- Sandy Soils
- Physical pores (cracks)-High Clay soils
- Biological pores
  - Earthworm macropores
  - Decaying root channels-Tap root system

Effect of Discontinuities

Perillo et al., (1998, 1999)

Preferential Flow in Sandy Outwash soils

Perillo et al., (1998,1999)

Effect of tap root system

Perillo et al., (1998, 1999)

Effect of Tap root system

Perillo et al., (1998, 1999)

Earthworm Burrows

Earthworm and a Macropore

Degree of Disturbance

No-till

Macropore Continuity Maintained

Chisel Plow

Macropore Continuity Broken

Dolliver et al. 2007

Effect of Tillage on Residue Cover and Number of Worms

Parameter	Spring/Summer 1995		Fall 1995		Spring/Summer 1996	
	NT	CH	NT	CH	NT	CH
Residue Cover %	86a	32b	97a	93a	82a	16b
Total worms (# m^{-2})	51a	9b	154a	73b	81a	16b
L. terrestris (# m^{-2})	7.1a	1.4a	17.6a	4.3a	9.5a	4.8a

Numbers followed by the same letter in any sampling period are not different at p=0.5

Matt Hanewall, (1996)

Effect of Tillage on Infiltration Rate, mm hr^{-1}

Parameter	Spring/Summer 1995		Fall 1995		Spring/Summer 1996	
	NT	CH	NT	CH	NT	CH
Ponded infiltration	146a	81a	134a	41a	57a	42b
Simulated Rainfall	49a	30b	55a	40a	41a	36a
-3.5 cm Tension	5a	3a	3a	2a	2a	2a

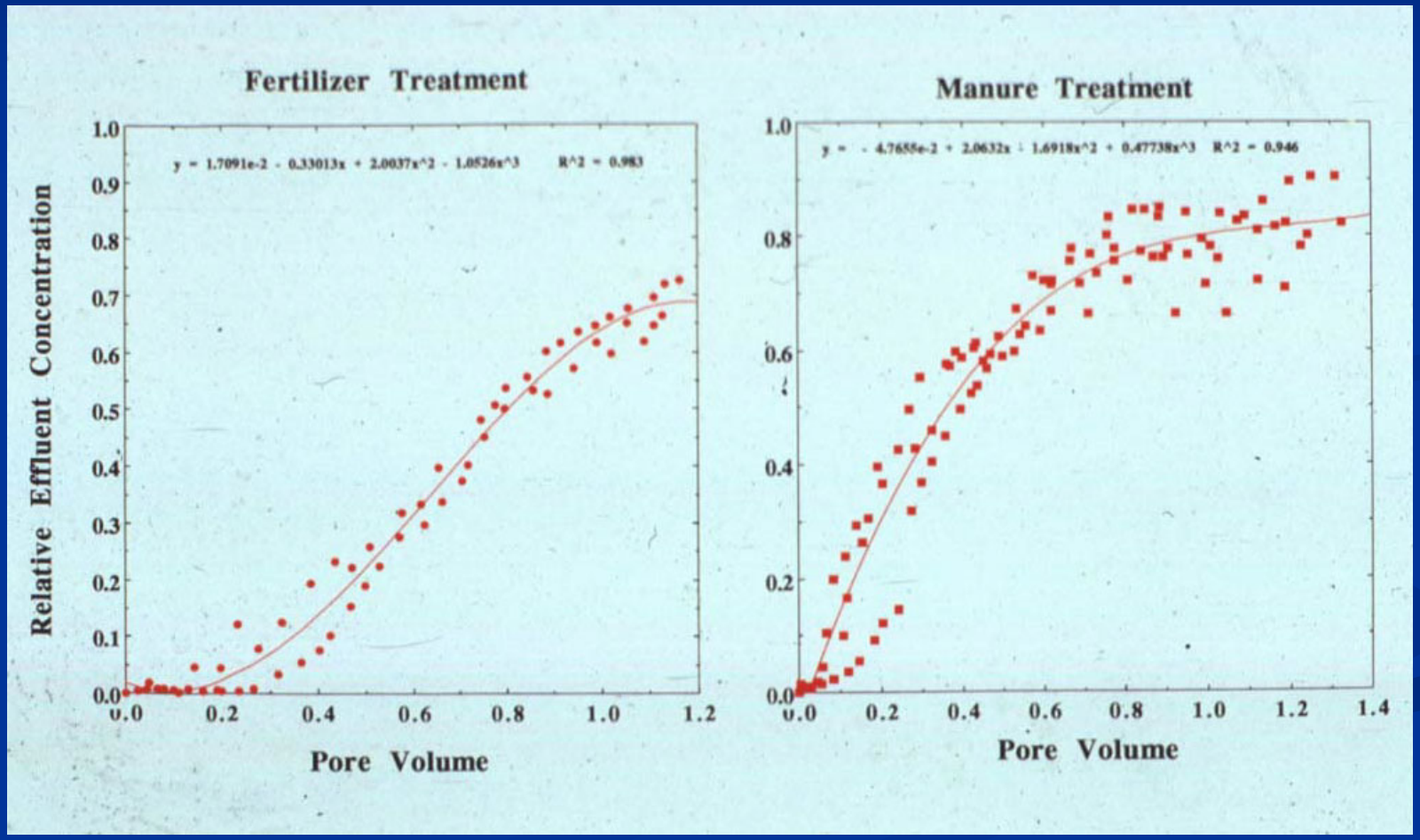
Numbers followed by the same letter in any sampling period are not different at p=0.5

Matt Hanewall, (1996)

Undisturbed Core Extraction

Munyankusi et al. (1994)

Breakthrough Curves



Munyankusi et al. (1994)

Continuity of macropores- 0-cm depth

Munyankusi et al. (1994)

Continuity of macropores 1-cm depth

Munyankusi et al. (1994)

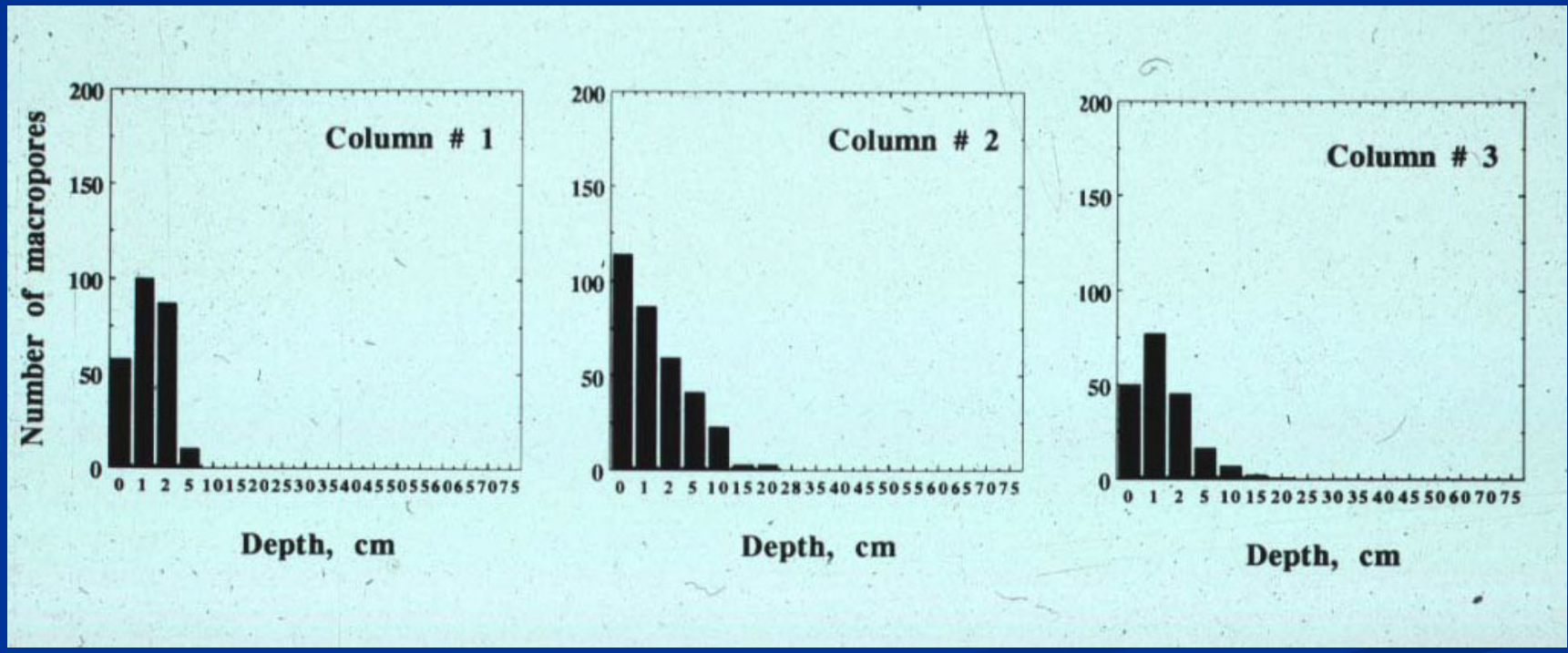
Continuity of macropores 1-cm depth

Munyankusi et al. (1994)

Continuity of macropores 2-cm depth

Munyankusi et al. (1994)

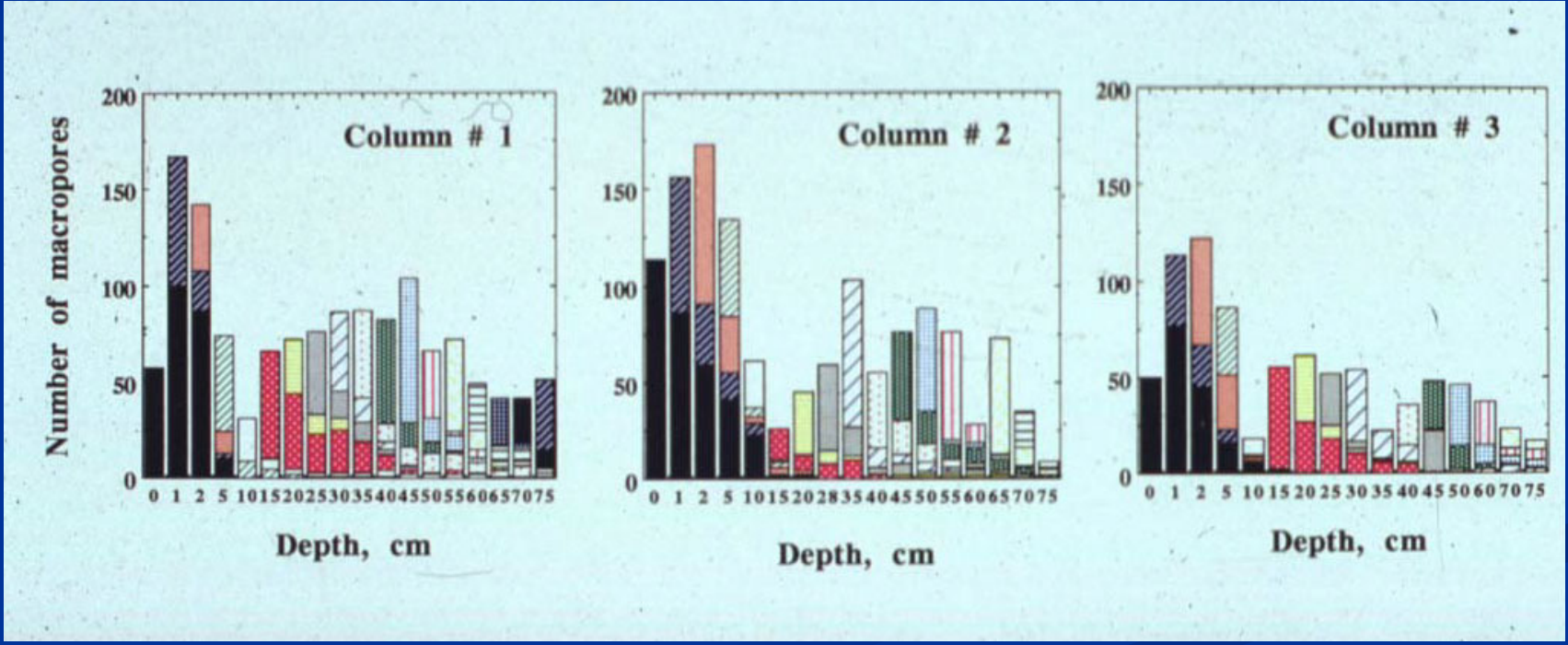
Surface Macropore continuity with soil depth (Fertilizer trt.)



Munyankusi et al. (1994)

Macropore distribution and its continuity

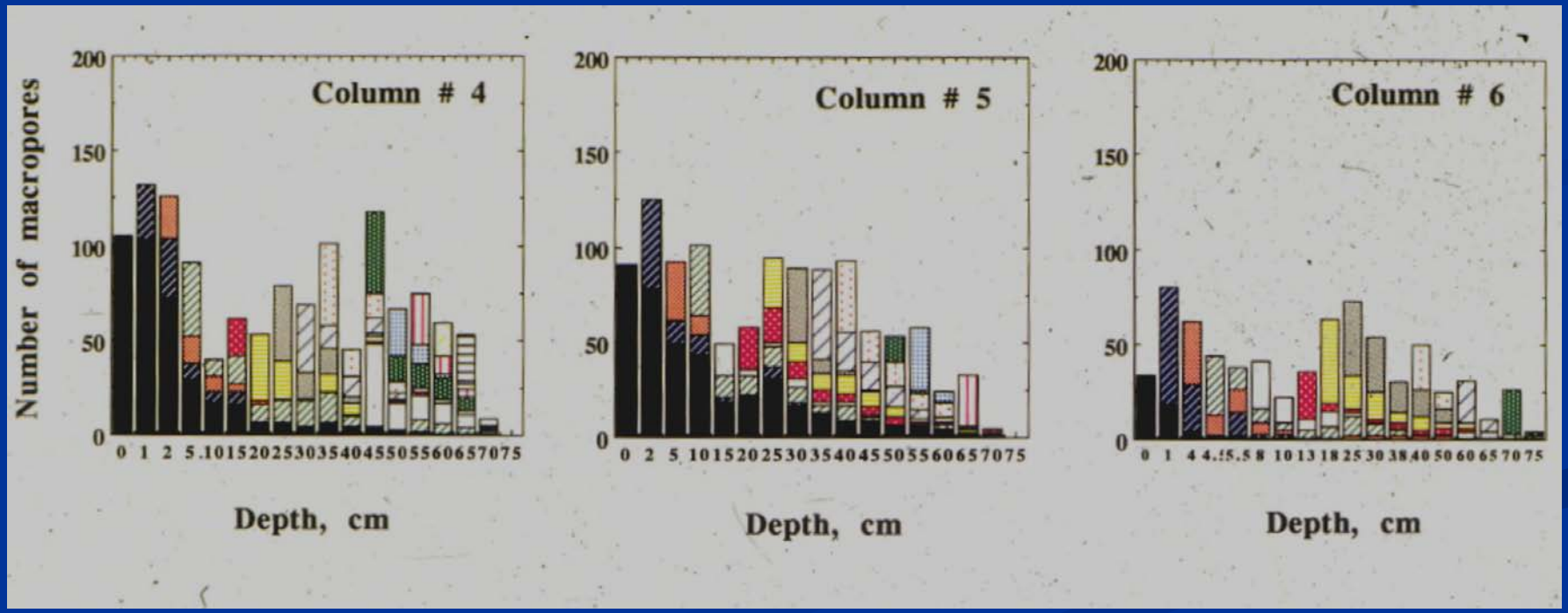
(Fertilizer columns)



Munyankusi et al. (1994)

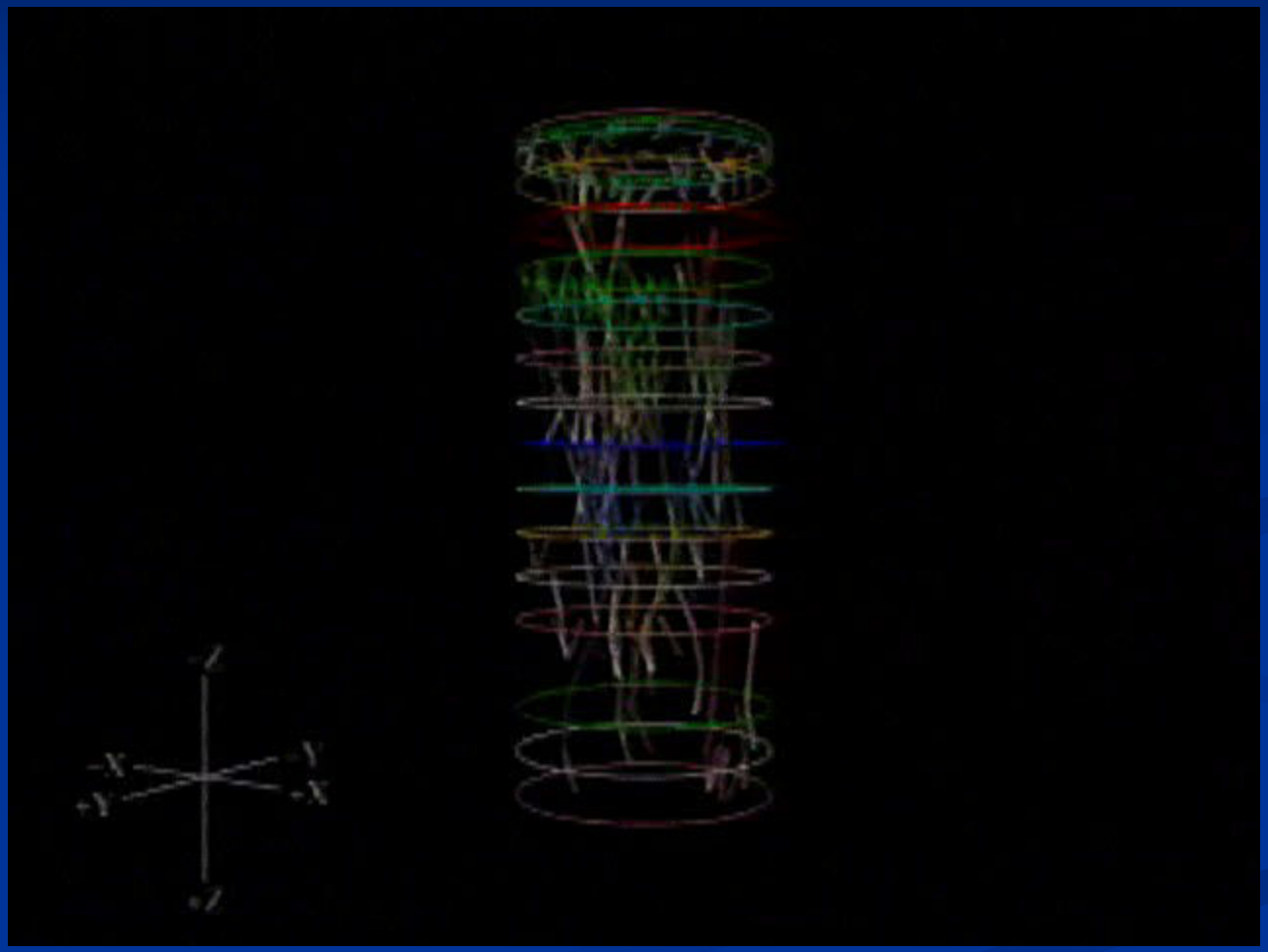
Macropore distribution and its continuity

(Manure columns)



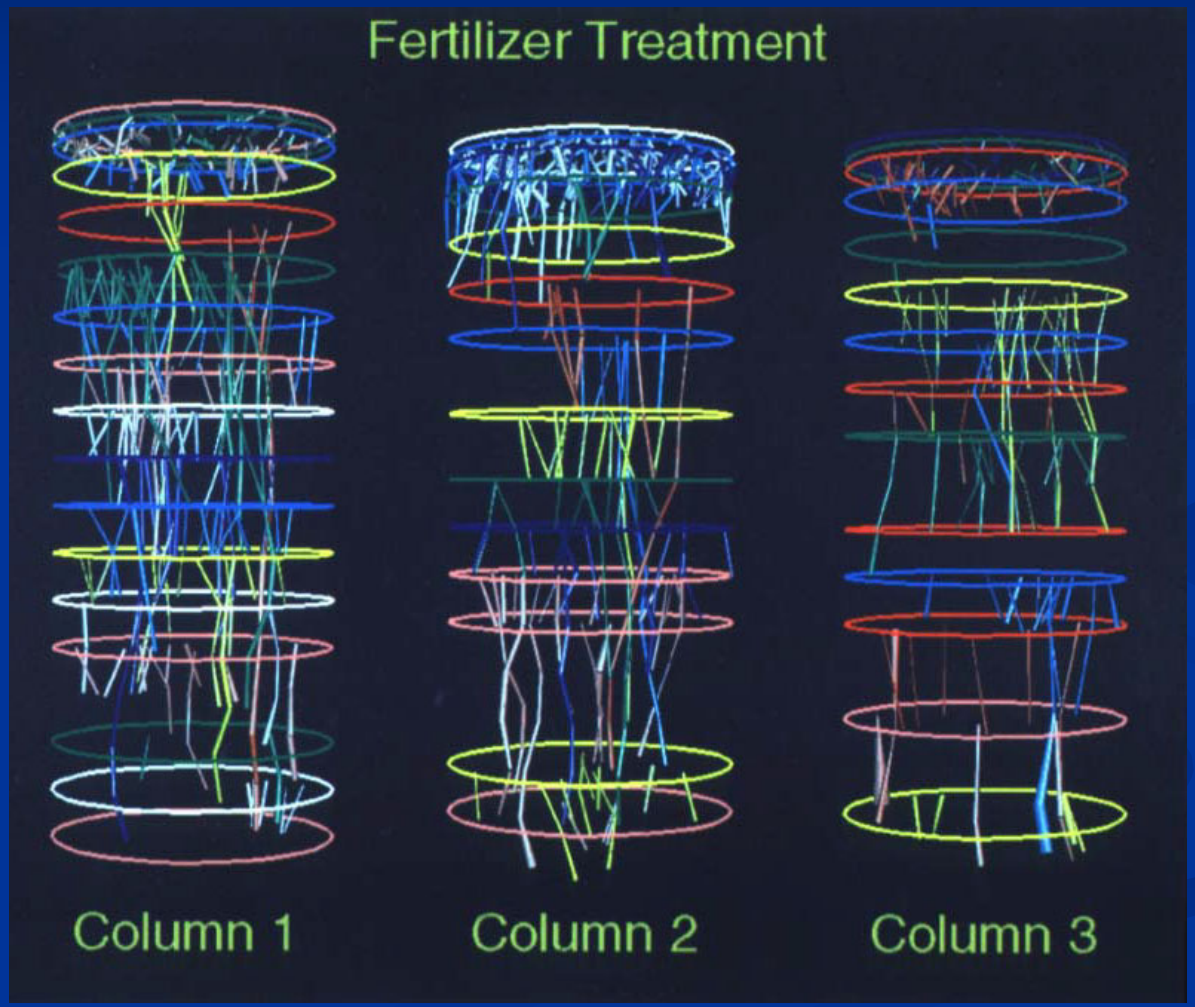
Munyankusi et al. (1994)

Macropore Animation (Fertilizer)



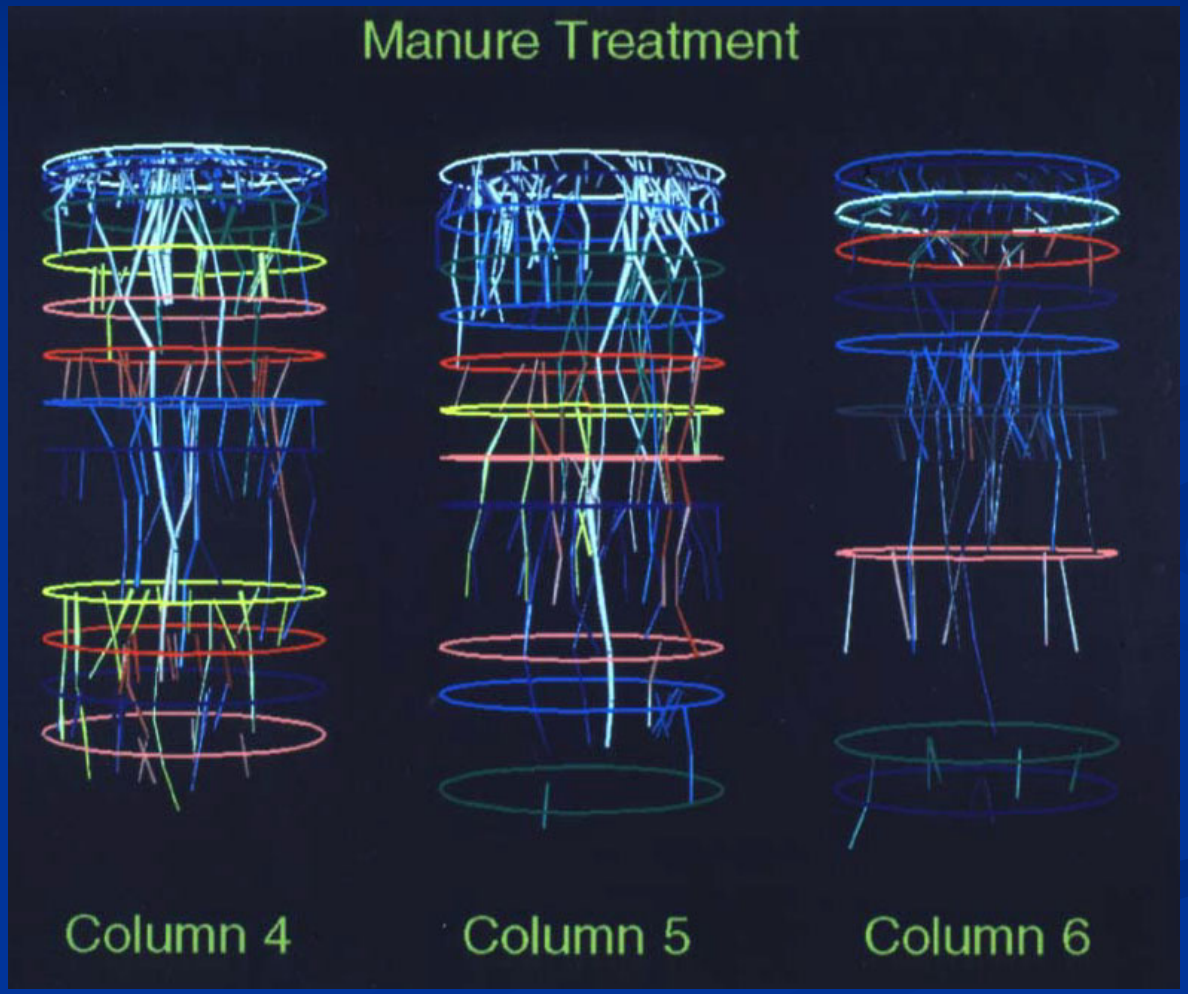
Munyankusi et al. (1994)

Computer Rendering of Macropores



Munyankusi et al. (1994)

Computer Rendering of Macropores



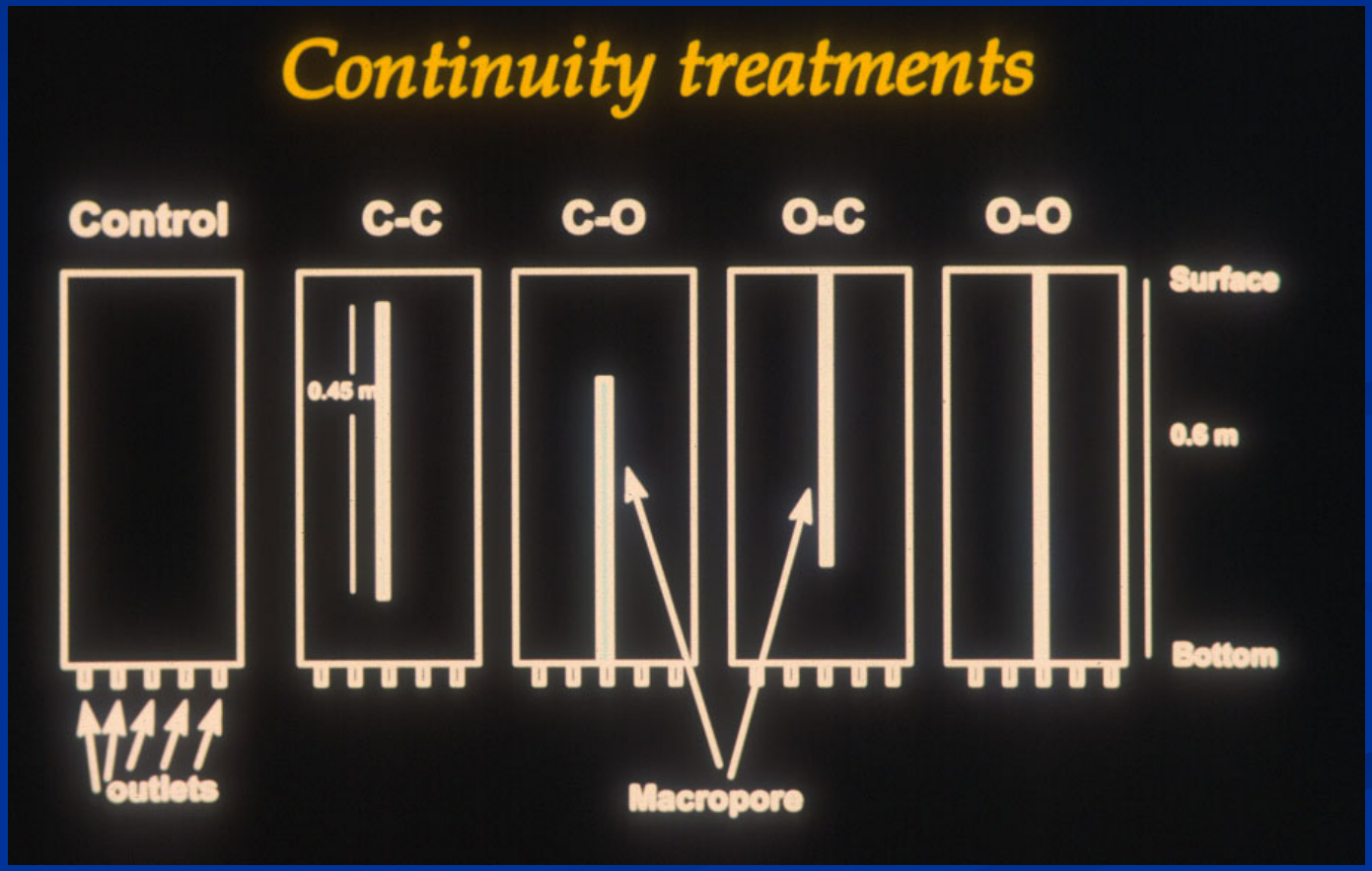
Munyankusi et al. (1994)

Conclusions & New Questions

- Macropore continuity and tortuosity vary and have an impact on preferential flow.

- **New Questions:**
- What is the role of macropore continuity and tortuosity on preferential flow?
- How do different earthworm species and food source placement affect macropore continuity, macropore tortuosity,and preferential flow?

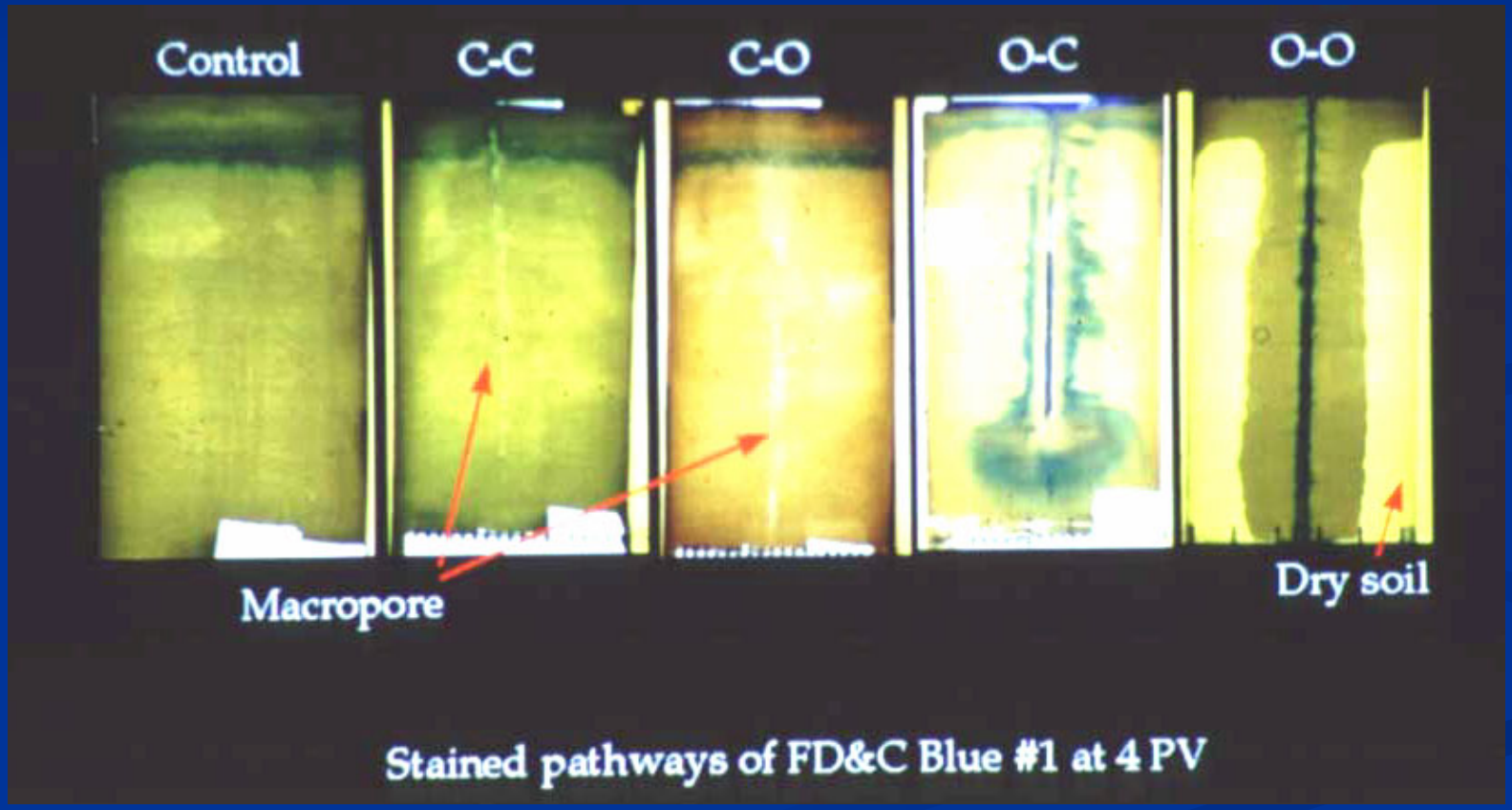
Continuity Effects



C=Close, O=Open

Allaire-Leung et al. (2000)

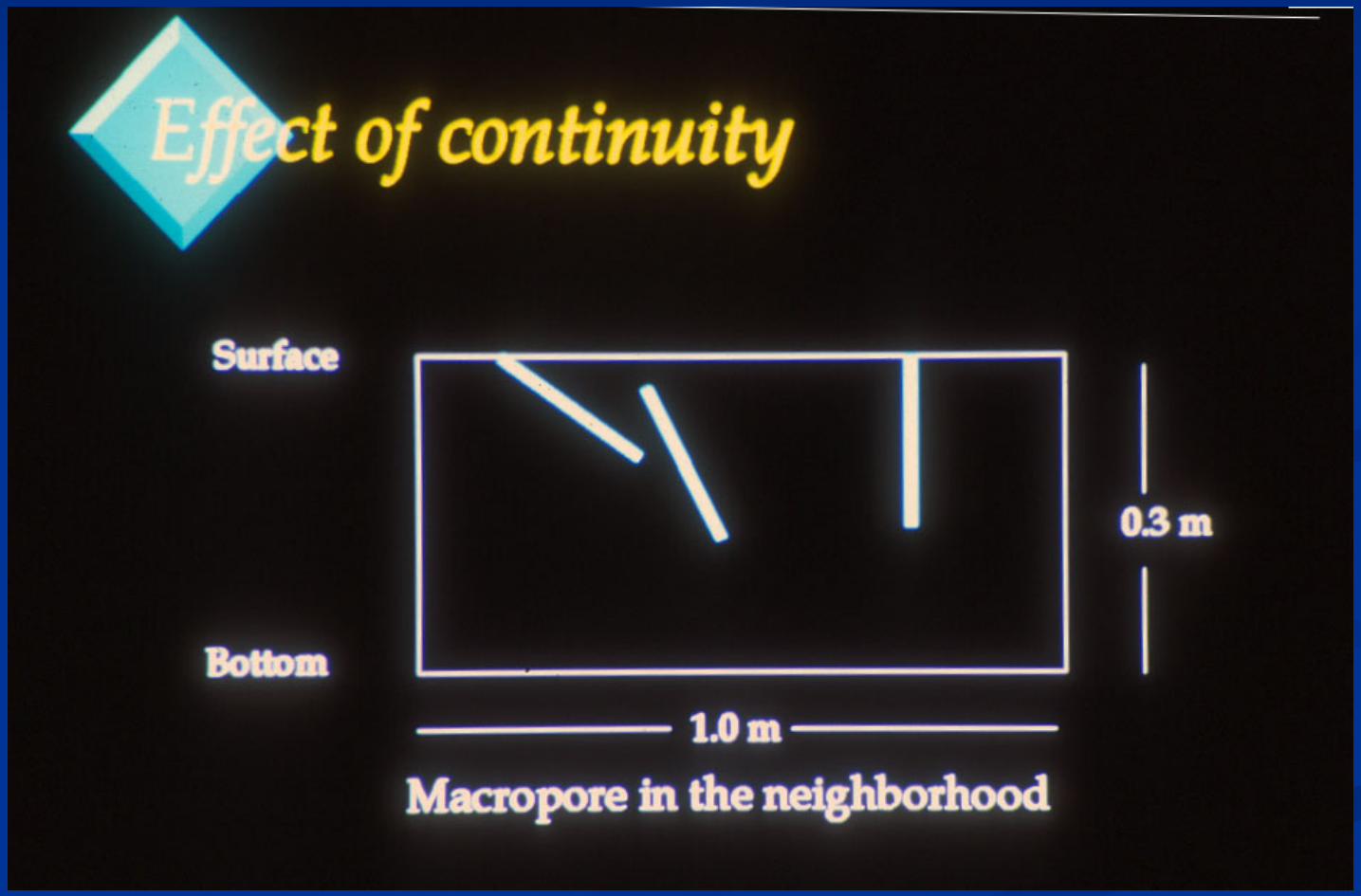
Effect of Continuity



C=Close, O=Open

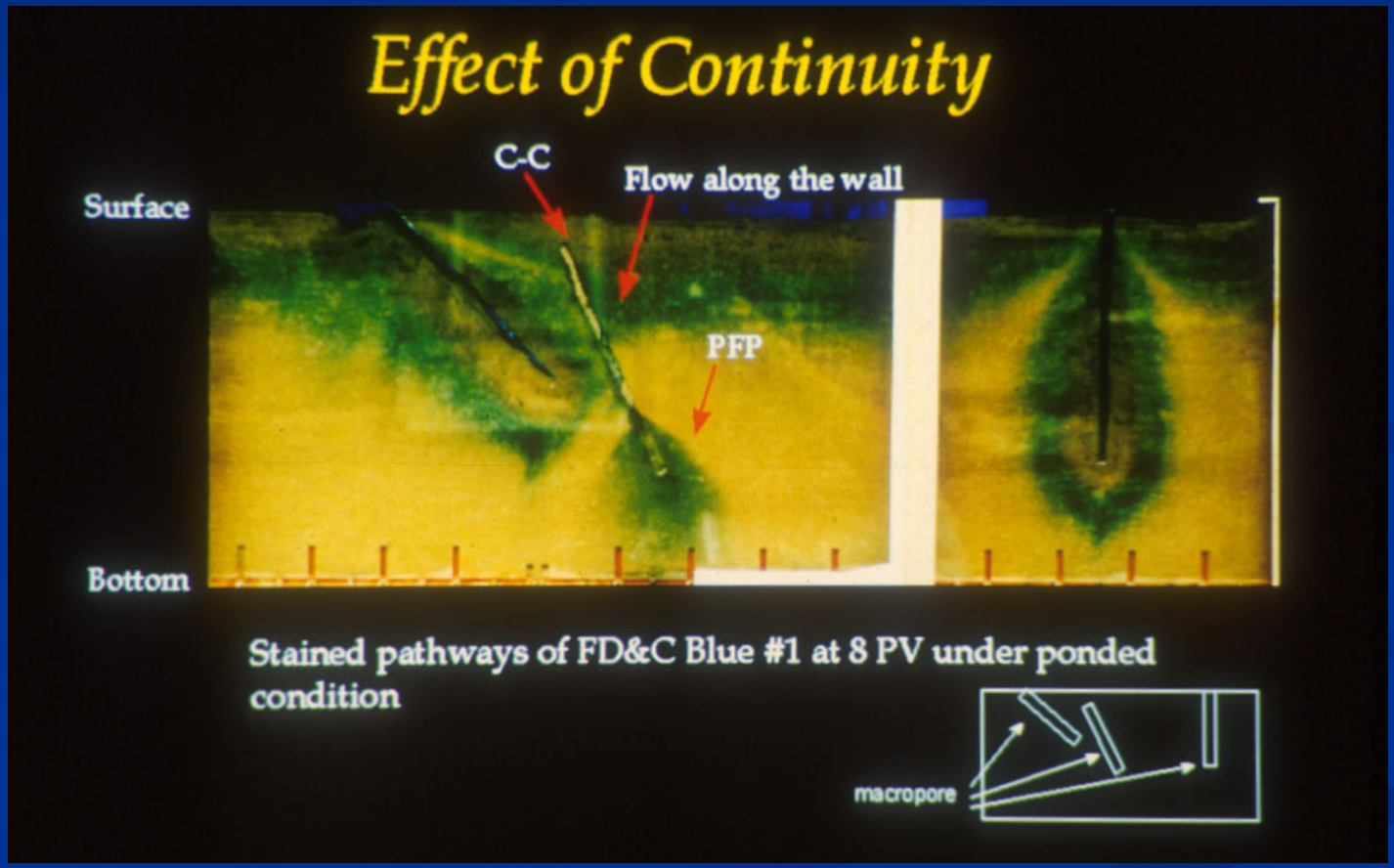
Allaire-Leung et al. (2000)

Effect of neighboring Macropores



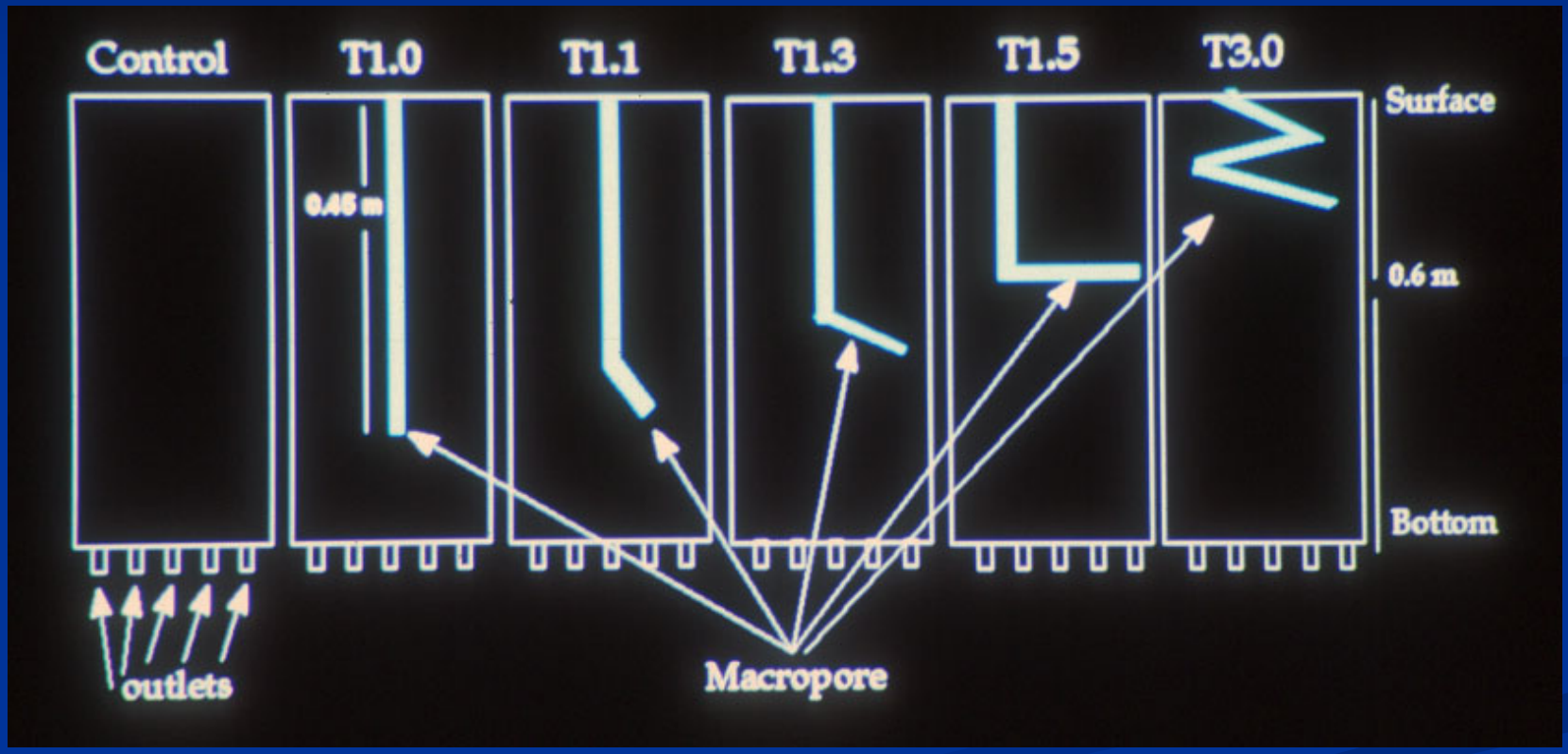
Allaire-Leung et al. (2000)

Effect of Neighboring Macropores



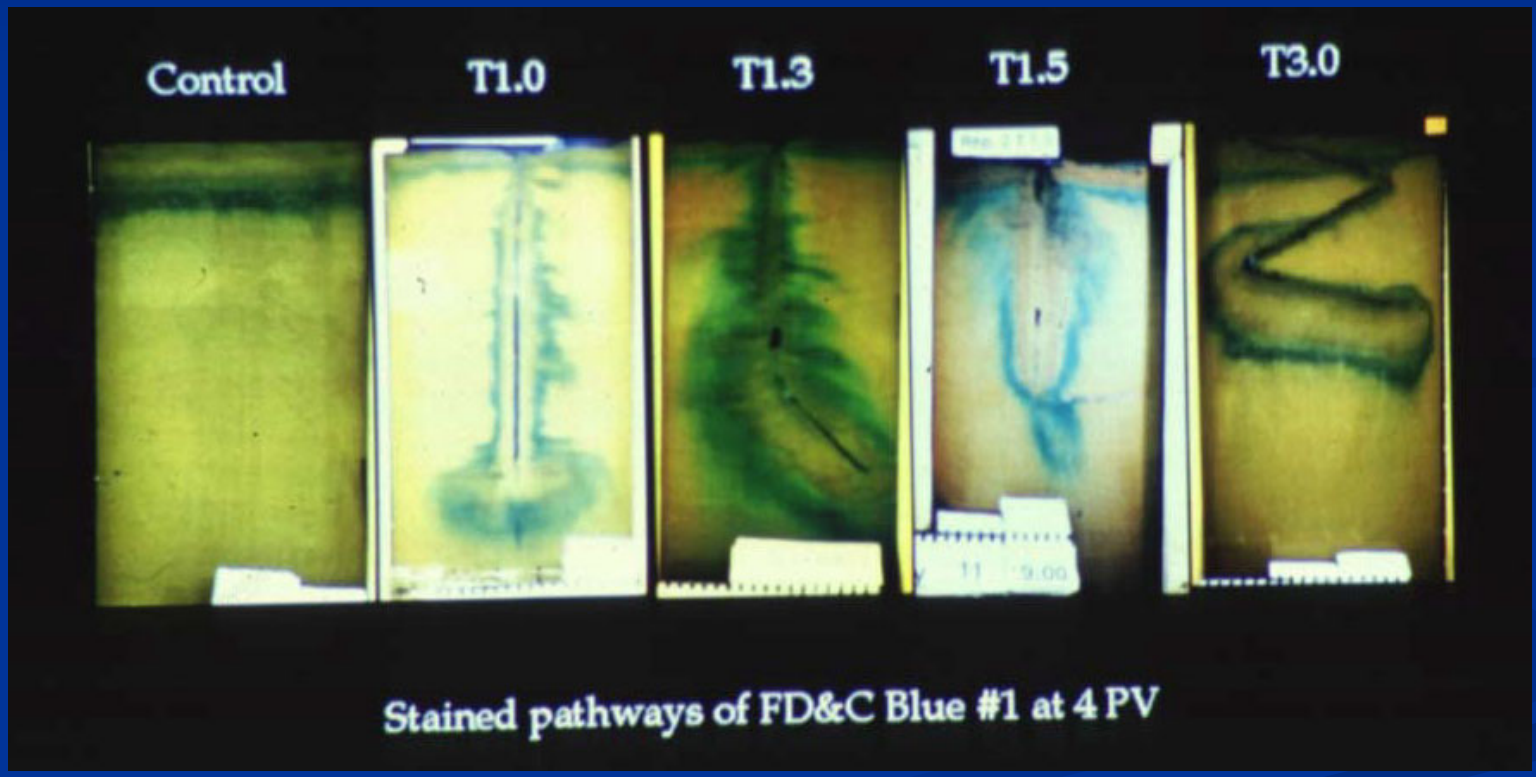
Allaire-Leung et al. (2000)

Tortuosity Treatments



Allaire-Leung et al. (2000, 2002)

Effect of tortuosity



T1.0=No tortuosity
T3.0=Highly tortuous

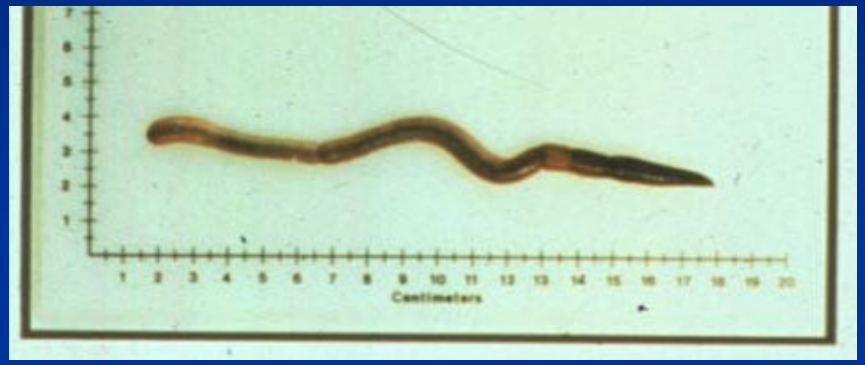
Allaire-Leung et al. (2000)

Earthworm Species and Depth of Residue Placement: Incubation Study

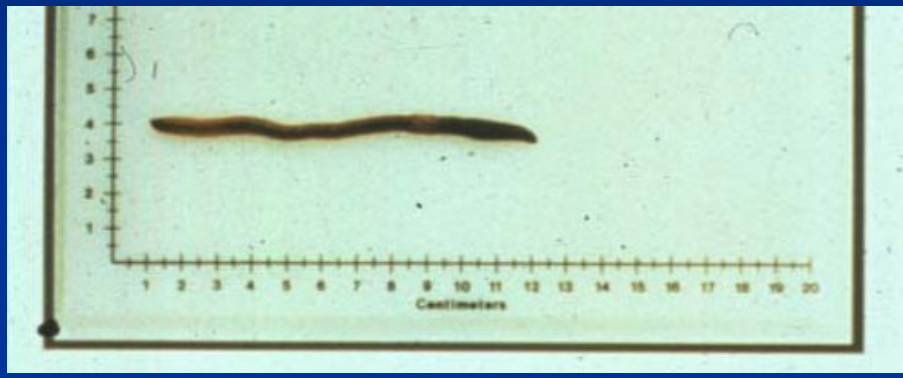
Treatments

- Three Earthworm Species
  - *Lumbriscus terrestris* (detritivorous)
  - *Lumbricus rubellus* (detritivorous)
  - *Aporrectodea trapezoides* (geophagous)
- Two Depths of Residue Placement
  - Surface (no-till)
  - 3-10 cm depth (chisel plow)

Type of Earthworms



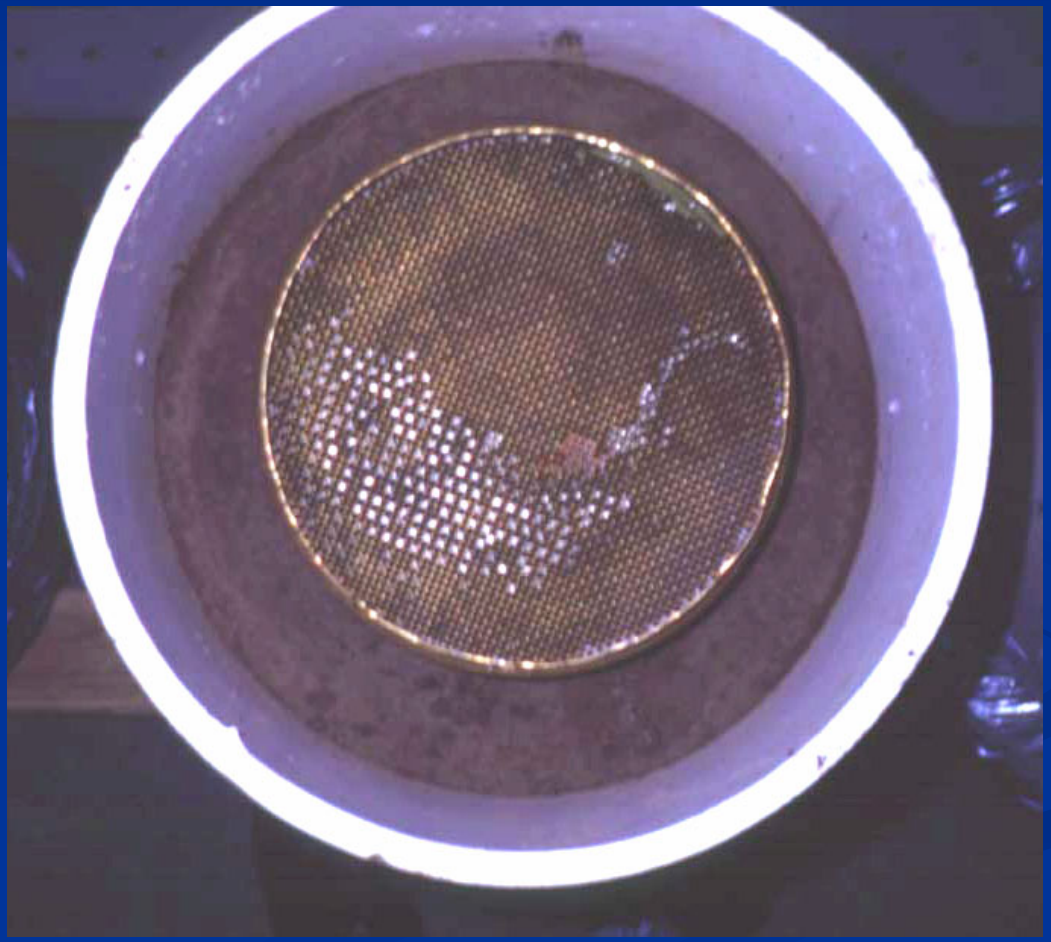
Lumbricus terrestris



Lumricus rubellus

Aprrectodea tuberculata

Start of incubation study



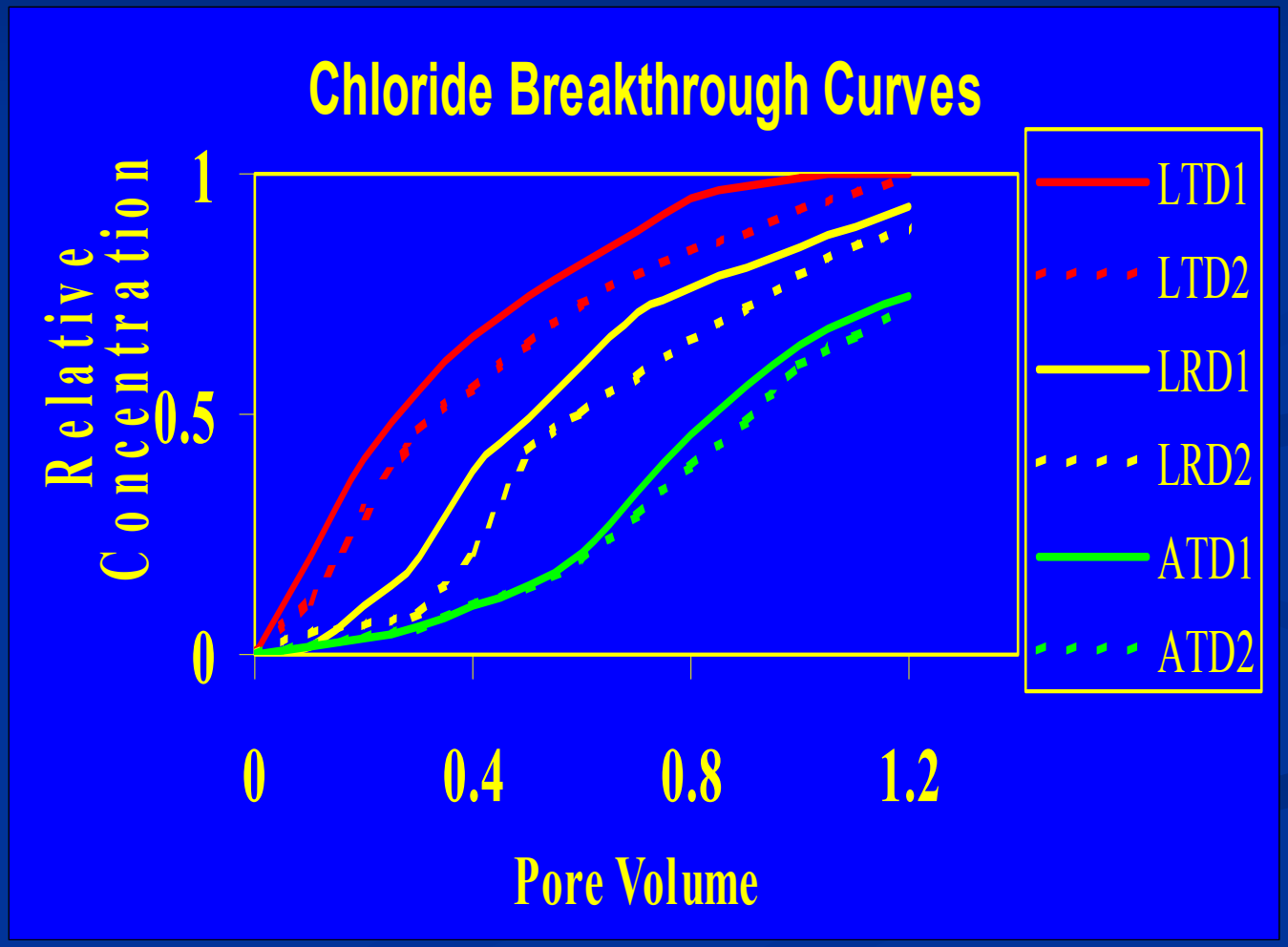
Residue at the Soil Surface
L. terrestris-Day 1

Residue at the Soil Surface
L. terrestris-28 Days

Residue at the Soil Surface
L. terrestris-67 days

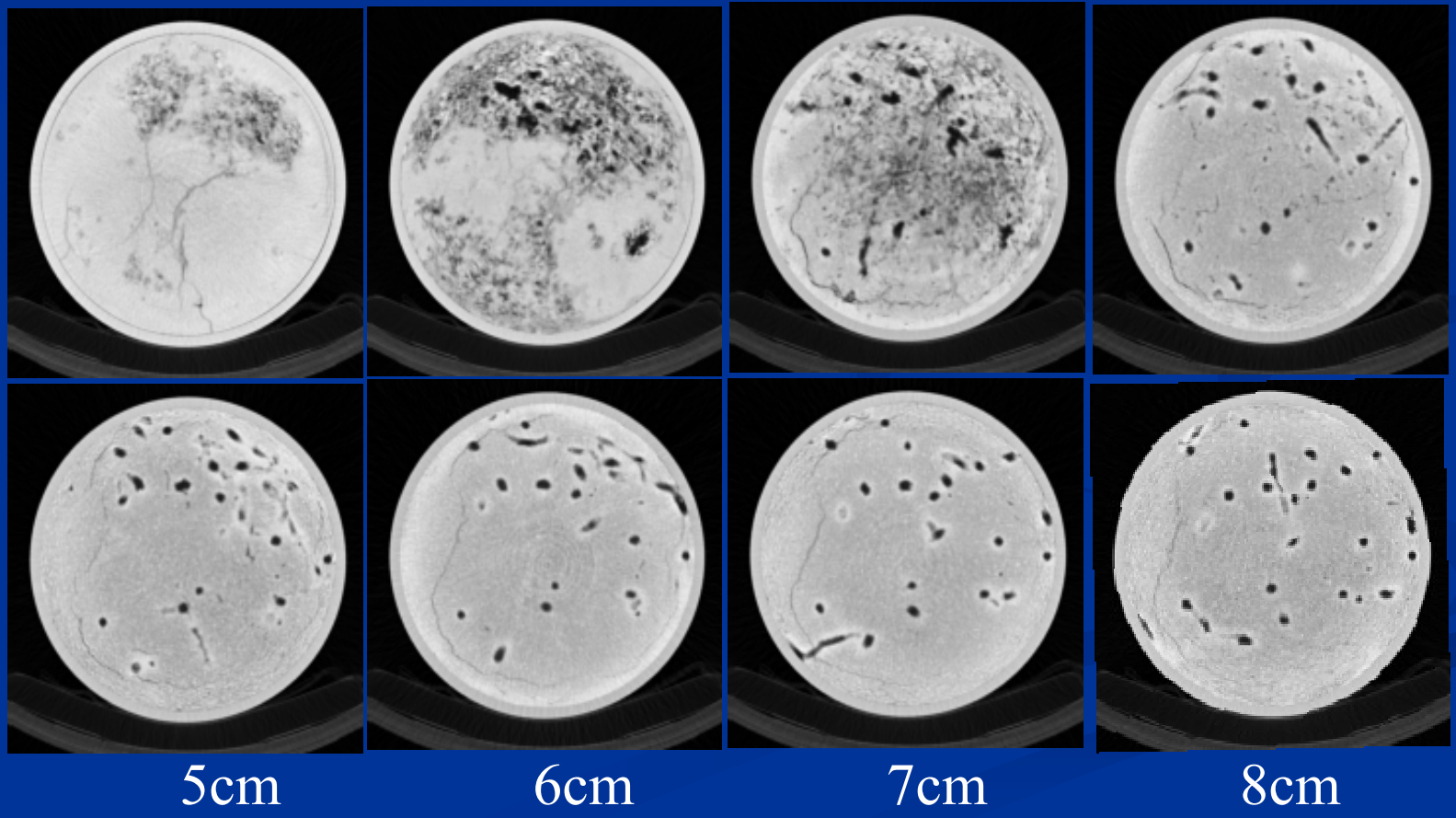
Residue at the 3-10 cm depths *L. terrestris*-67 days

Species & Food Source Effects on BTC

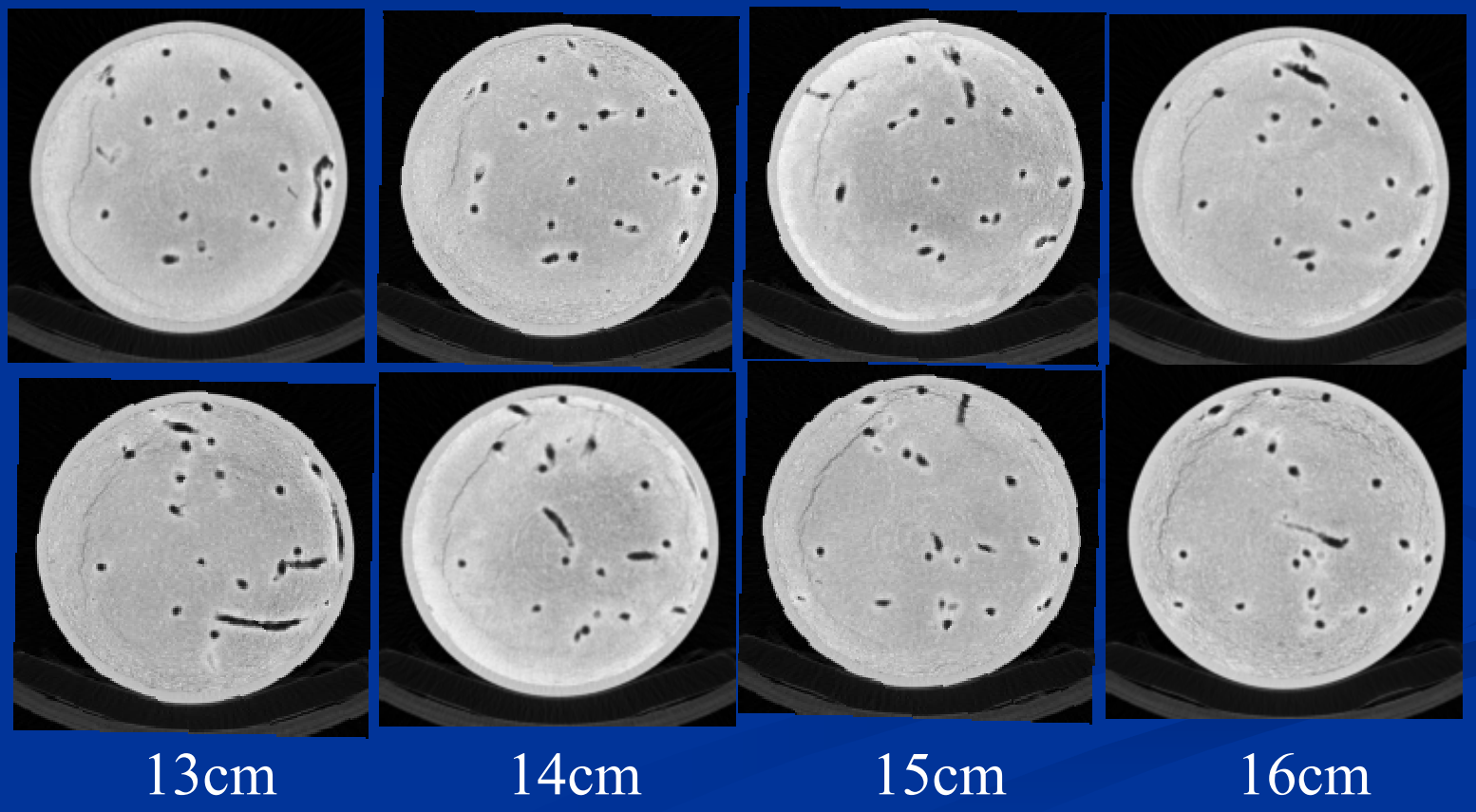


CT-Scan set-up

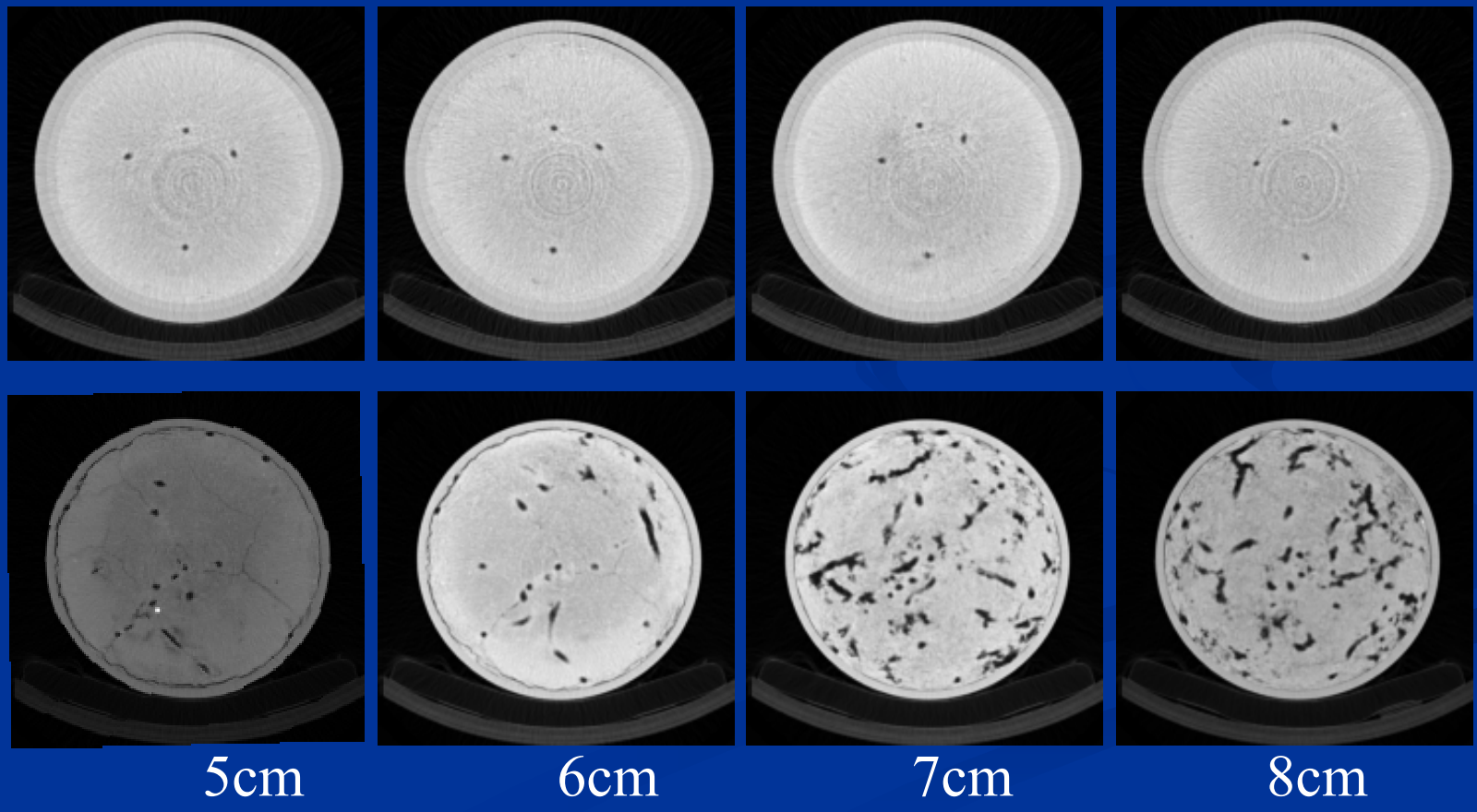
Lumbricus terrestris
Residue at the Soil Surface



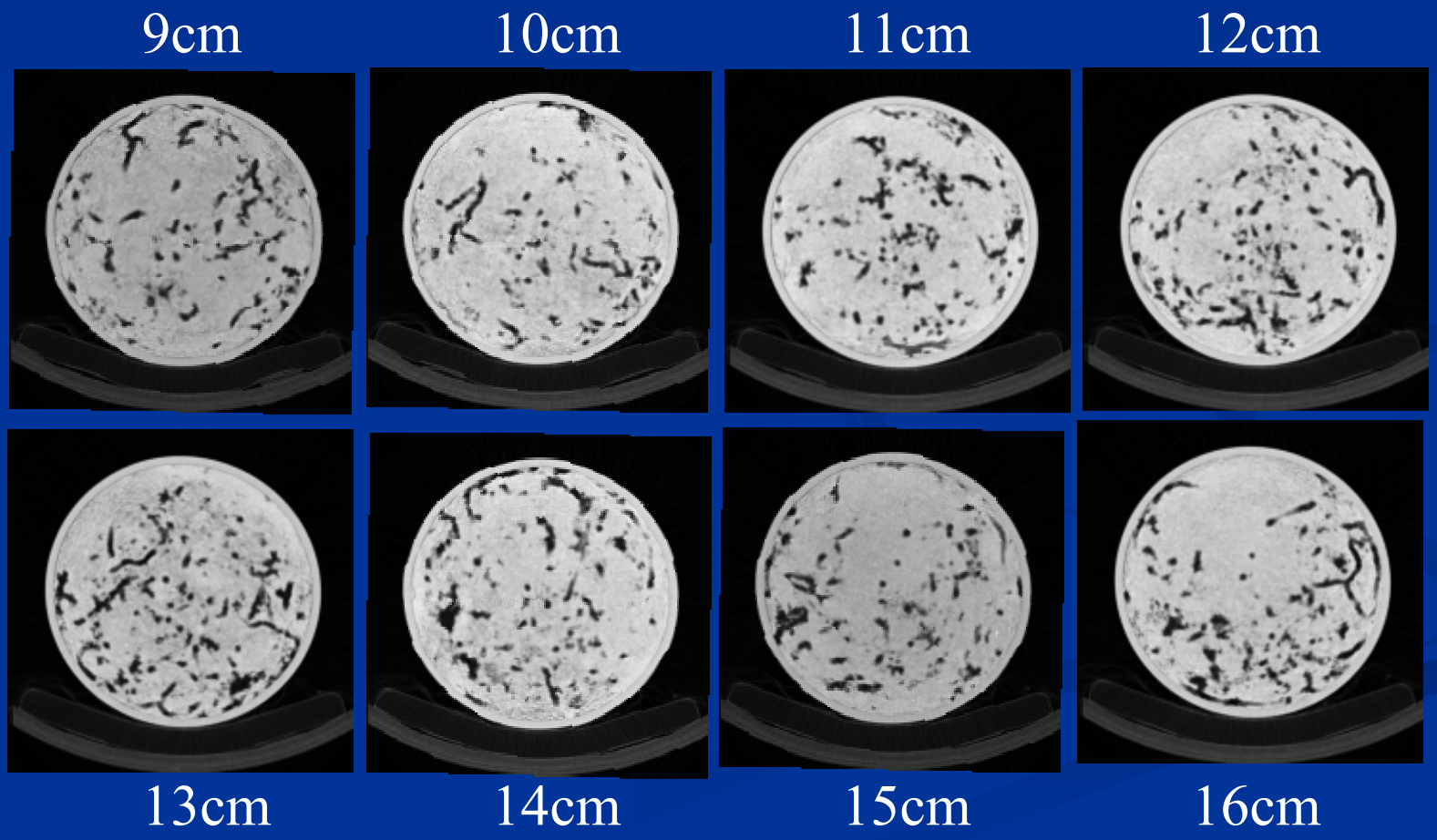
Lumbricus terrestris
Residue at the Soil Surface



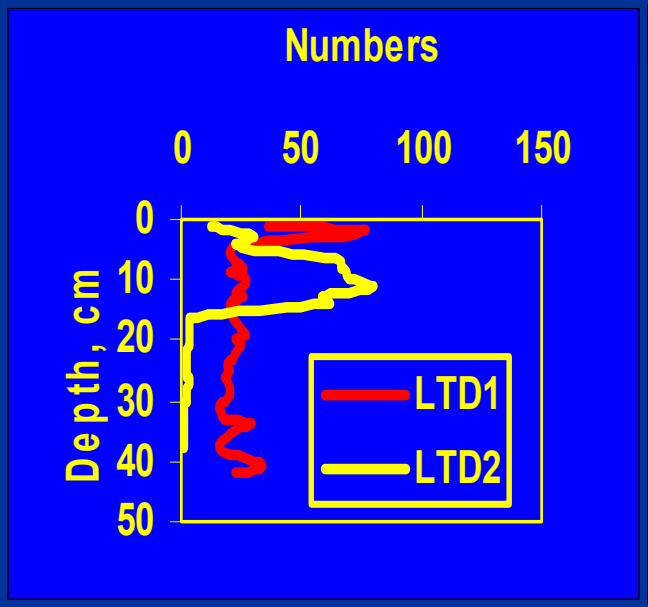
Lumbricus terrestris
Residue at 3-10 cm Depth

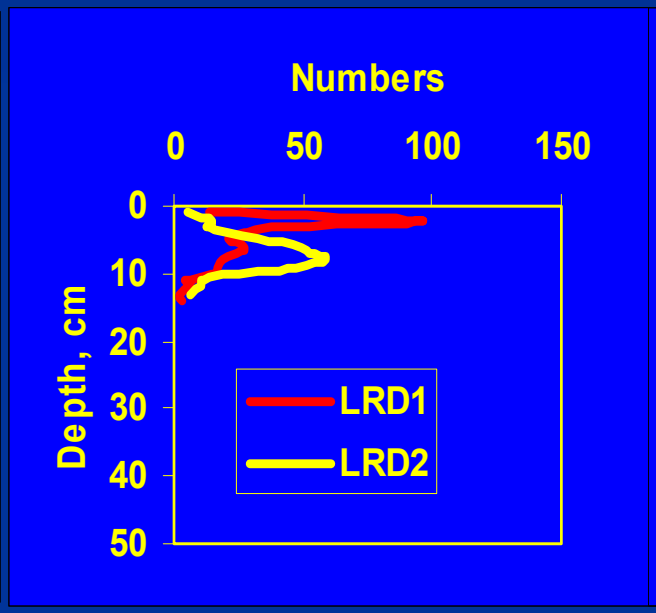


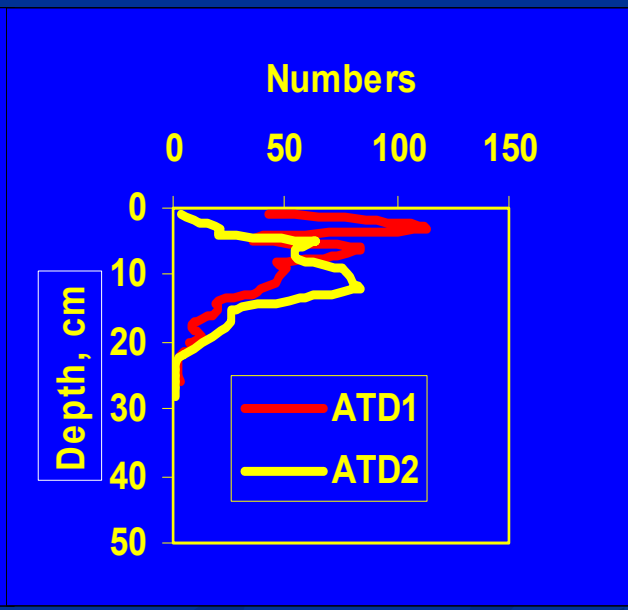
Lumbricus terrestris
Residue at 3-10 cm Depth



Number of Macropores





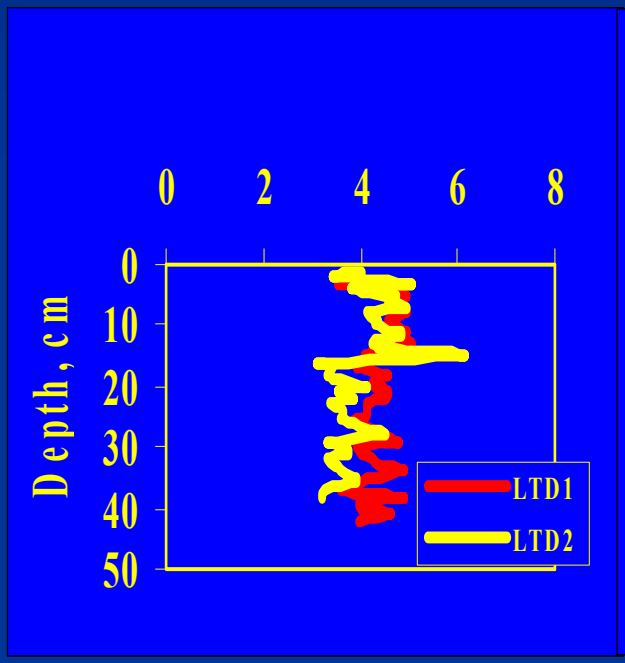


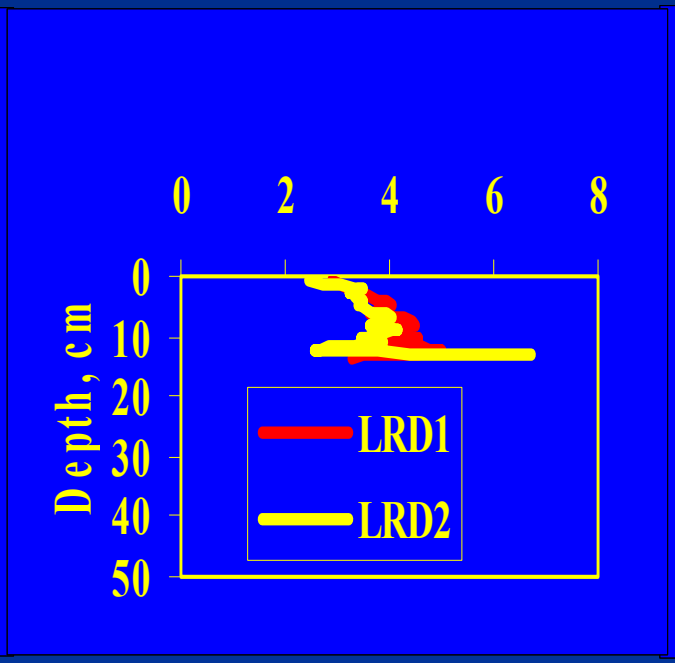
L. terrestris *L. rubellus* *A. trapezoides*

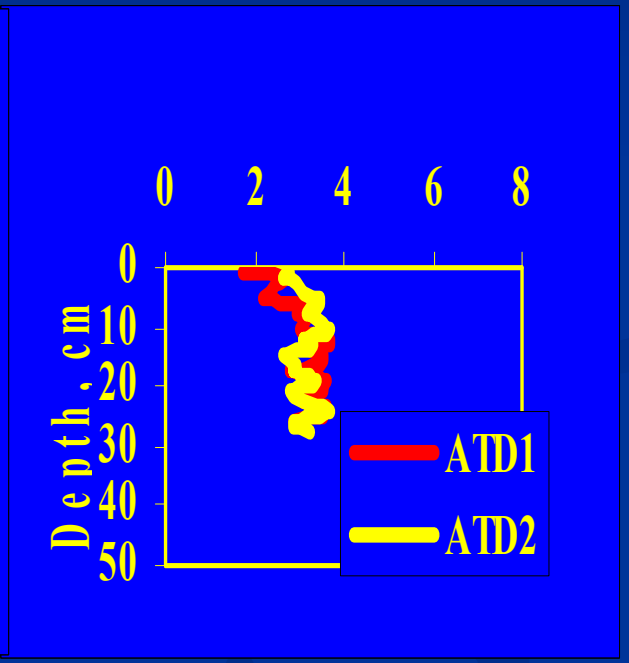
Macropore Radius

$$r = \sqrt{\frac{area}{\pi}}$$

Macropore Radius, mm

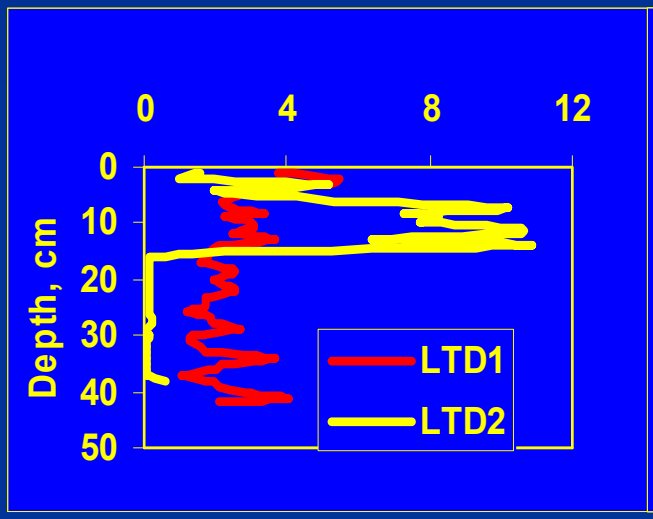


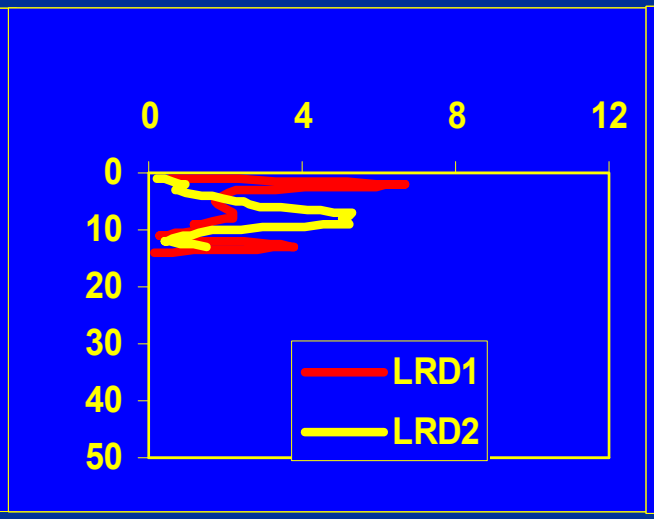


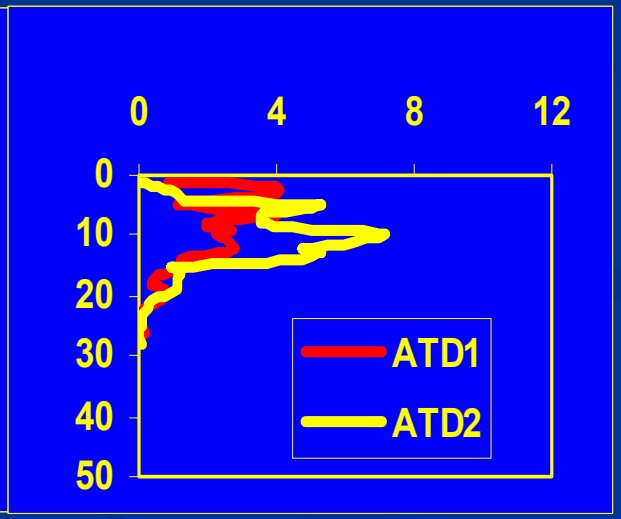


L. terrestris *L. rubellus* *A. trapezoides*

Macroporosity, %

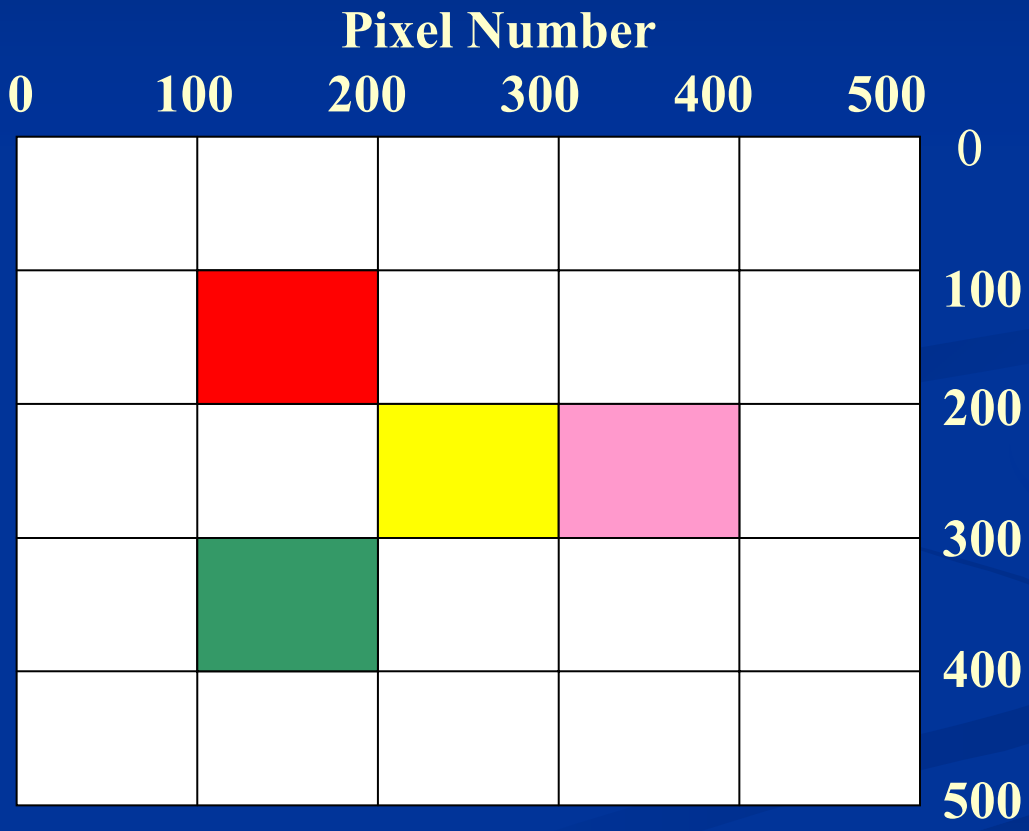






L. terrestris *L. rubellus* *A. trapezoides*

Characterizing Networks

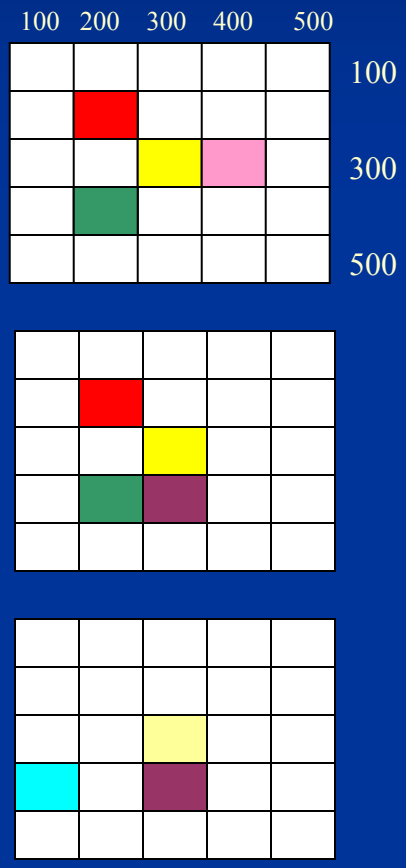


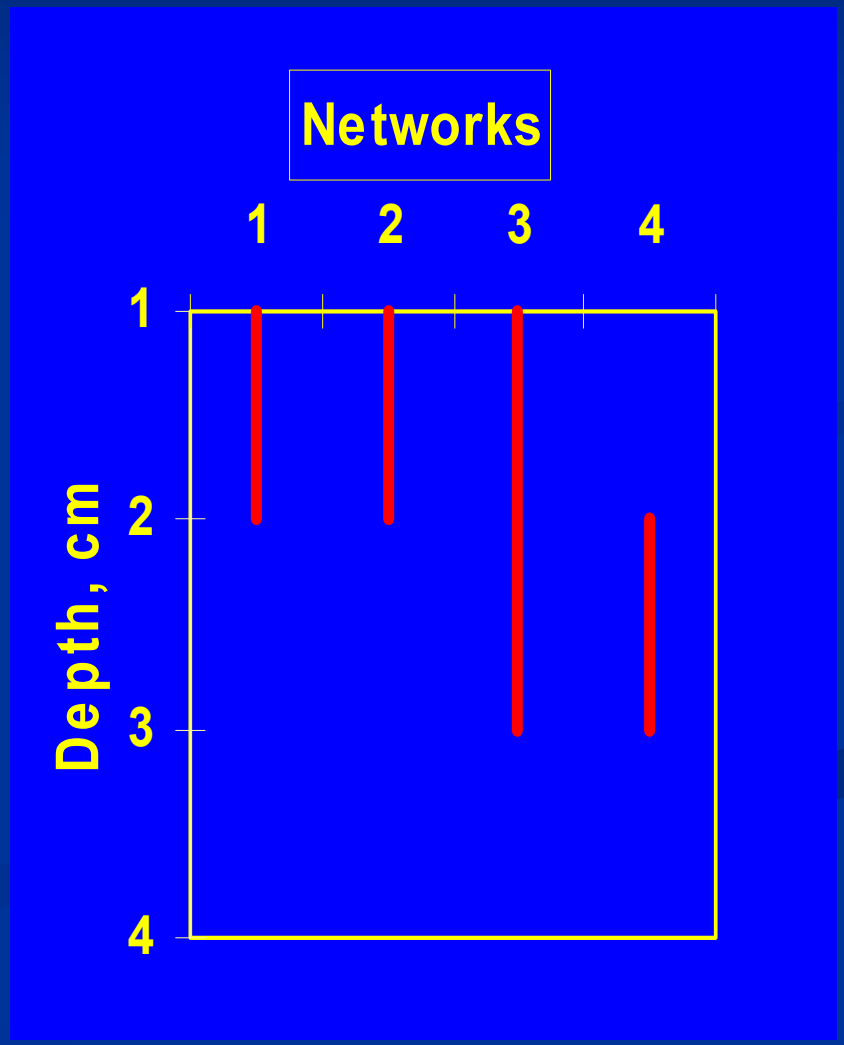
Procedure for Characterizing Networks

Depth 1 cm

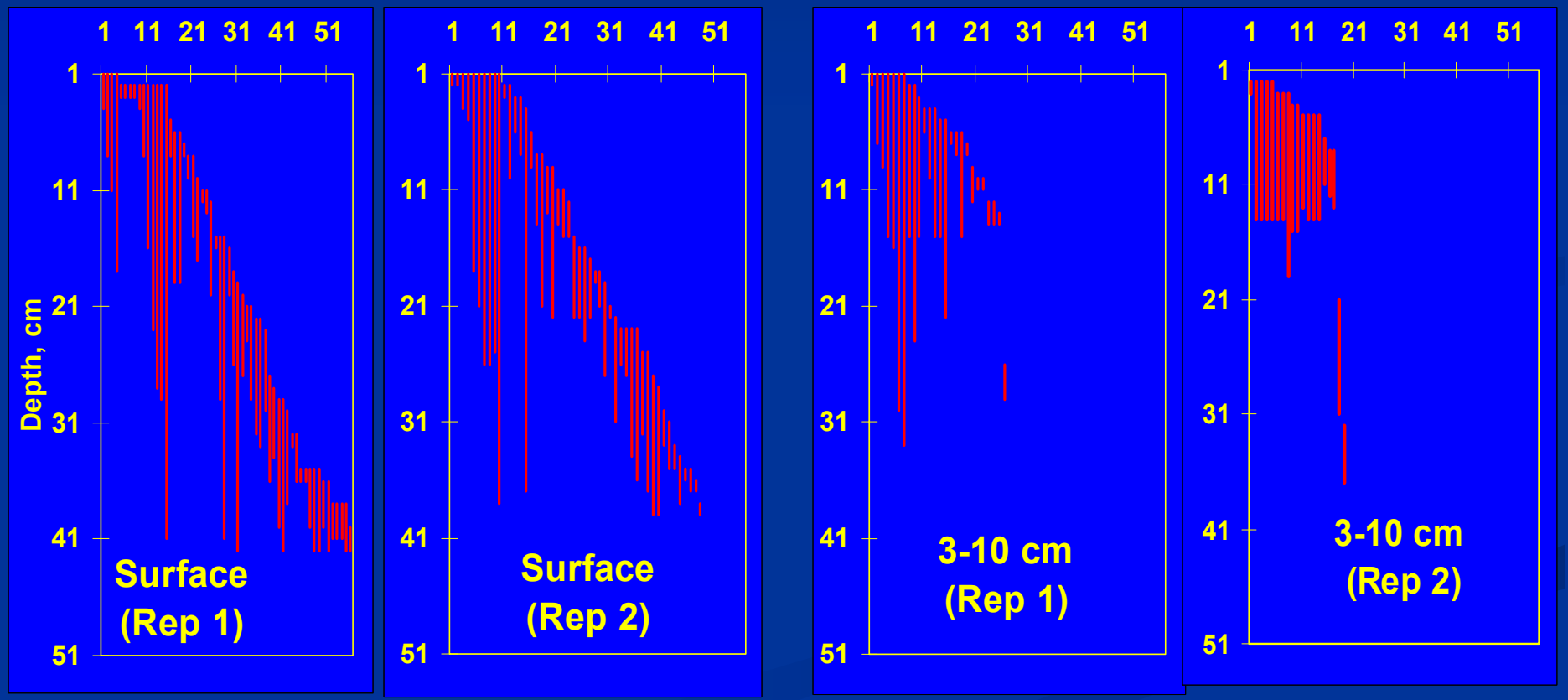
Depth 2 cm

Depth 3 cm

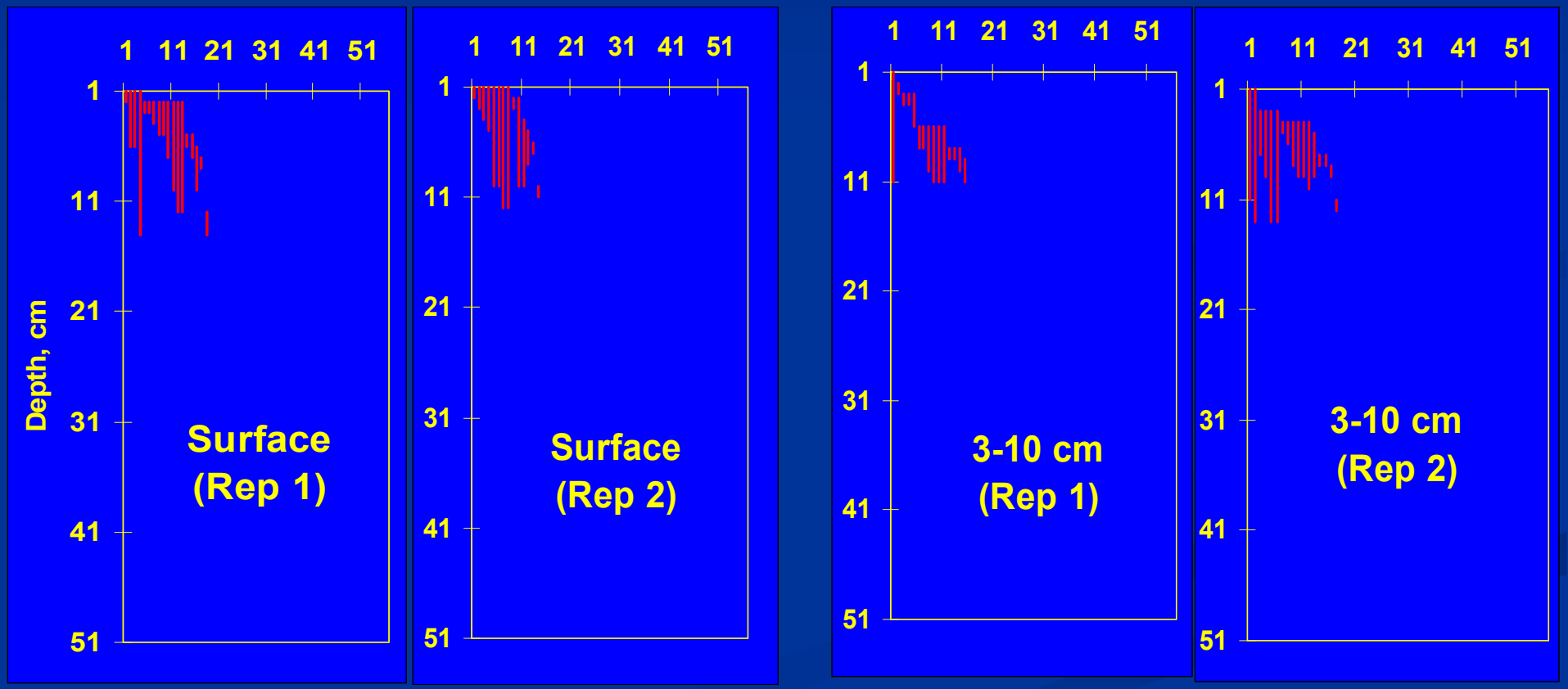




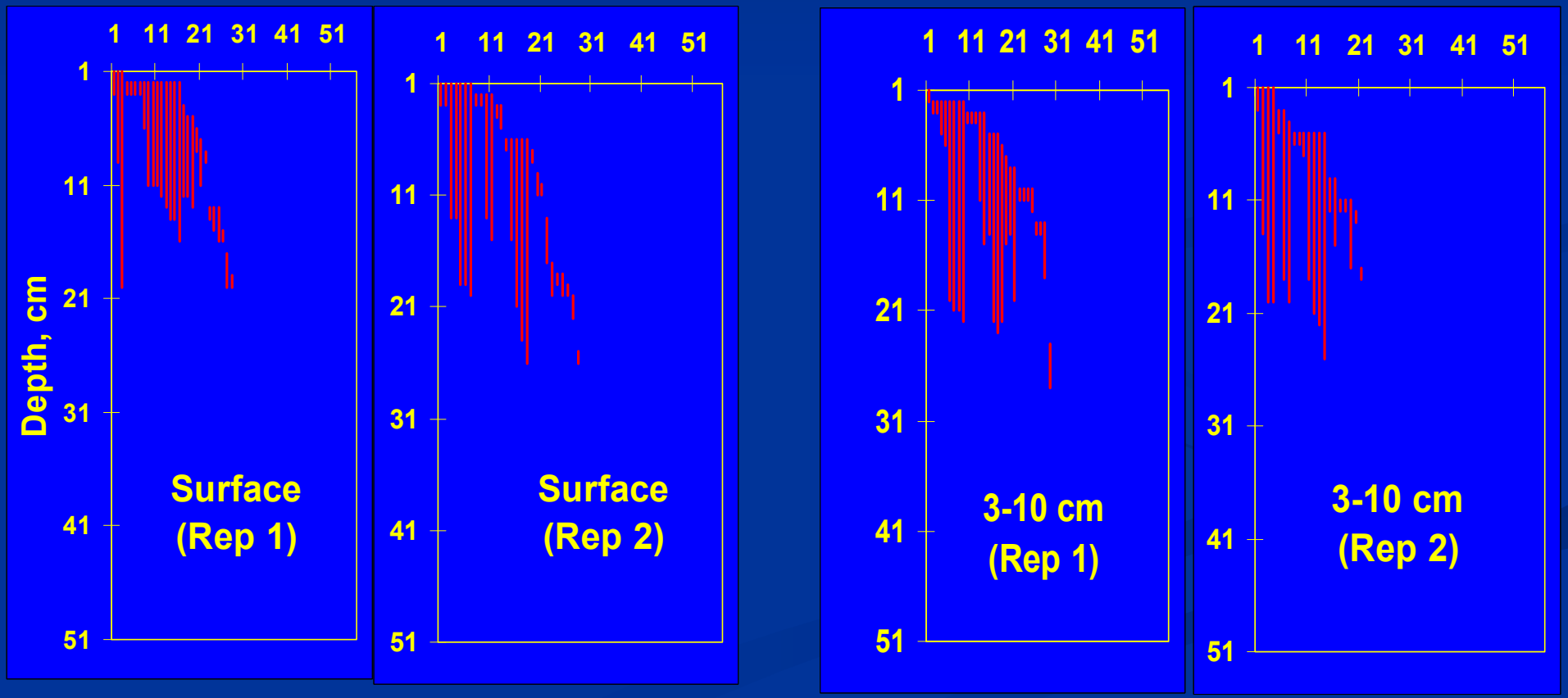
Macropore Networks
Lumbricus terrestris



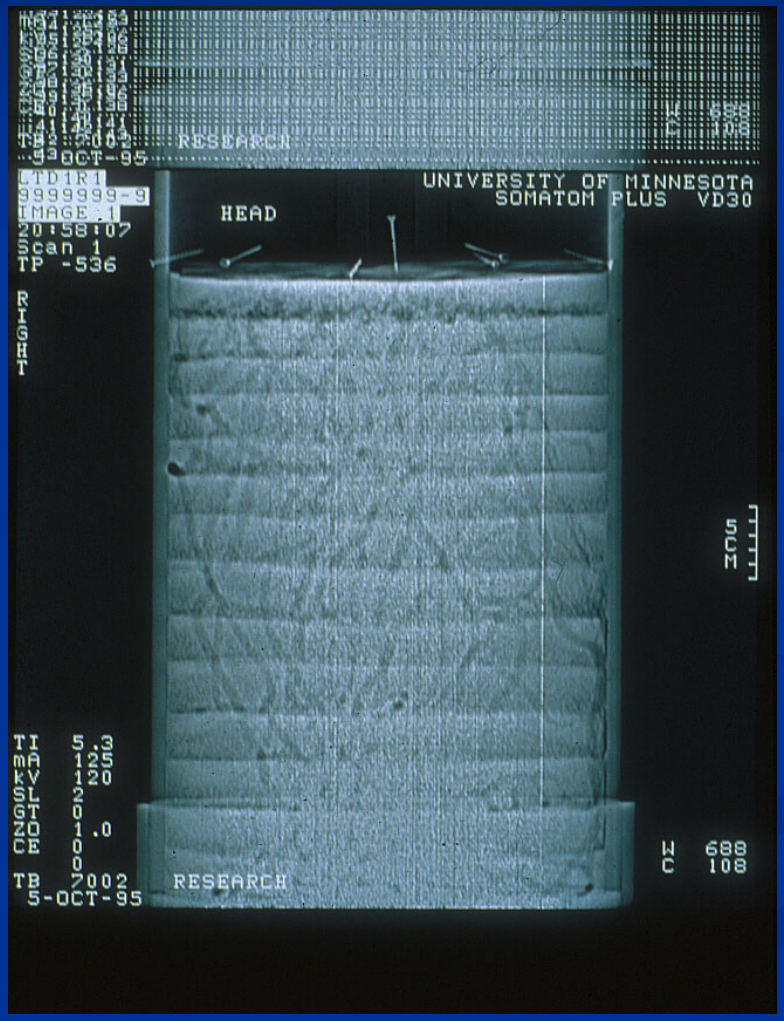
Macropore Networks
Lumbricus rubellus



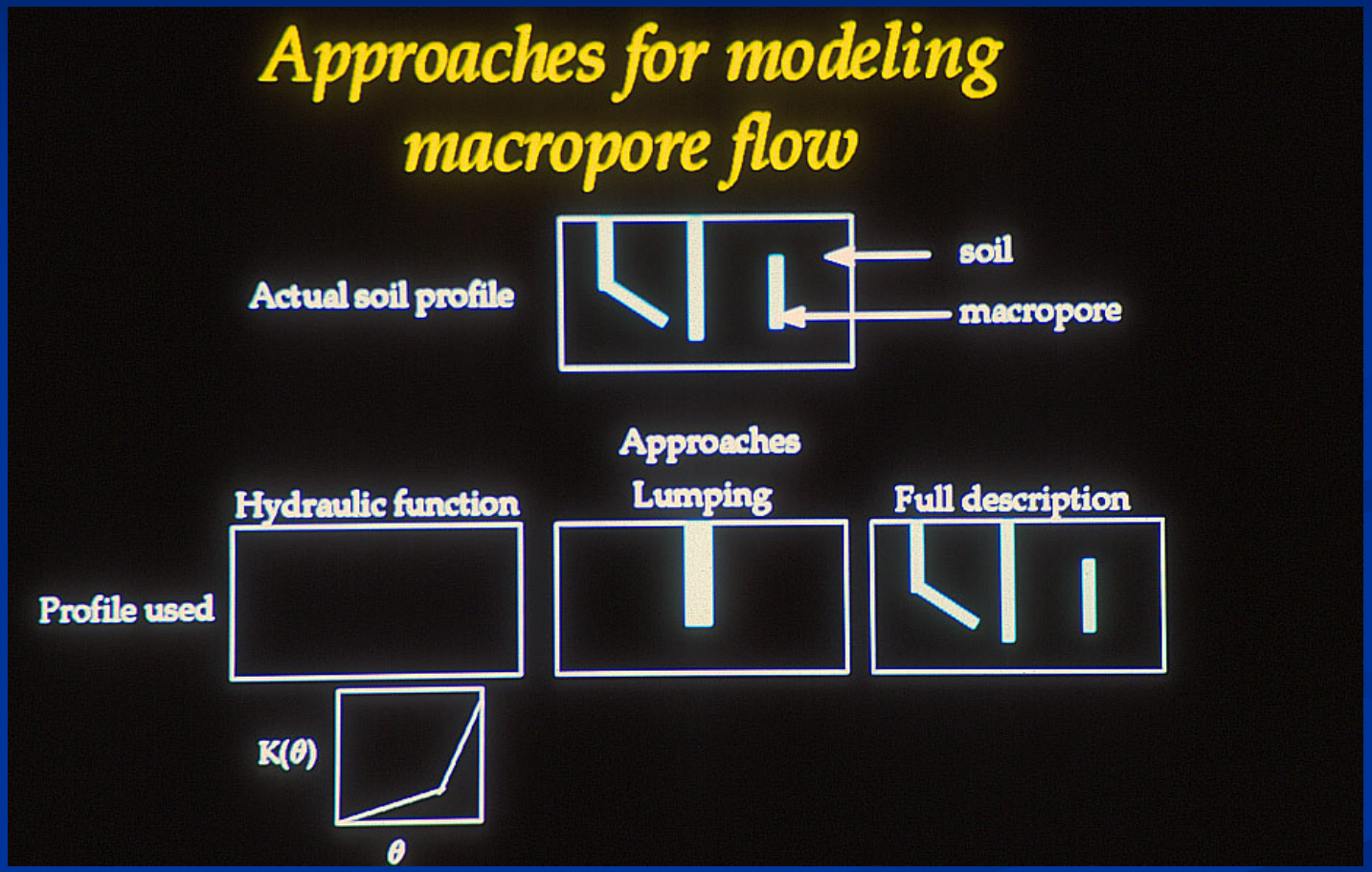
Macropore Networks
Aporrectodea trapezoides



Reconstruction of Macropores

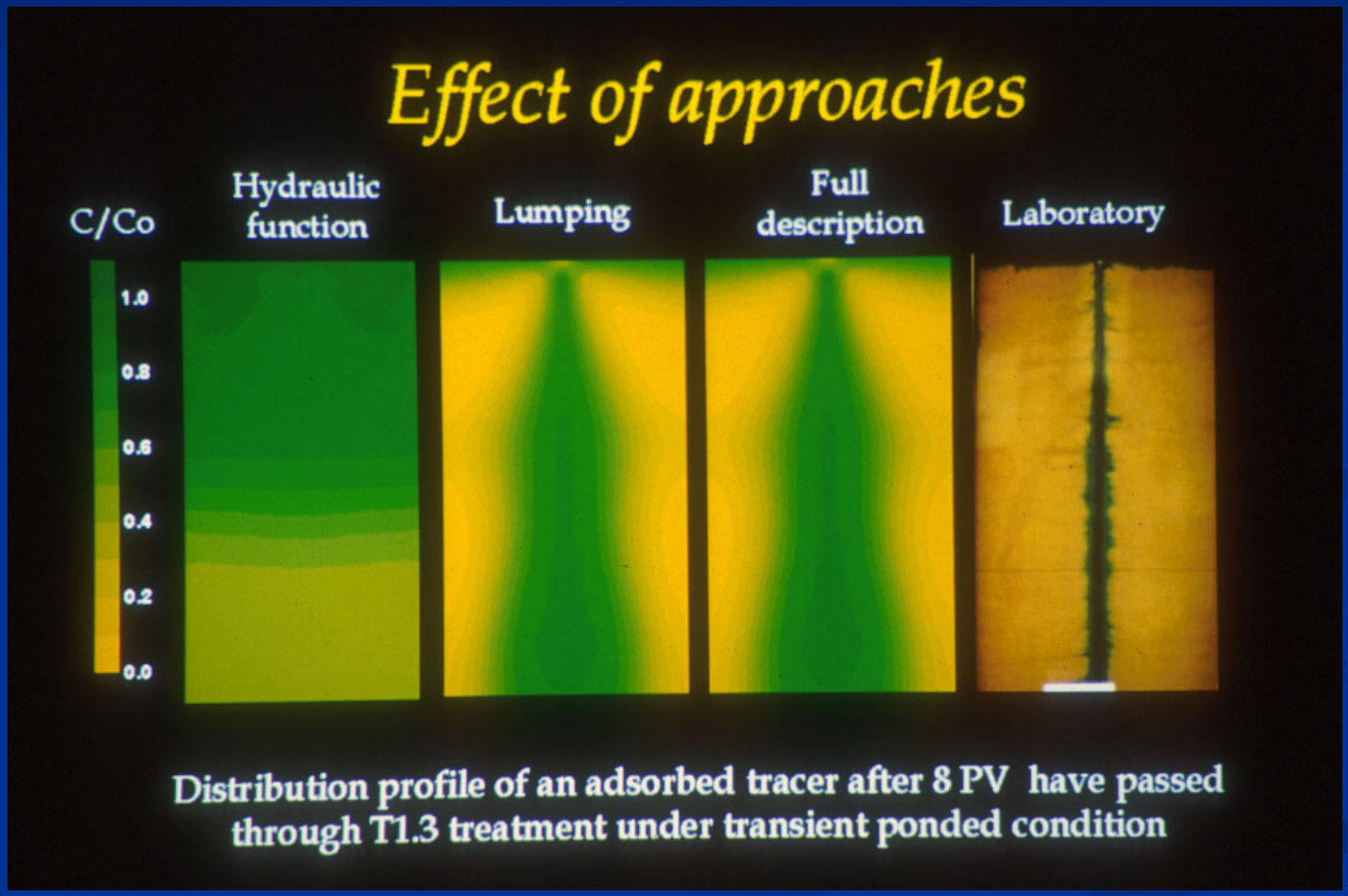


Modeling Approaches



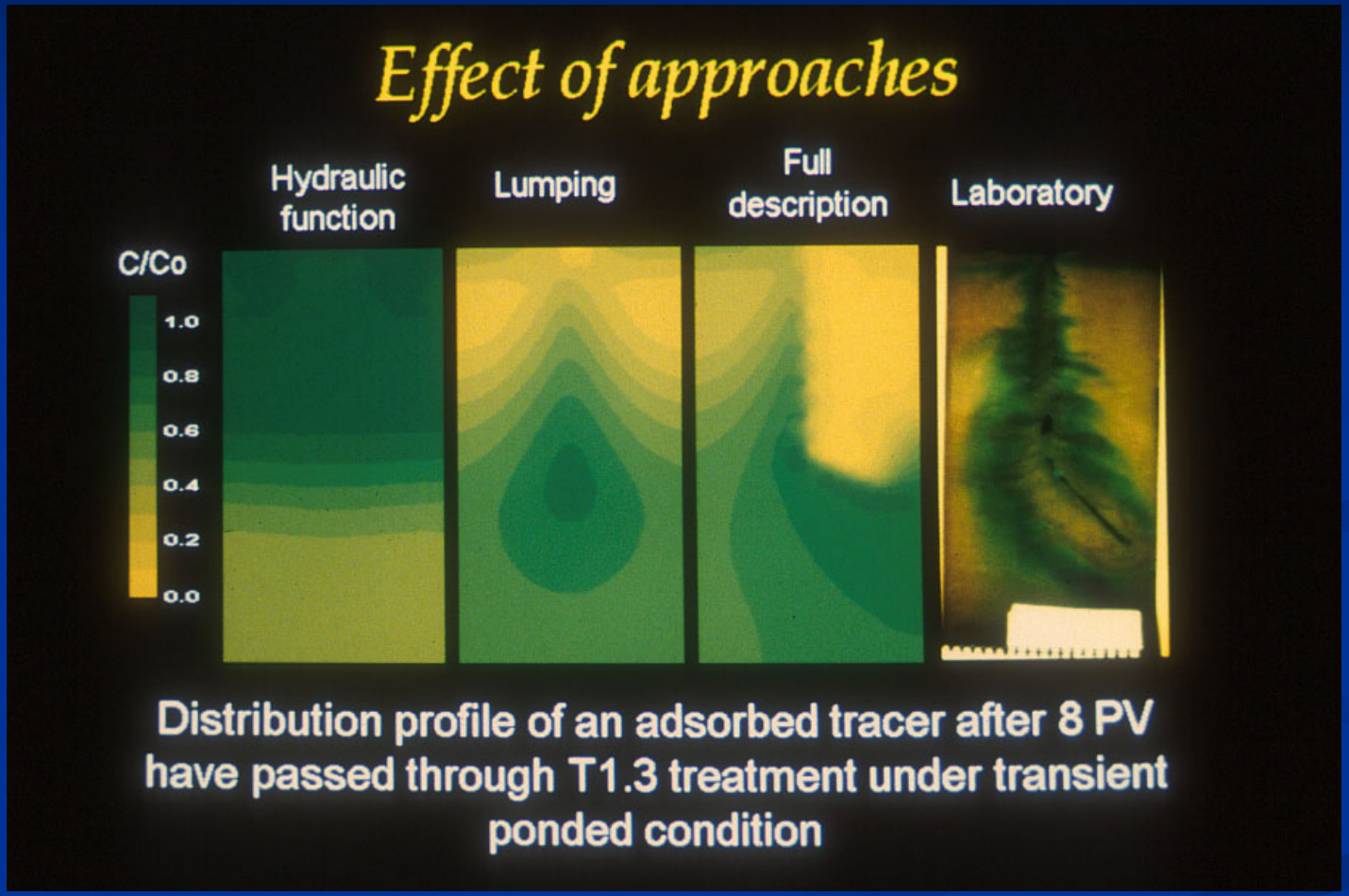
Allaire-Leung et al. (2000)

Modeling Different Approaches



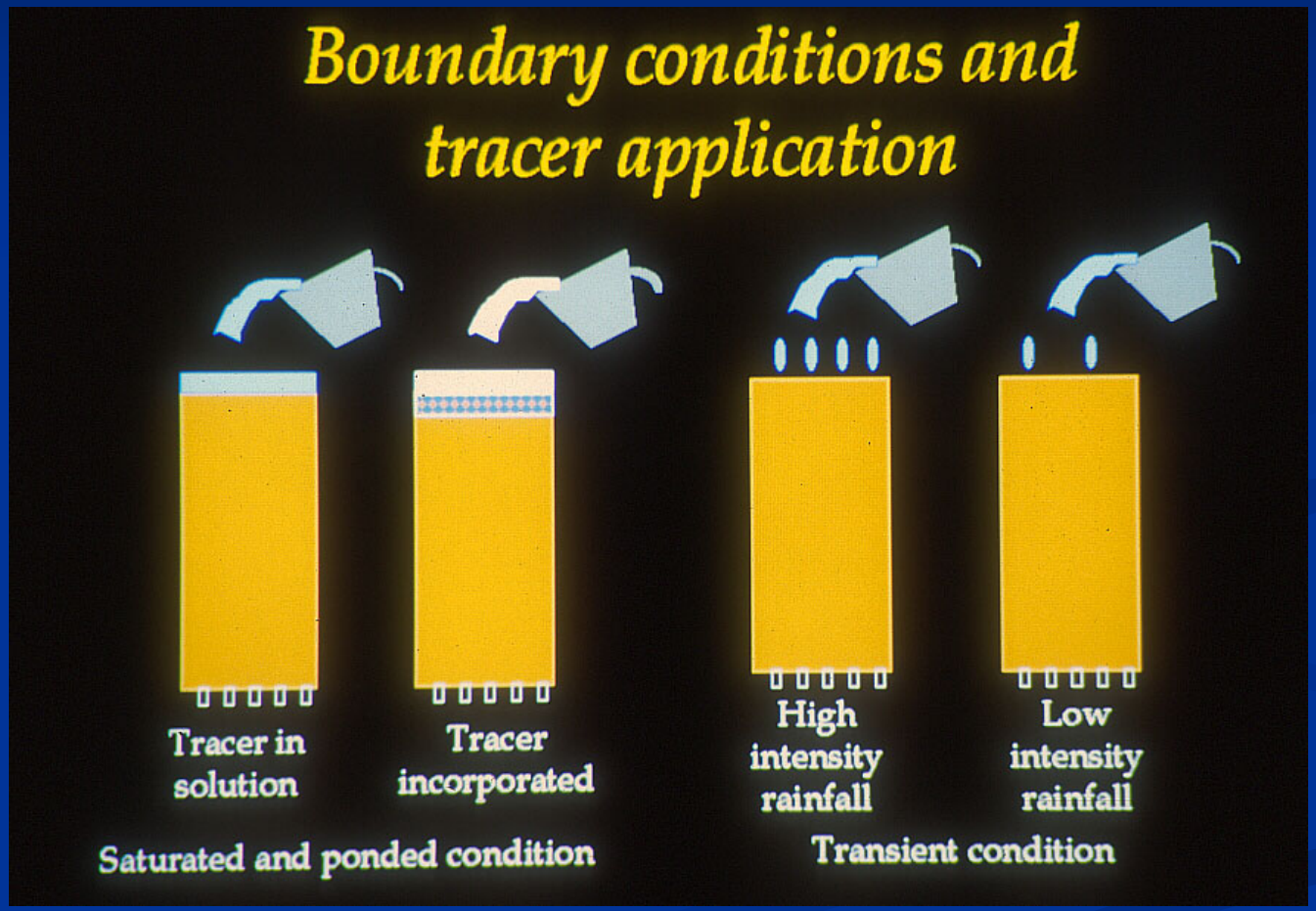
Allaire-Leung et al. (2000)

Modeling Tortuosity Effects



Allaire-Leung et al. (2000)

Simulated Boundary Conditions



Allaire-Leung et al. (2000)

Conclusions

- Macropores definitely impact preferential transport of water and in turn contaminants even if we can not measure an increase in infiltration rate.

- Since macropores are not uniformly distributed, their impact can not be easily characterized by taking small soil samples.

Conclusions I

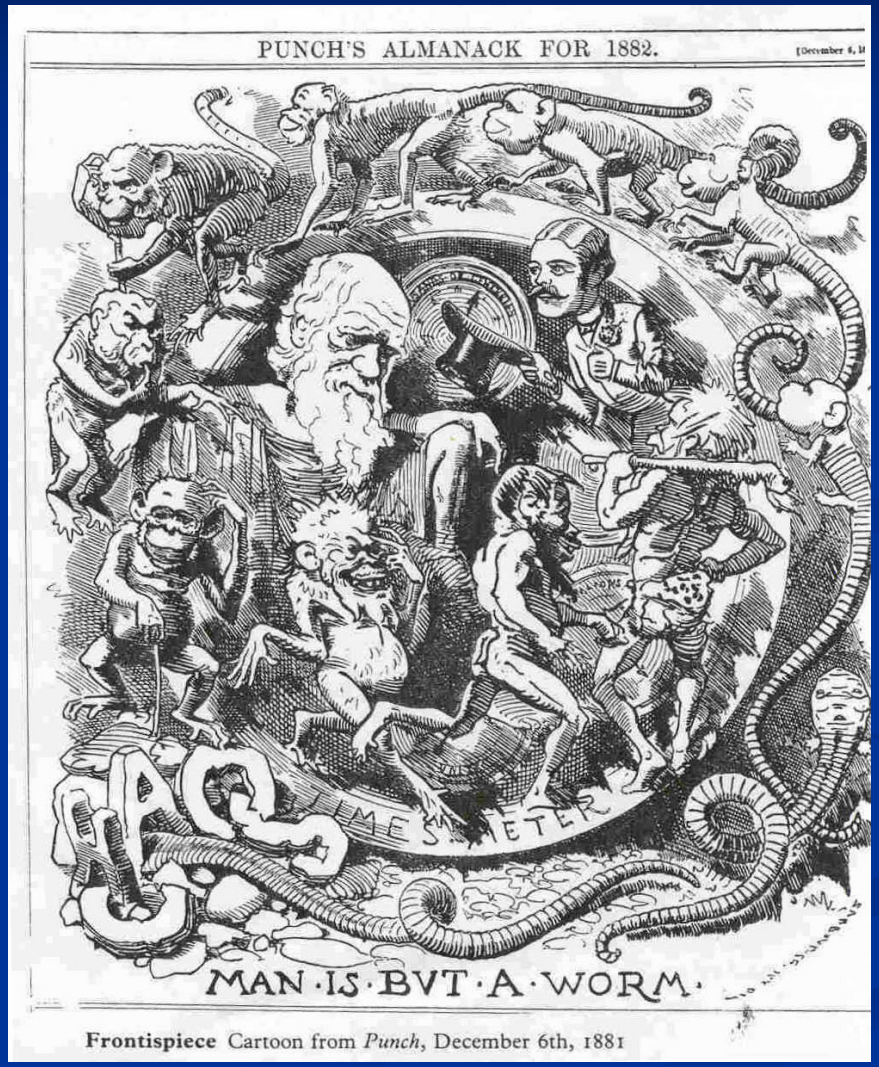
- The continuity of earthworm macropores varies with species and appears to dependent on the biology and ecology of the earthworms.

- Since management practices impact ecology of the worm, they in turn effect the preferential flow.

Conclusions II

- Simpler macropore models are acceptable when contaminants have been incorporated in soil or there is no flooding at the soil surface.
- Macropore continuity is more important for assessing the degree of groundwater contamination.
- Macropore tortuosity is more important for assessing the degree of soil contamination.

Man is but a worm (Punch, 1881)



Frontispiece Cartoon from *Punch*, December 6th, 1881

Macropore Animation
A. tuberculata