

# Radionuclide Dating of Hyporheic Fine Particles From the Bed Material of the South River at Relative River Mile 2.95-3.0

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# Outline

- Motivation
- Study Area
- Methods
- Results
- Discussion
- Conclusions

# Motivation - Significance

- Sand, silt, clay, and fine organic particulate matter stored in the matrix of gravel river beds is important because it influences:
  - Ecological processes in stream beds
    - Benthic organisms
    - Fish spawning
    - Etc.
  - Cycling of contaminants (MERCURY) and nutrients

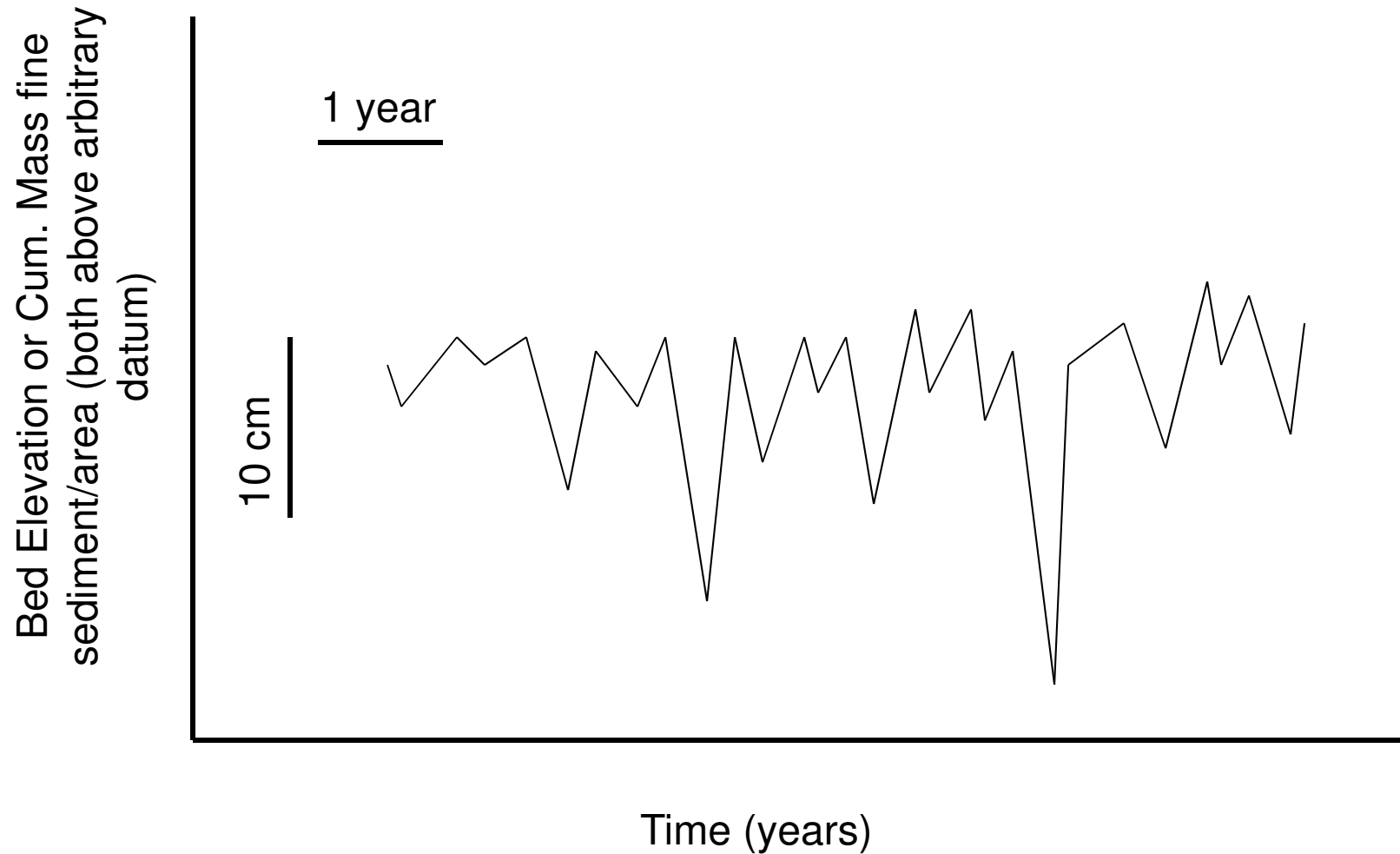
# Key Processes

- Deposition and resuspension of fine particles into and out of the gravel matrix
  - During periods when the gravel bed is not necessarily in motion
- Scour and deposition of coarse bed material during high flows
- Net deposition or erosion through time

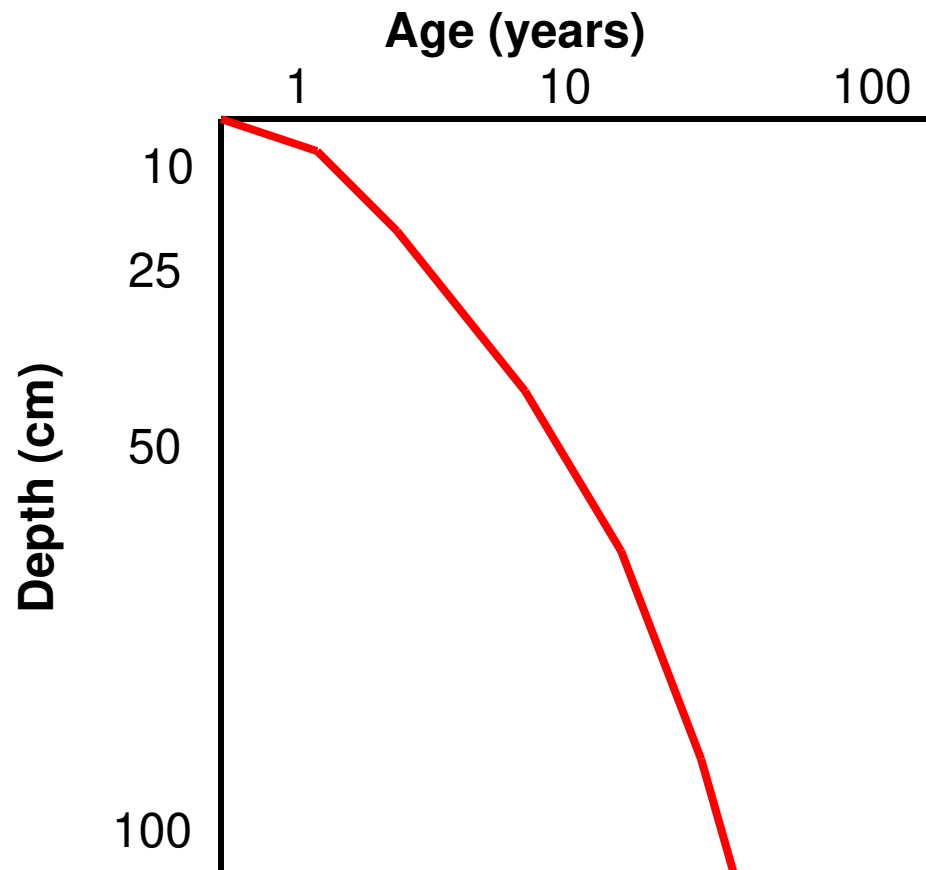
# Initial Hypotheses To Be Tested

- Silt, clay, and organic material near the surface of the bed are affected by high discharges several times a year
- The bed should be scoured and filled on a scale of decimeters annually
- Both processes should be more important than long term bed elevation changes caused by net sedimentation or erosion

# Graphical Illustration of Hypothesis



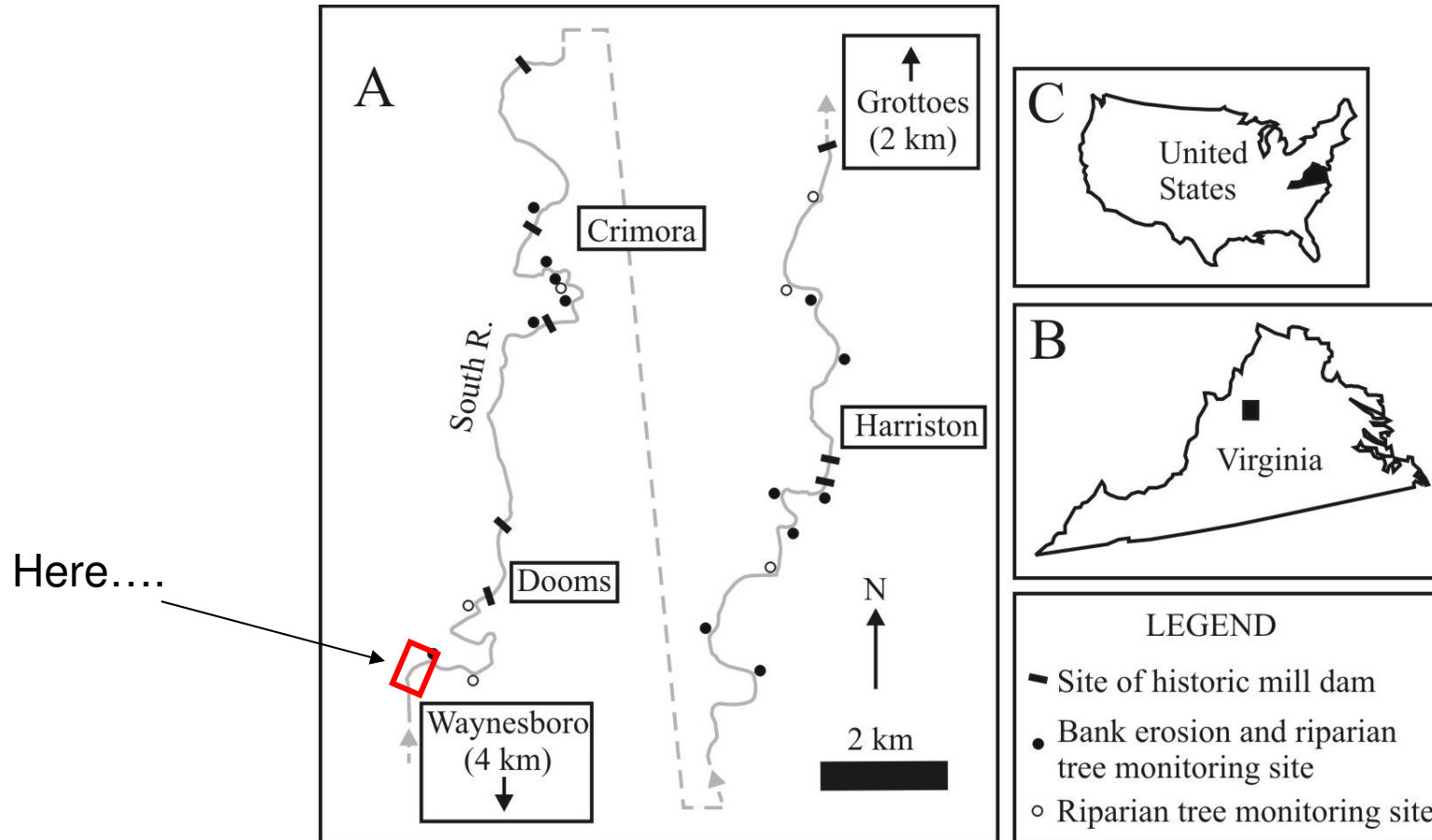
# Implied Sediment Age Distribution With Depth



# Study Area

- South River, Virginia
- Relative River Mile 2.95-3.0

# Location of the Study Area

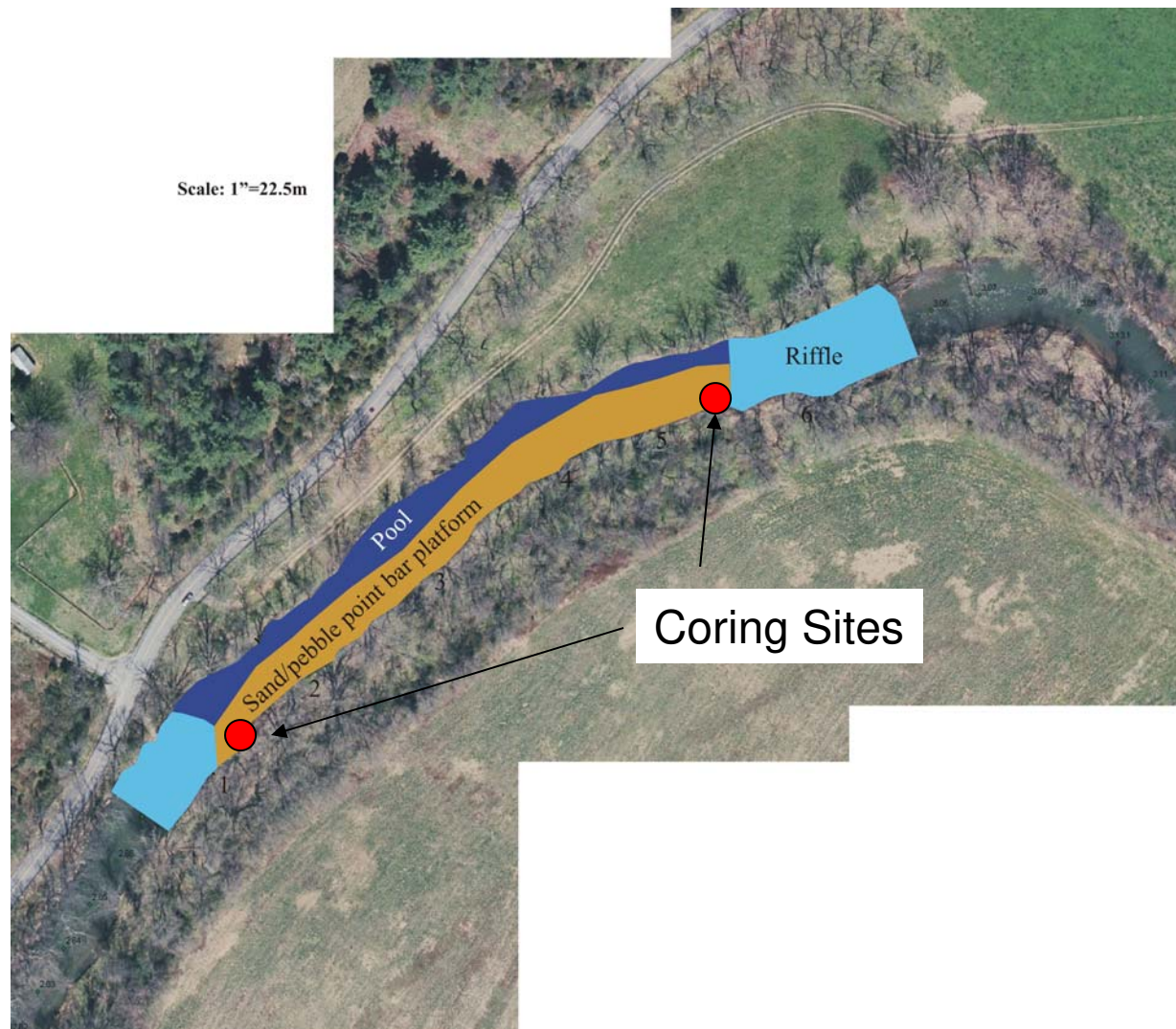


# Coring Sites

Scale: 1"=22.5m

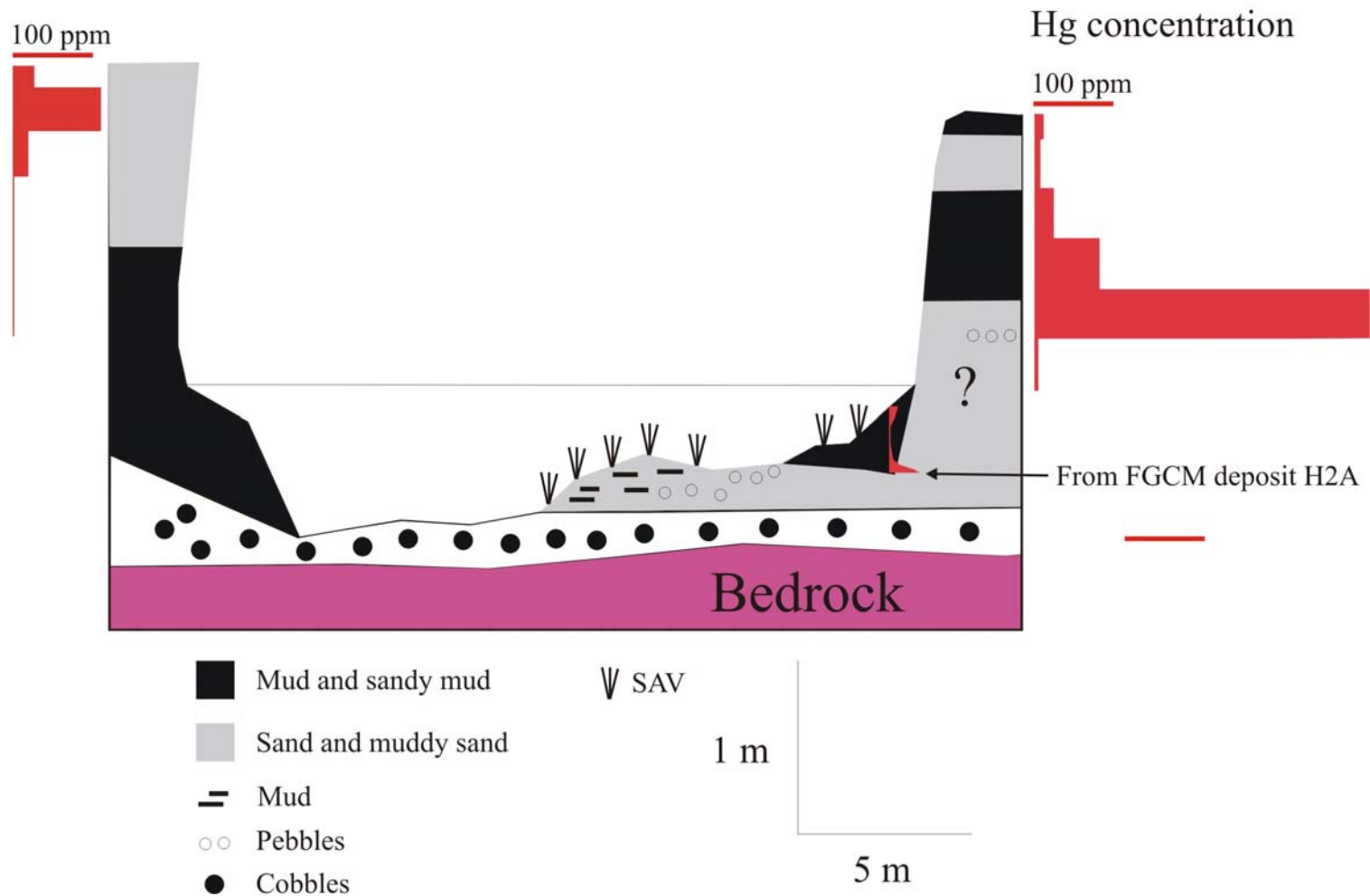


# Geomorphic Map of The Study Area

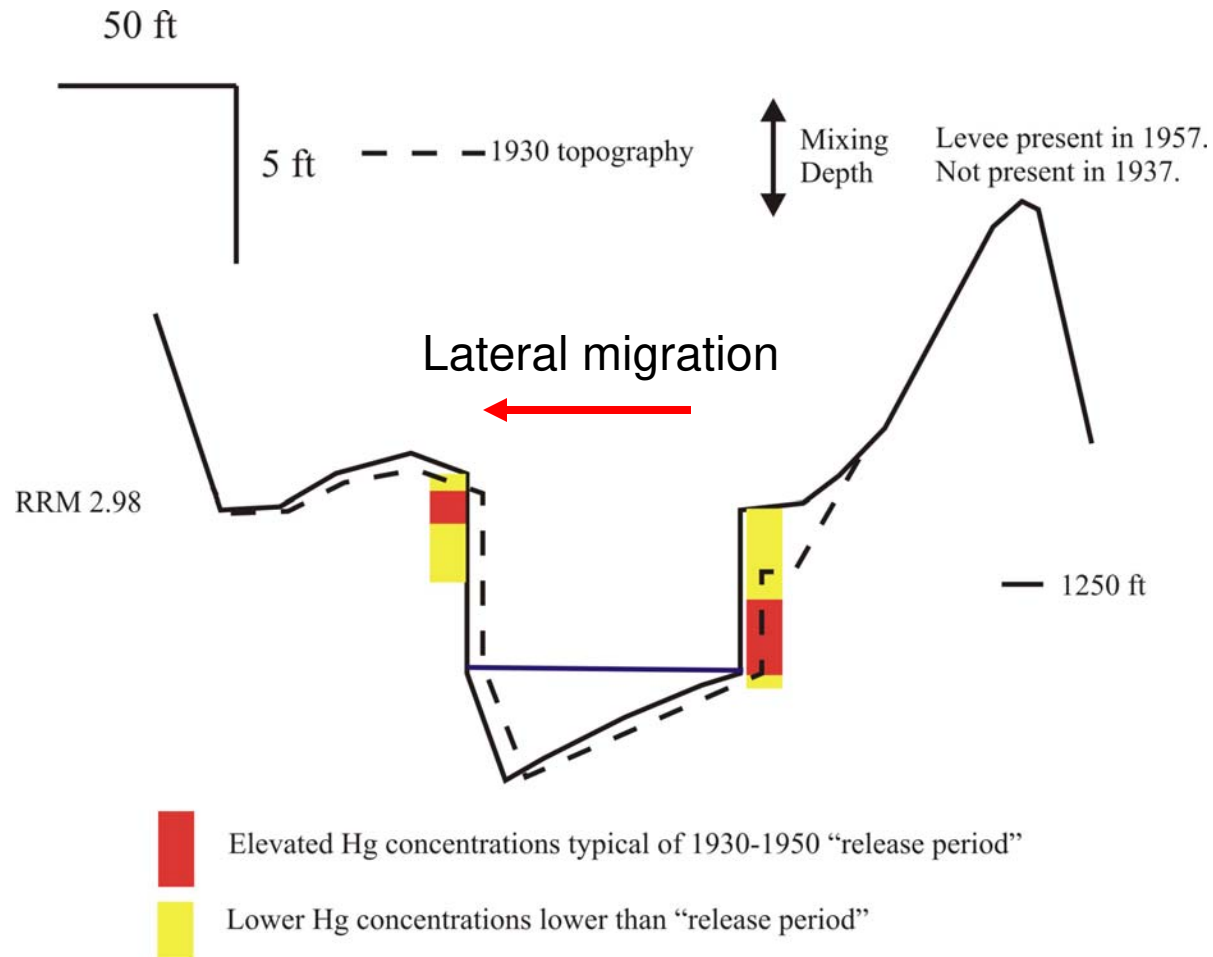


# Typical Cross-Section

## Cross-Section RRM 2.98



# Slow Lateral Migration, 1930-2005



# Methods

- Overview of Approach
- Coring methods
- Methods used to sample suspended sediment
- Adjusting radionuclide profiles for changes in grain size and organic content

# Approach

- Use Pb-210, Cs-137, and Be7 to estimates “ages” of sediment in the river bed
- Analyze suspended sediment in contemporary events to estimate radionuclide activities at time of deposition
- Adjust all results as necessary for differences in texture and organic content
- Also measure Hg concentrations
  - Known history of Hg contamination provides independent check on the ages determined using radionuclides

# The Radionuclides

- Pb-210
  - Half-life of 22.26 years
- Be-7
  - Half-life of 53.3 days
- Cs-137
  - Generated by atmospheric nuclear weapons testing
  - Peak atmospheric concentrations - 1963

# Radionuclide Analysis

- Activities determined by gamma detection
  - Dr. Kyungsoo Yoo's laboratory
    - UD Plant and Soil Science
  - All the hard work:
    - Chunmei Chen, PhD graduate student, Plant and Soil Science

# South River Hg Chronologies

From Dated Core Samples

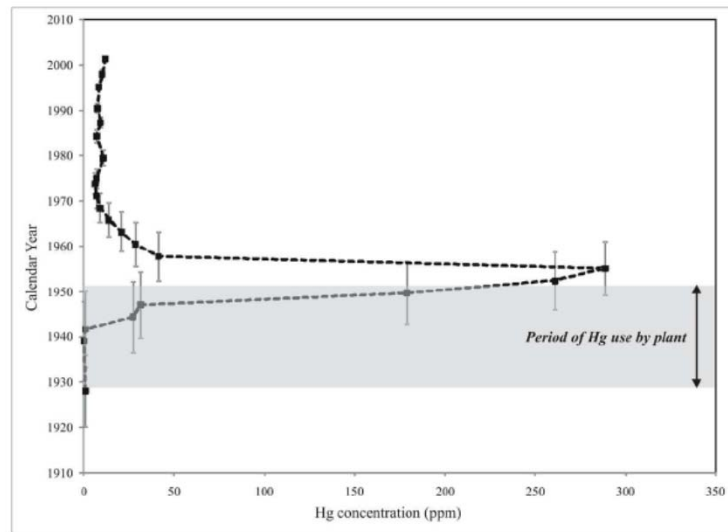
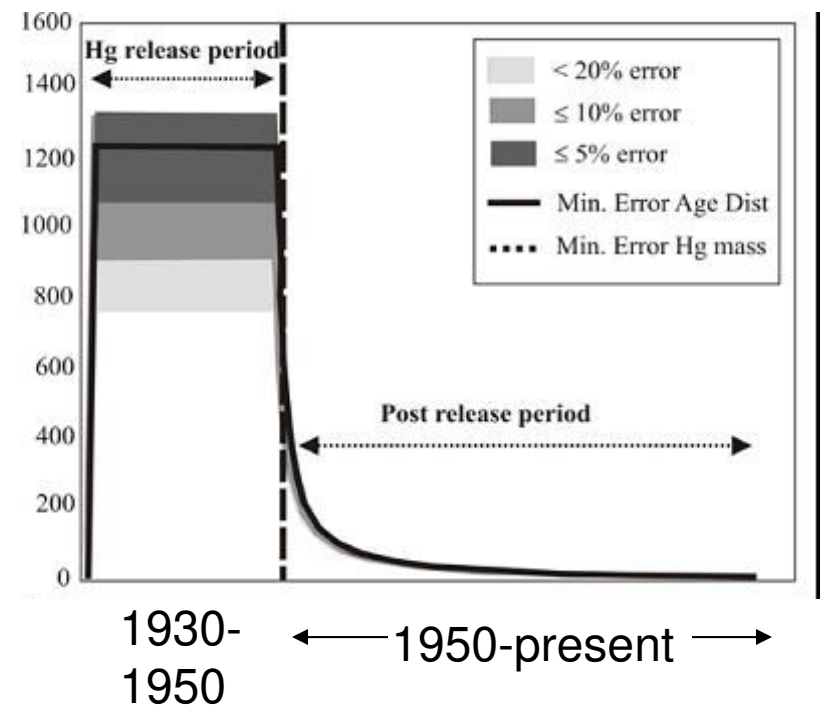


Figure 7. Mercury concentration (ppm) as a function of time for the core dated using Pb-210 and Cs-137 (Figure 6). The error bars present the upper and lower 99% confidence bands from the Pb-210 analysis. Shading indicates the dates of mercury use by the plant in Waynesboro.

*Skalak and Pizzuto, in review*

From Modeling Hg on Suspended Sediment

Hg Concentration on Suspended Sediment in Transport



*Skalak and Pizzuto, in prep*

Coring.....



# Sampling Suspended Sediment

- Installed “passive” sediment collection devices at downstream coring location at RRM 3
- To be sampled more or less immediately after a “high discharge” event

## Passive Suspended Sediment Sampler Location RRM 3.0



## 4 Passive Suspended Sediment Samplers



# Suspended Sediment Collectors In Place....



# Adjusting Radionuclide Counts for Differences in Texture

- Suspended sediment has very different texture from bed sediment
- Samples of the bed sediment differ from each other

# “Modeling” Concept

- Partition measured activities into 4 components of particle composition:
  - *Organic matter*
  - *Silt-clay*
  - *Fine-sand*
  - *Medium-coarse sand*
- Activity of a sample composed of 100% of each textural component at the time of deposition,  $A_{itot0}$ :
  - *Treated as a constant unique for each textural component*
- Measured activities then depend on:
  - ***Amount of each component in the sample (known)***
  - ***Initial activities of each component (unknown)***
  - *Sample ages*
    - ***Unknown for cores***
    - ***0 for suspended sediment***

# Computing the Activity of Each Sample

$$A_t = \sum_1^4 A_i = \sum_1^4 A_{itot0} f_i e^{-\kappa t}$$

$A_t$ -total activity measured in a core sample

$A_i$ -activity of textural component  $i$

$A_{itot0}$ -activity of textural component  $i$  at time 0

$f_i$ -proportion of textural component  $i$  in a sample

$\kappa$  – decay constant (0.03114/yr for Pb210)

$t$  – sample age

## Calibration:

*vary parameters until computed  $A_t$  = measured  $A_t$*

$$A_t = \sum_{i=1}^4 A_i = \sum_{i=1}^4 A_{itot0} f_i e^{-\kappa t}$$

$A_t$ -total activity measured in a core sample

$A_i$ -activity of textural component  $i$

$A_{itot0}$ -activity of textural component  $i$  at time 0  
(unknown)

$f_i$ -proportion of textural component  $i$  in a sample

$\kappa$  – decay constant (0.03114/yr for Pb210)

$t$  – sample age (unknown)

# Known values, Unknown values, Measured Activities, Computed Results

***13 observed activities values, 14 unknowns to be determined.....***

A single slice  
from a core

|                                  |         | Total initial activity |                           |           |             |       |                         |  |
|----------------------------------|---------|------------------------|---------------------------|-----------|-------------|-------|-------------------------|--|
|                                  |         | Organic                | mud                       | fine sand | coarse sand |       |                         |  |
|                                  |         | 0.08                   | 0.09                      | 0.02      | 0.005       |       |                         |  |
| Observed Activity                |         | Age (years)            | fractions for each sample |           |             |       | Computed total activity |  |
| Core<br>SR-2-3-09-3              | 0.00555 | 20                     | 0.014                     | 0.059     | 0.067       | 0.860 | 0.00648                 |  |
|                                  | 0.00271 | 45                     | 0.022                     | 0.067     | 0.043       | 0.867 | 0.00321                 |  |
|                                  | 0.00186 | 75                     | 0.031                     | 0.148     | 0.078       | 0.743 | 0.00204                 |  |
|                                  | 0.00076 | 95                     | 0.017                     | 0.095     | 0.164       | 0.724 | 0.00087                 |  |
| Core<br>SR-2-3-09-5              | 0.01648 | 2                      | 0.024                     | 0.032     | 0.204       | 0.740 | 0.01182                 |  |
|                                  | 0.00475 | 18                     | 0.021                     | 0.007     | 0.033       | 0.939 | 0.00437                 |  |
|                                  | 0.00231 | 30                     | 0.008                     | 0.004     | 0.026       | 0.962 | 0.00248                 |  |
|                                  | 0.00197 | 40                     | 0.011                     | 0.012     | 0.004       | 0.974 | 0.00196                 |  |
|                                  | 0.00101 | 75                     | 0.025                     | 0.038     | 0.007       | 0.931 | 0.00098                 |  |
|                                  | 0.00057 | 110                    | 0.009                     | 0.141     | 0.042       | 0.807 | 0.00060                 |  |
| Suspended<br>Sediment<br>Samples | 0.10400 | 0                      | 0.031                     | 0.533     | 0.436       | 0.000 | 0.05917                 |  |
|                                  | 0.10400 | 0                      | 0.079                     | 0.580     | 0.342       | 0.000 | 0.06529                 |  |
|                                  | 0.06300 | 0                      | 0.053                     | 0.469     | 0.477       | 0.000 | 0.05606                 |  |

Decay constant  $\text{yr}^{-1}$  0.03115

# Results

# Suspended Sediment From 3 “High Flows” Sampled

| Date          | Peak Discharge at<br>Waynesboro, VA |
|---------------|-------------------------------------|
| April 3, 2009 | 910                                 |
| May 7, 2009   | 330                                 |
| May 27, 2009  | 392                                 |

Note: 1 year recurrence interval discharge at Waynesboro = 2513 cfs

# Particle Size and Organic Material, Suspended Sediment and Bed Material (typical values)

| Sample             | Loss On Ignition (%) | % Silt-Clay | % vf-f Sand | % med.-coarse Sand | % Gravel |
|--------------------|----------------------|-------------|-------------|--------------------|----------|
| Suspended Sediment | 5                    | 53          | 47          | 0                  | 0        |
| Bed Material       | 0.5                  | 0.4         | 2           | 19                 | 78.6     |

*Note: gravel removed from bed material before measuring radionuclide activity but huge textural differences between suspended sediment and bed material remain (% Silt-Clay and % med-coarse sand).*

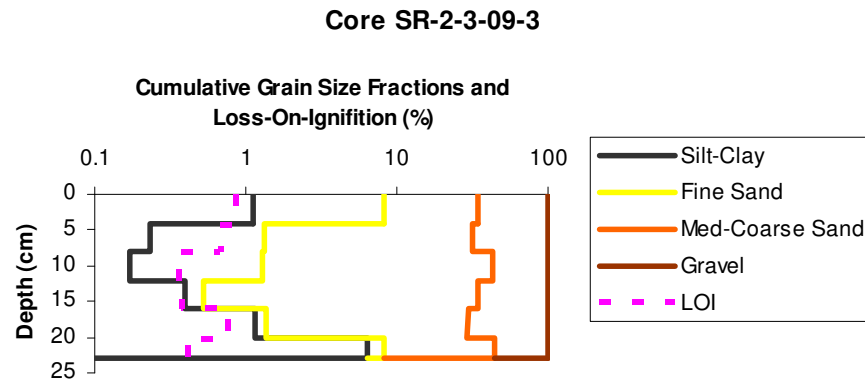
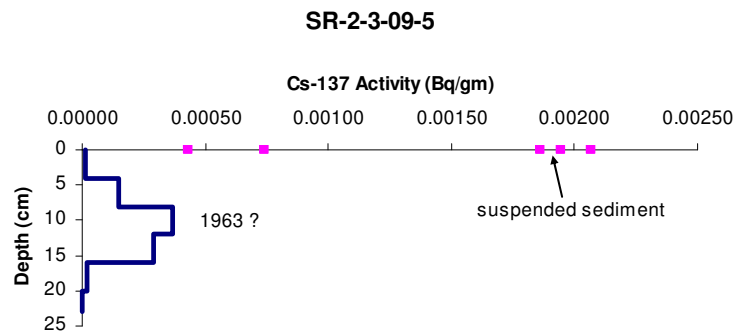
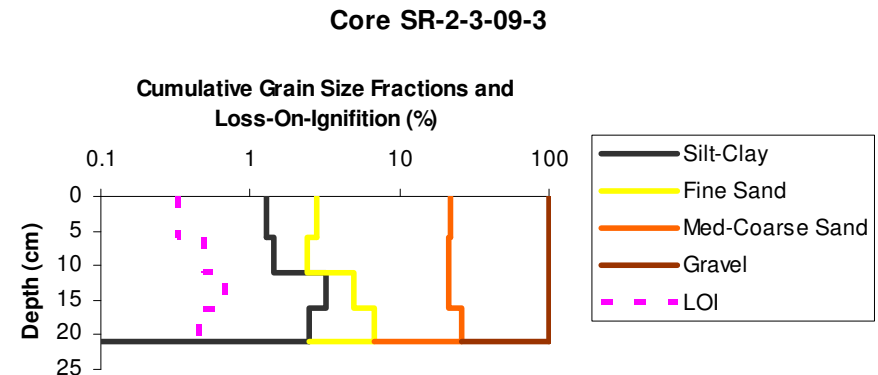
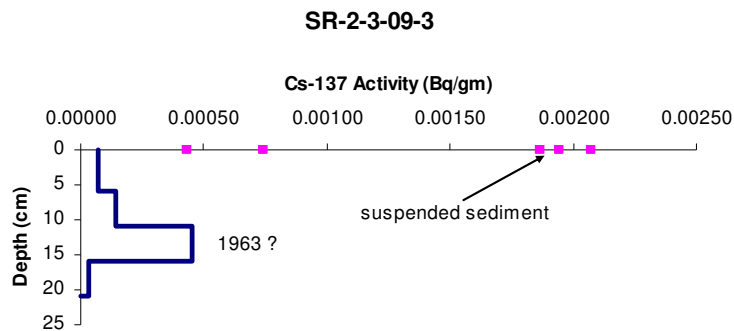
# Be7 Activities, Suspended Sediment and Bed Material

| Sample            | Be7 Activity (Bq/gm) |
|-------------------|----------------------|
| SR-6-9-09-Qss     | 0.085                |
| SR-5-7-09-Qss     | 0.05                 |
| SR-4-3-09 Split 1 | 0.025                |
| SR-4-3-09 Split 2 | 0.017                |
| SR-4-3-09 Split 3 | 0.015                |
| All Bed Samples   | 0                    |

- All suspended sediment samples were exposed to atmospheric sources of Be7 within months...
- All bed samples have .....no measurable Be7 activity.

***Bed material is “old” compared to suspended sediment***

# Unadjusted Cs-137 Profiles

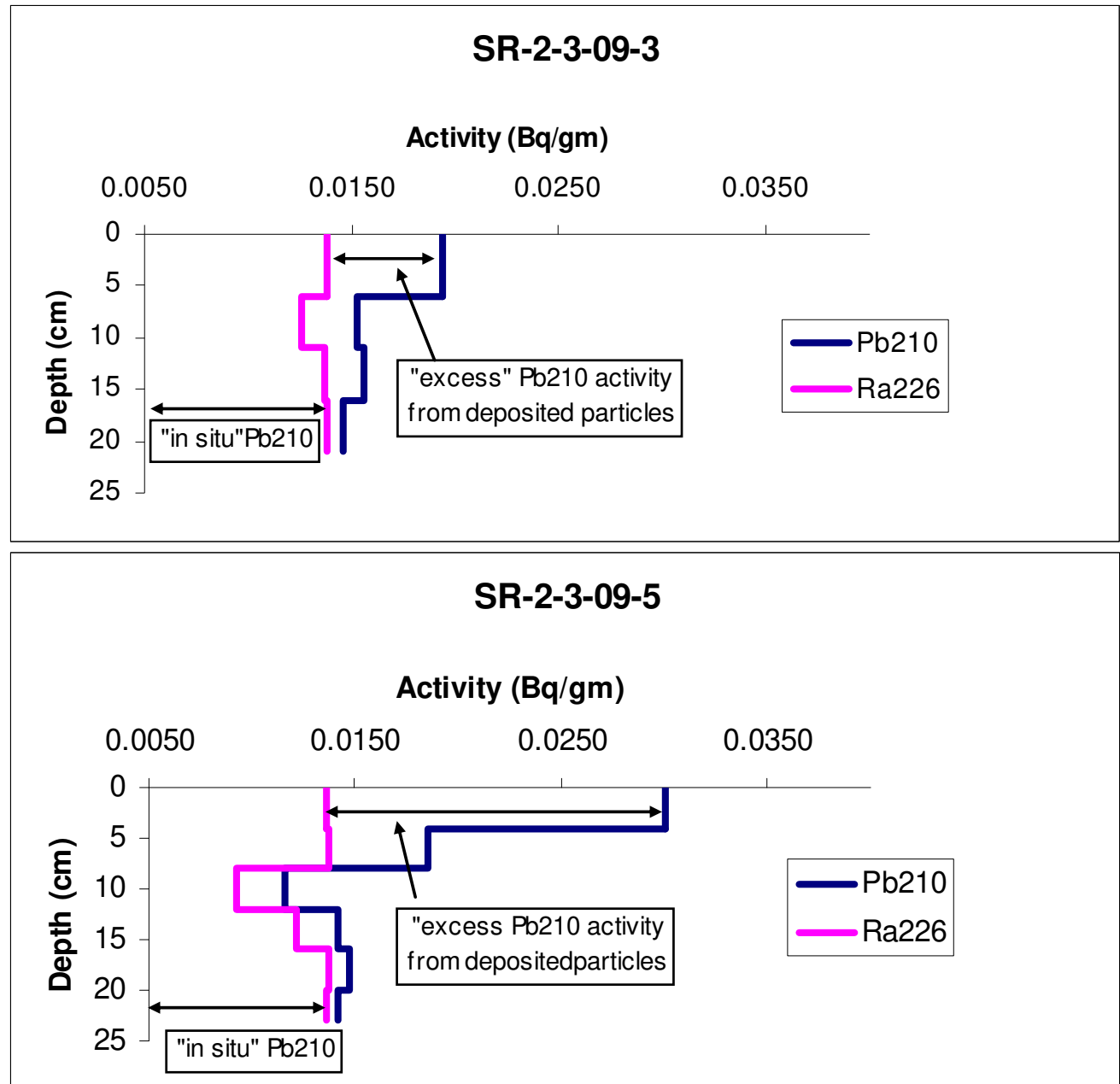


*Are peak concentrations dated at 1963 real, or related to textural variations??*

# Unadjusted Pb-210 Profiles

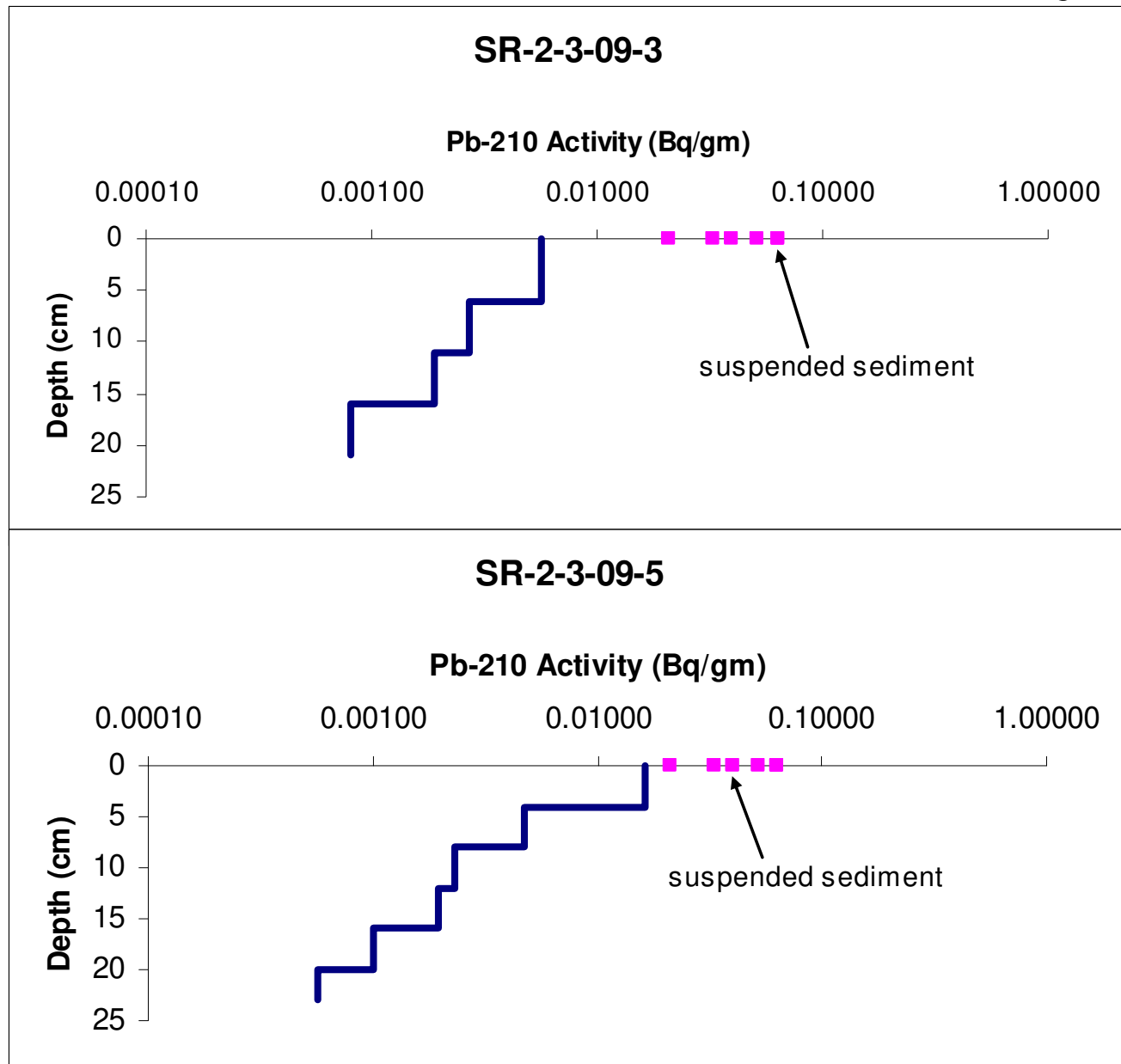
-“In situ” Pb210  
~ constant with  
depth and in  
both cores  
-“excess”  
Pb210 decays  
through several  
22.26 yr  $\frac{1}{2}$   
lives..??

-Implies  
sediment  
at depth is  
...”old”

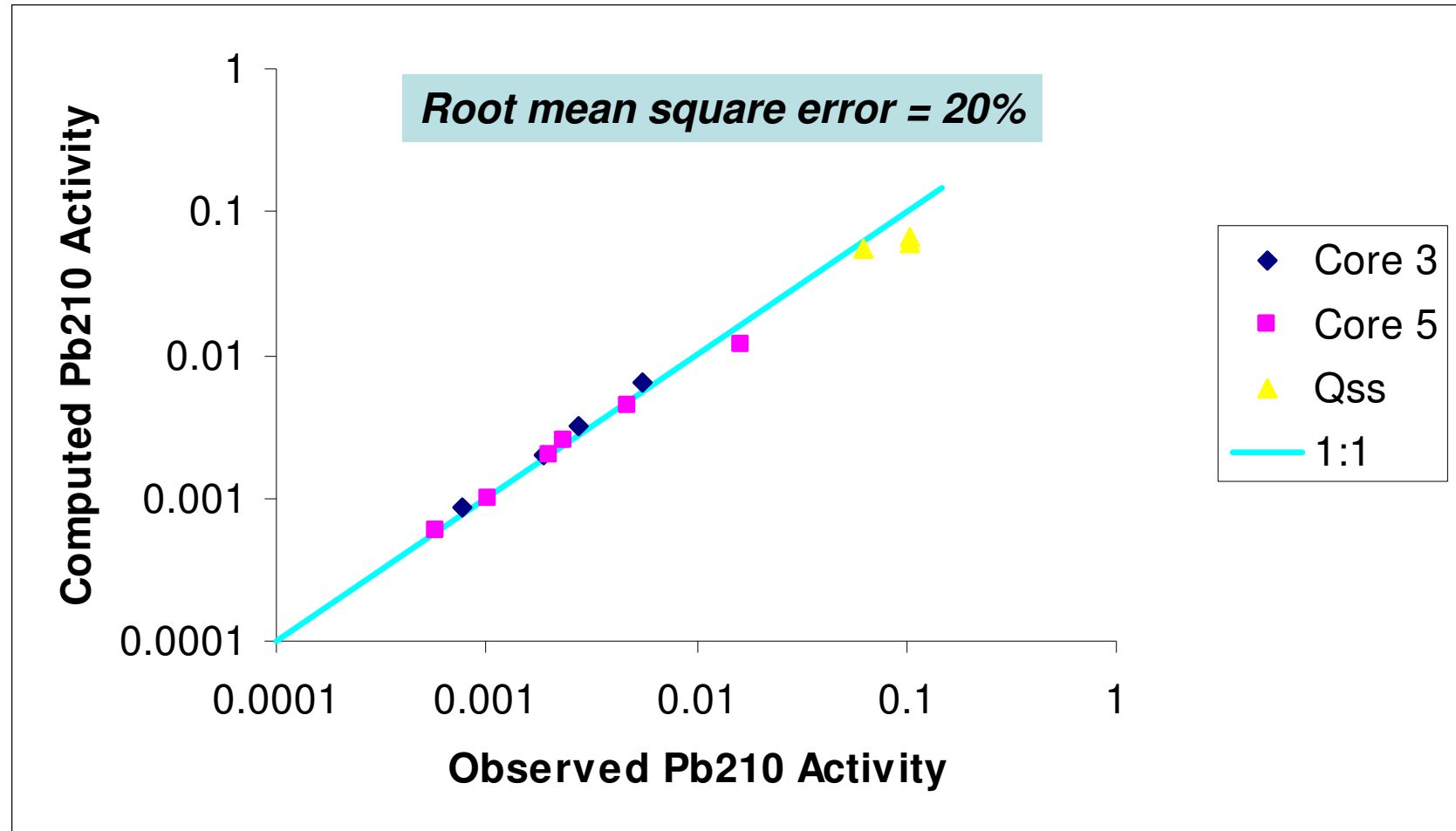


# Unadjusted “Excess” Pb210 Only

-Looks like several  $\frac{1}{2}$  lives of decay - though profiles need to be adjusted for changes in particle composition between layers



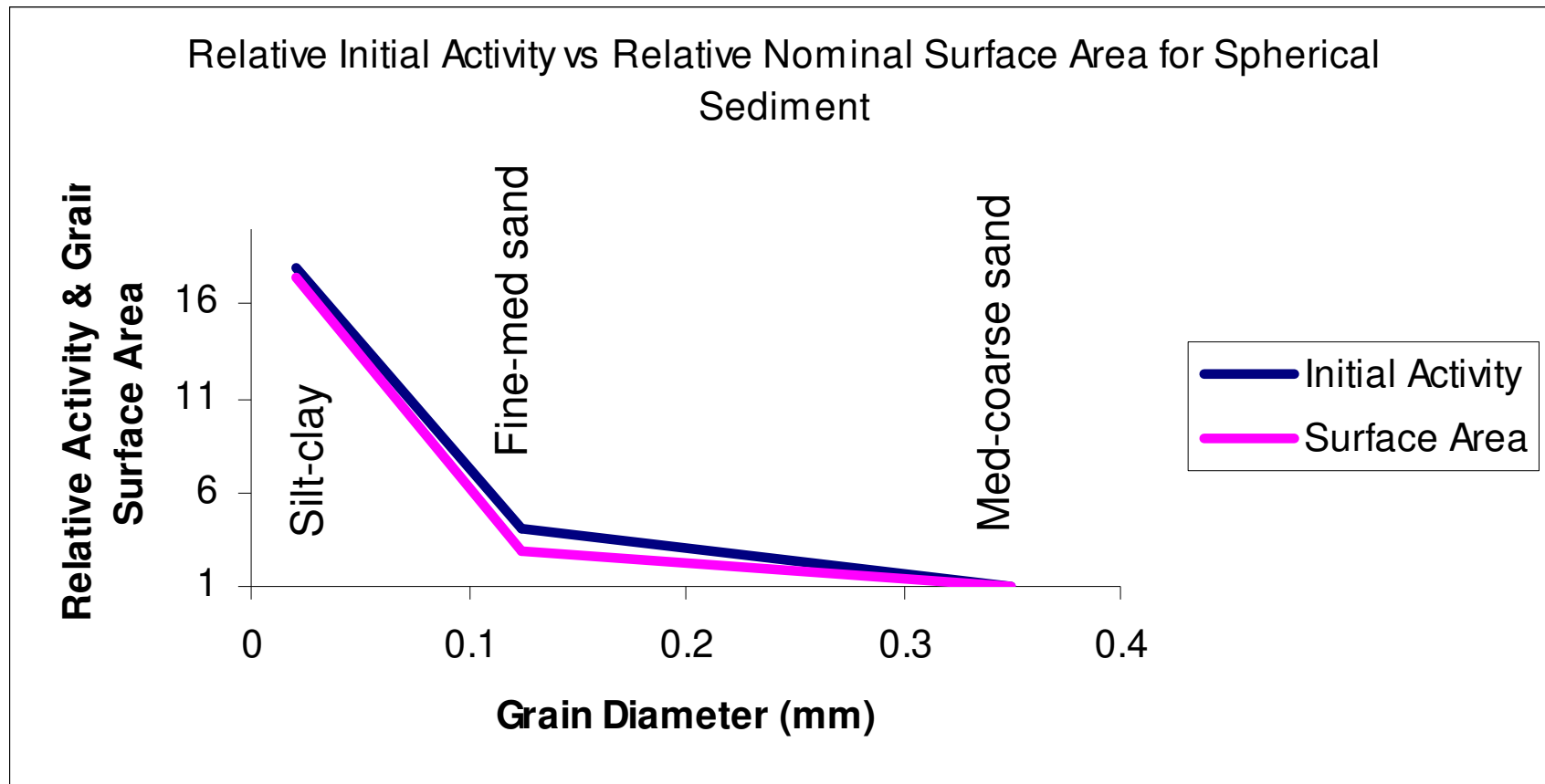
# “Excess Pb210” Activities, Adjusted for Texture and Age



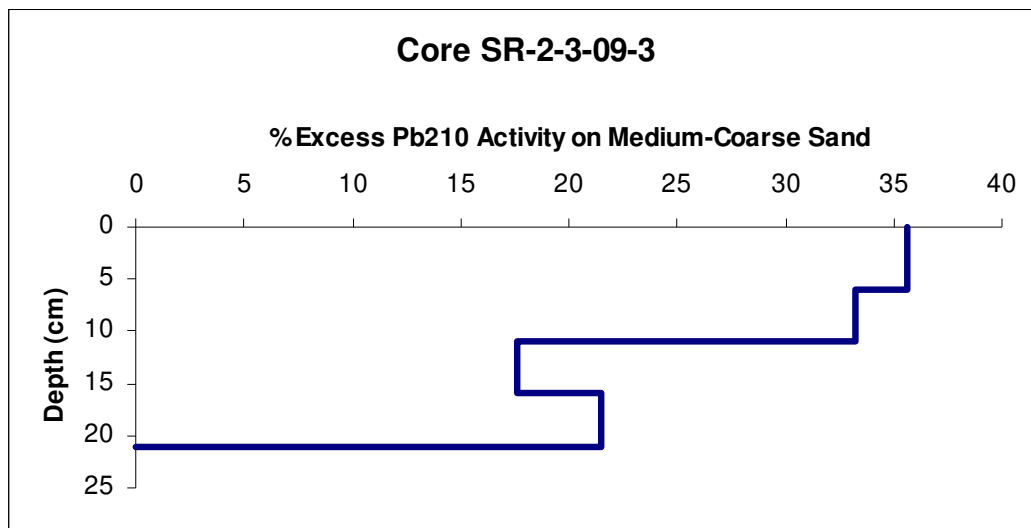
# Initial Activities by Particle Classification

| Particle Classification        | Organic | mud  | fine sand | coarse sand |
|--------------------------------|---------|------|-----------|-------------|
| Total Initial Activity (Bq/gm) | 0.08    | 0.09 | 0.02      | 0.005       |

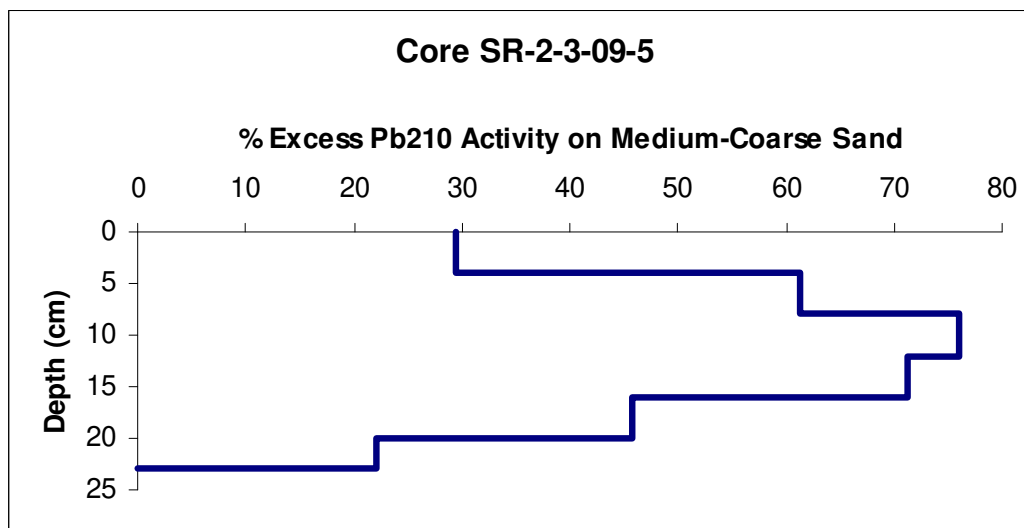
# Initial Activities May Be Explained By Changes in Particle Surface Area with Grain Size...



# Fraction of Total Activity, Medium-Coarse Sand



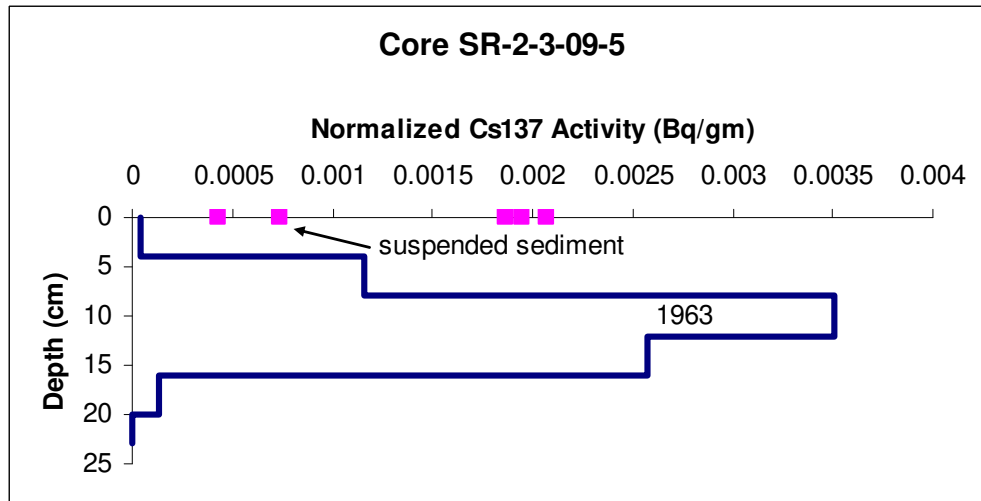
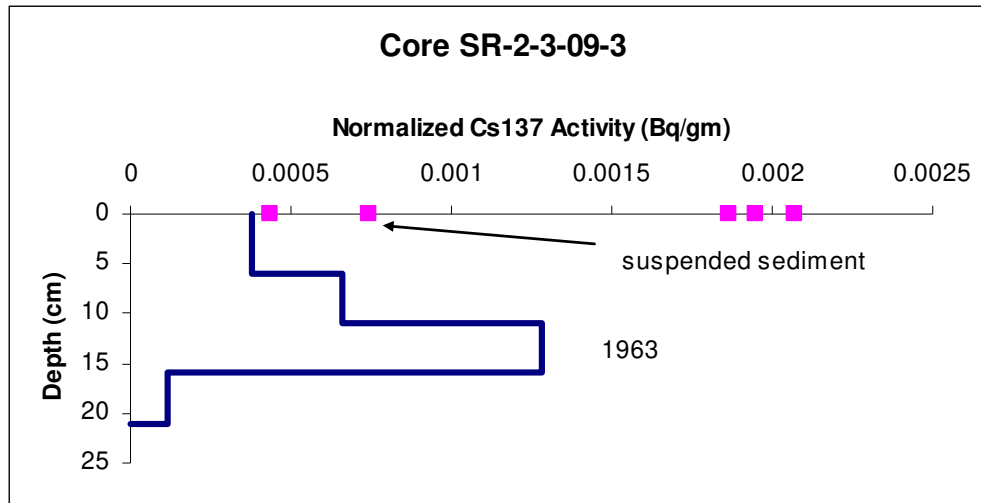
~ half of the activity is associated with particles likely transported at least intermittently as bedload!



# Normalize Cs137 Profiles By Texture

- Correct profiles for any vertical structure related to particle size
- Normalize to “mean suspended sediment” textural composition
  - Based on initial activities determined from “modeling” Pb210
  - i.e., assume partitioning of Cs137 and Pb210 are similar

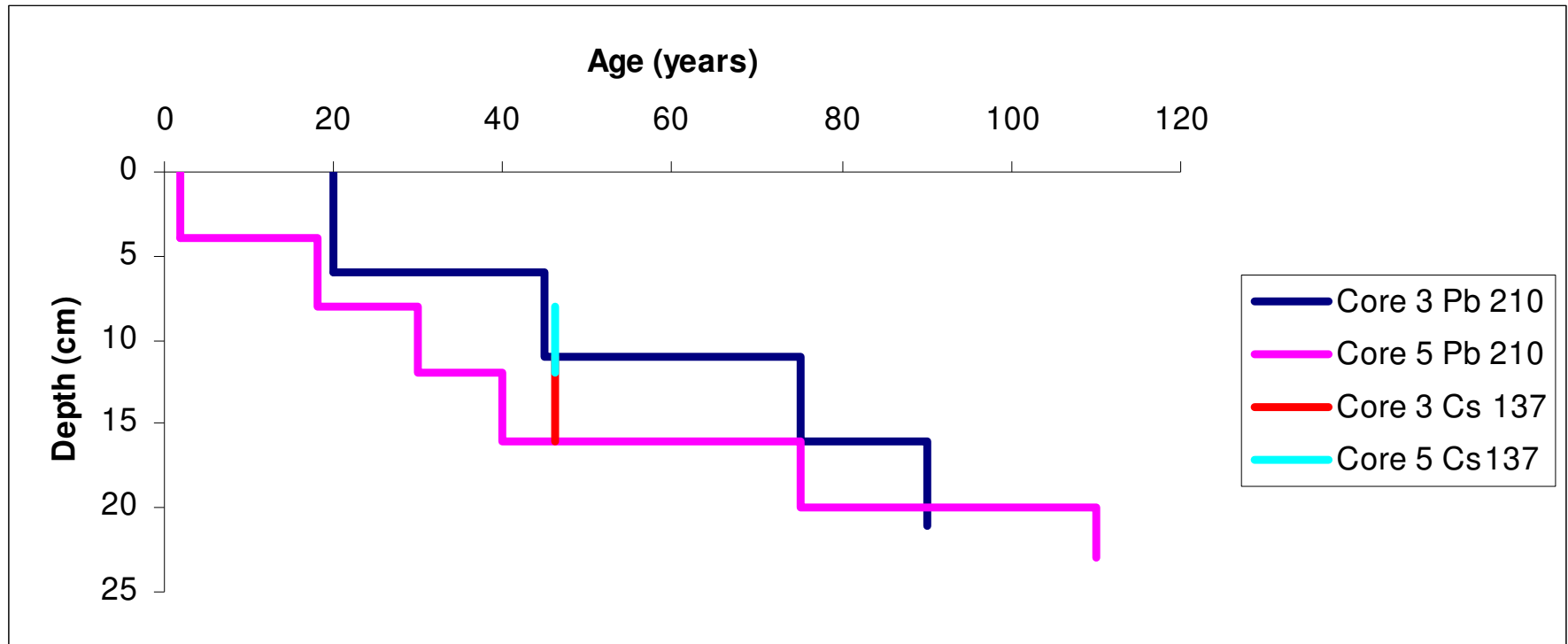
# Cs137 Normalized to Suspended Sediment



## *Interpretations*

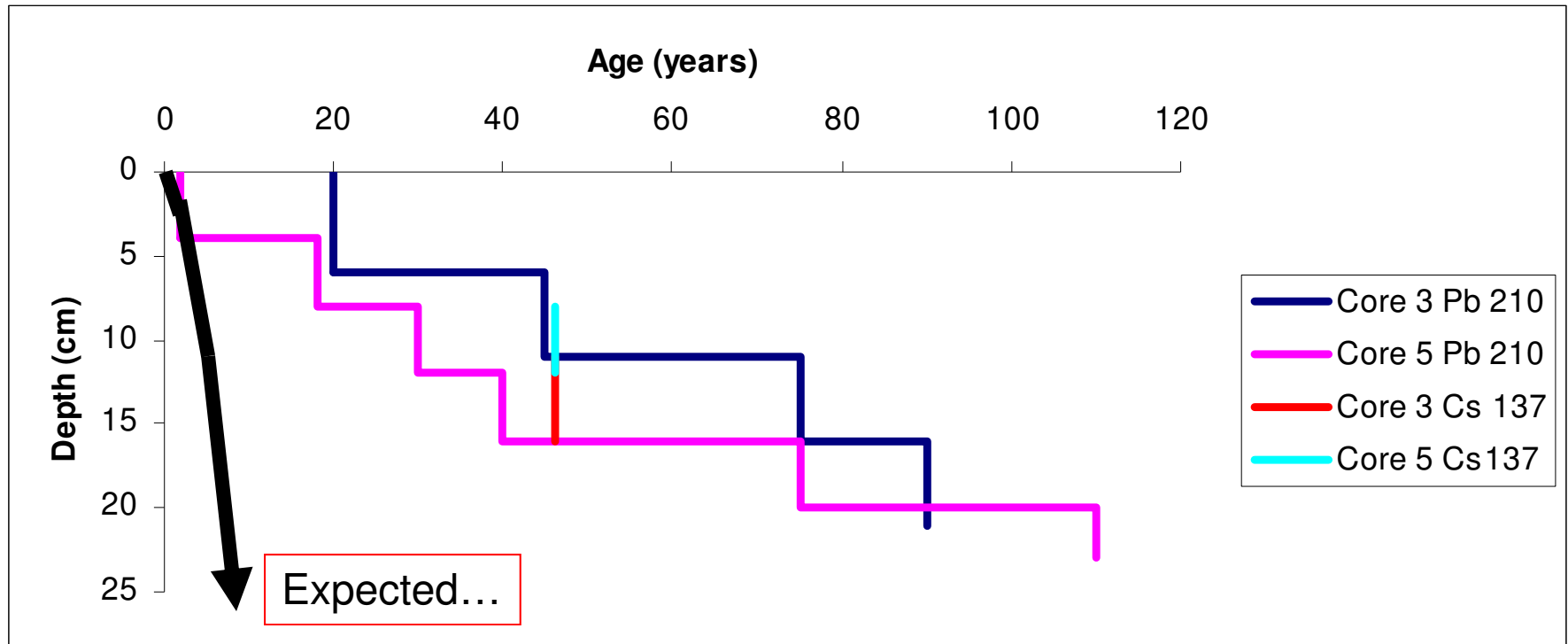
1. Peak concentrations (1963) are not related to texture)
  1. Implied dates might be correct!
2. Suspended sediment activities are higher than they should be for "present" conditions.

# Final Chronology



*Note that Pb210 and Cs137 Chronologies agree well!!*

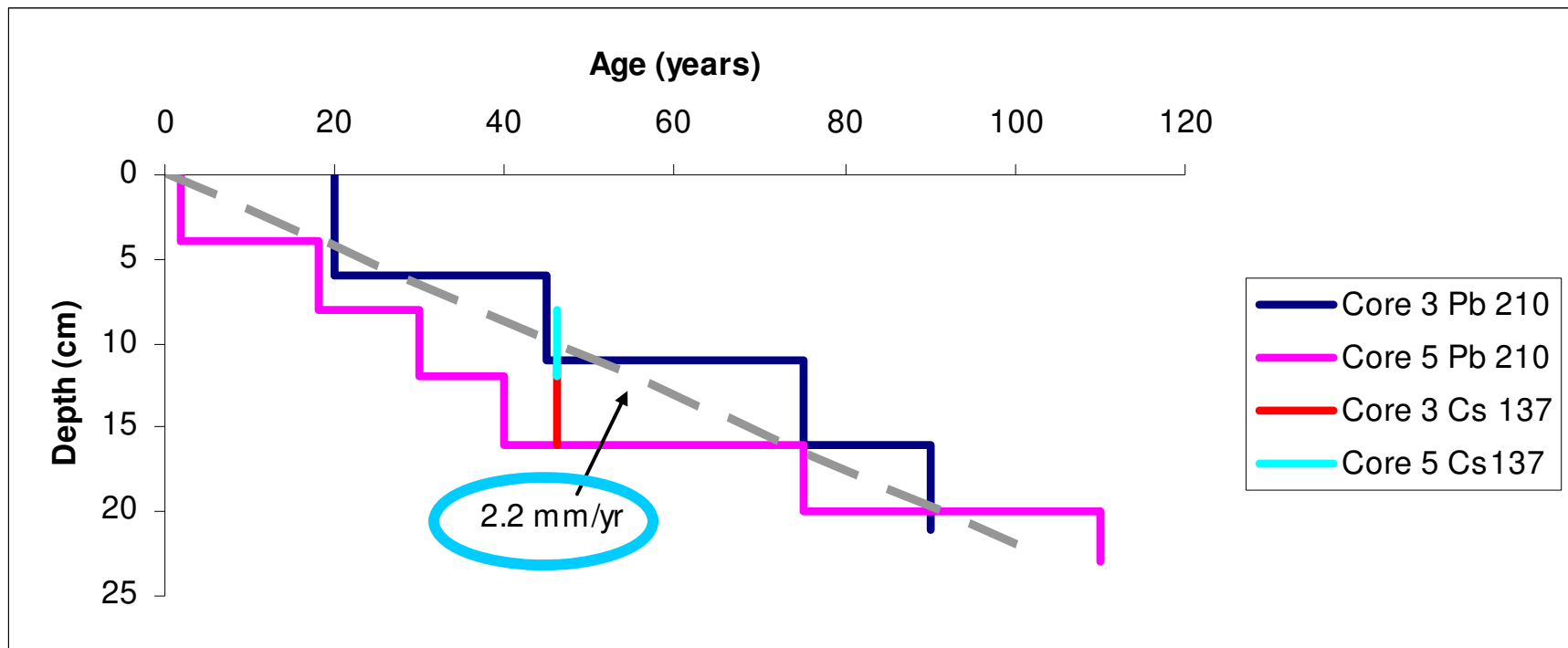
# Final vs “Expected” Chronology



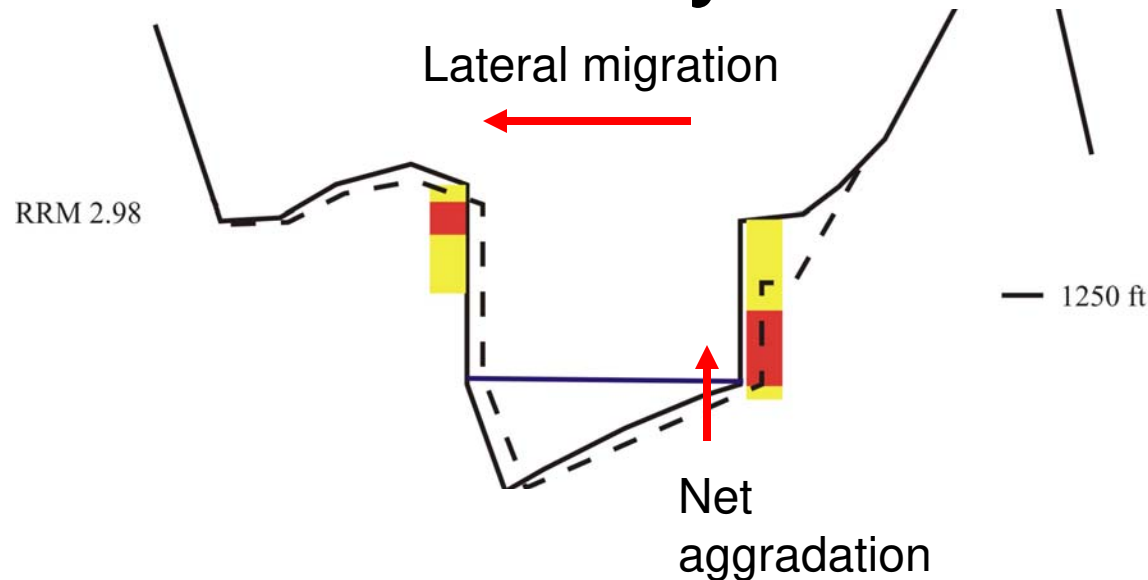
# Interpretations??

- Very limited scour and fill with a linear distribution of depth through time
- Or:
  - Slow aggradation of the bed through time
- Or:
  - Both of the above

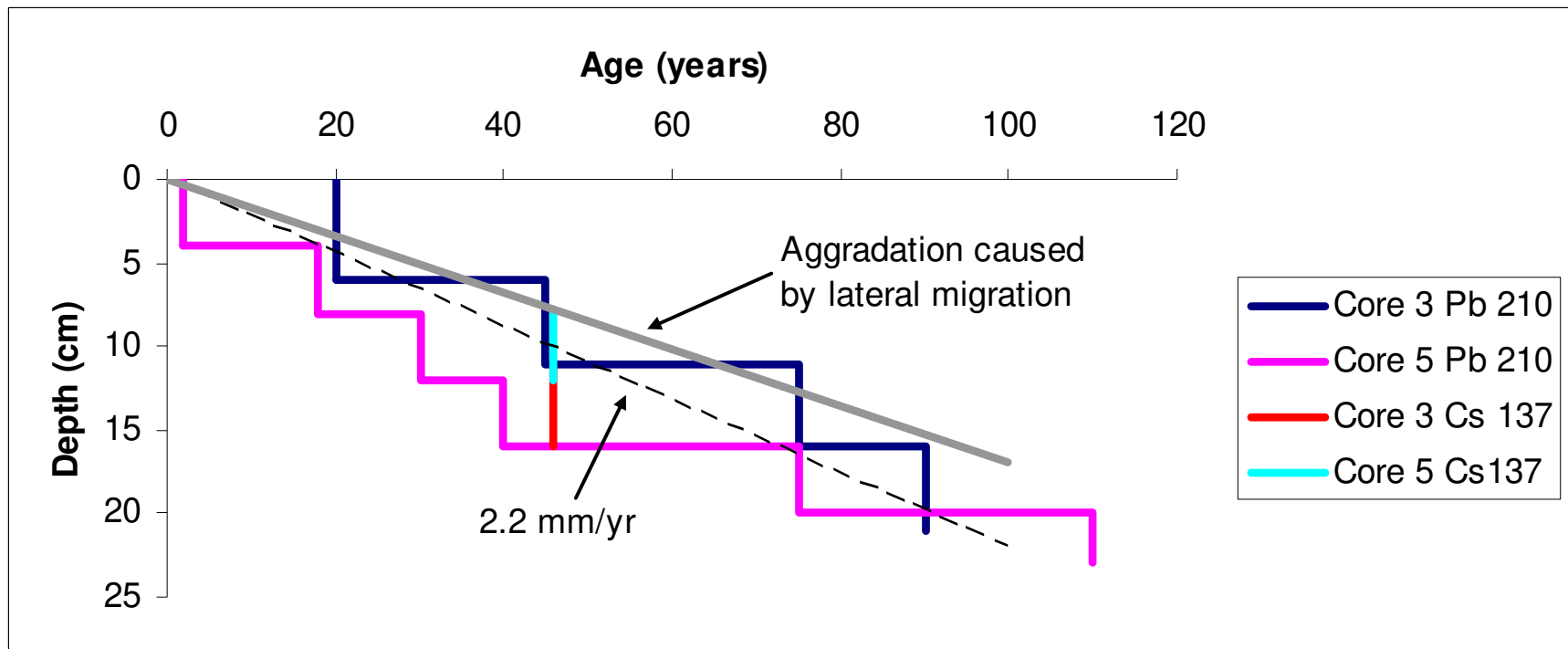
# “Apparent” Net Aggradation Rate



Lateral Migration Rate 1930-2005 ~  
4 cm/year Implies Point Bar  
Platform Aggradation Rate of ~ 2  
mm/yr



# Aggradation Related To Slow Bend Migration??



# Do Hg Data Support These Ages??

*(Hg > ~ 80 ppm from fine-grained deposits from 1930-1950)*

From Dated Core Samples

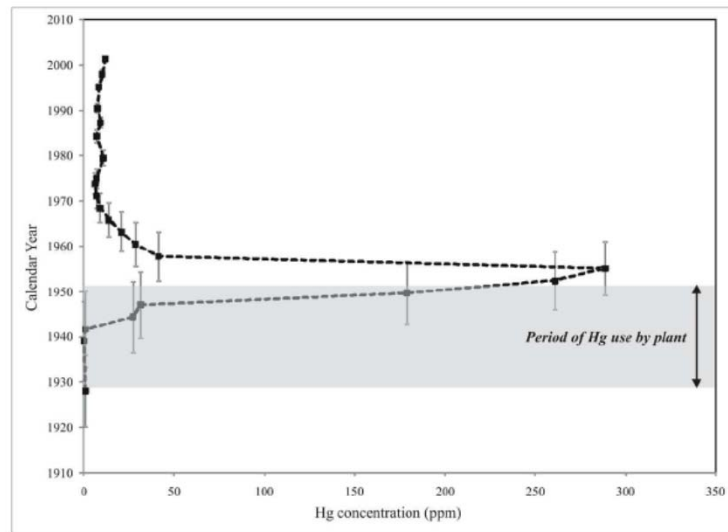
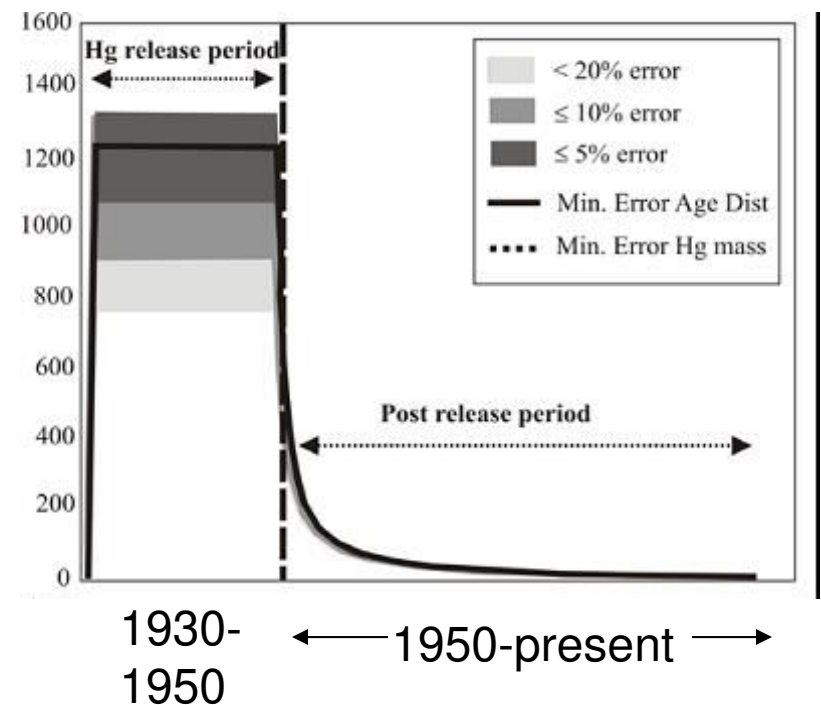


Figure 7. Mercury concentration (ppm) as a function of time for the core dated using Pb-210 and Cs-137 (Figure 6). The error bars present the upper and lower 99% confidence bands from the Pb-210 analysis. Shading indicates the dates of mercury use by the plant in Waynesboro.

Skalak and Pizzuto, in review

Hg Concentration on Suspended Sediment in Transport

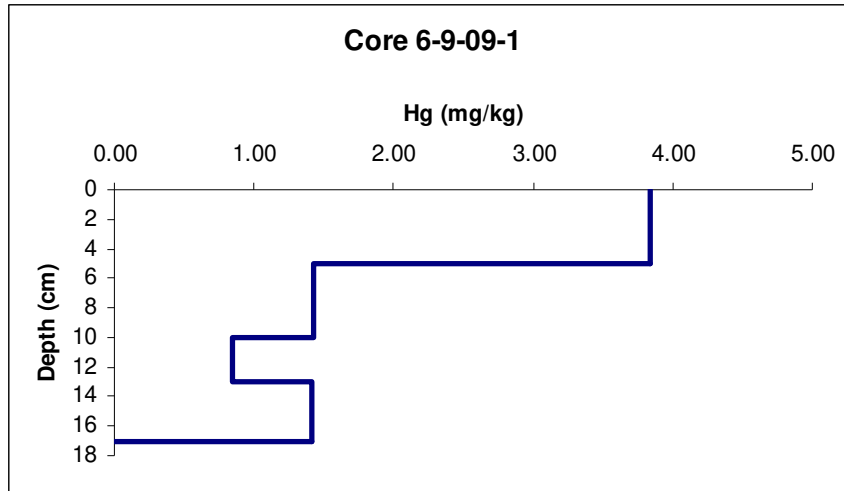
From Modeling Hg on Suspended Sediment



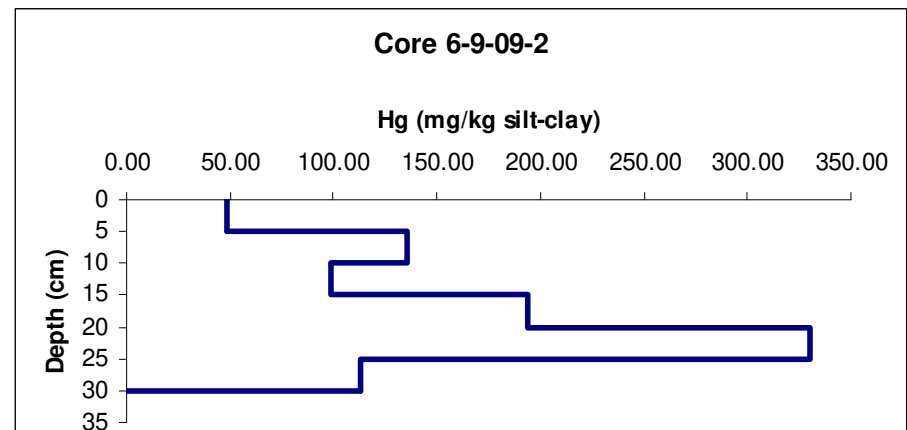
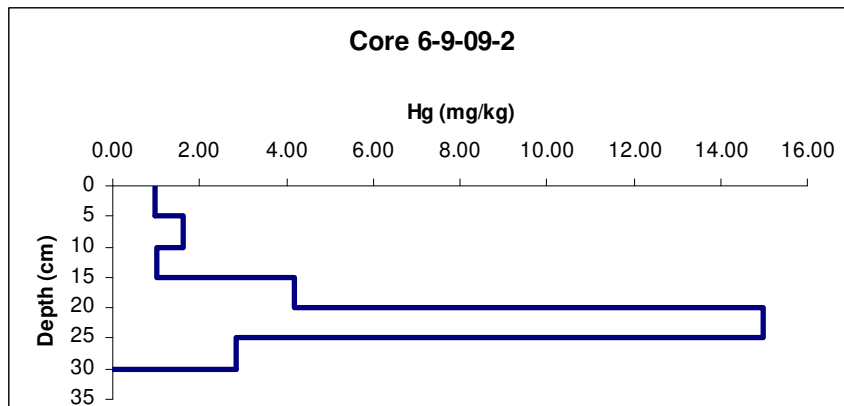
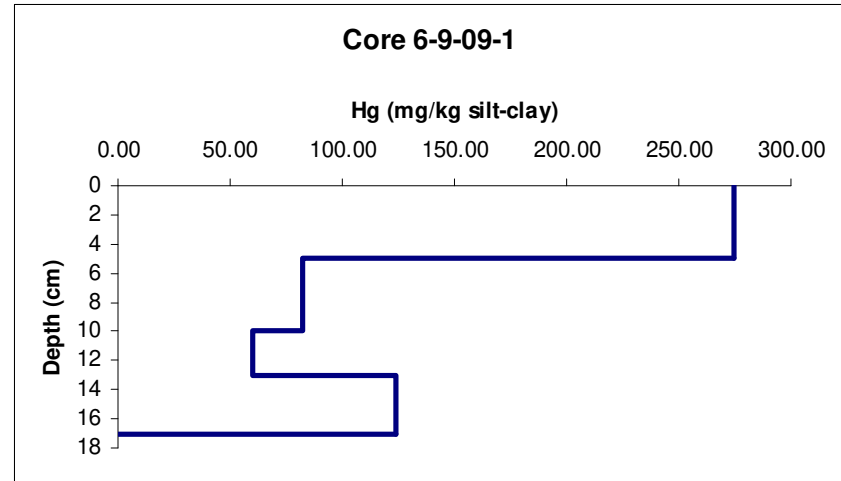
Skalak and Pizzuto, in prep

# Hg Analyses (from a different set of cores)

*Concentrations - Sand (~98%) and Mud (~2%)*

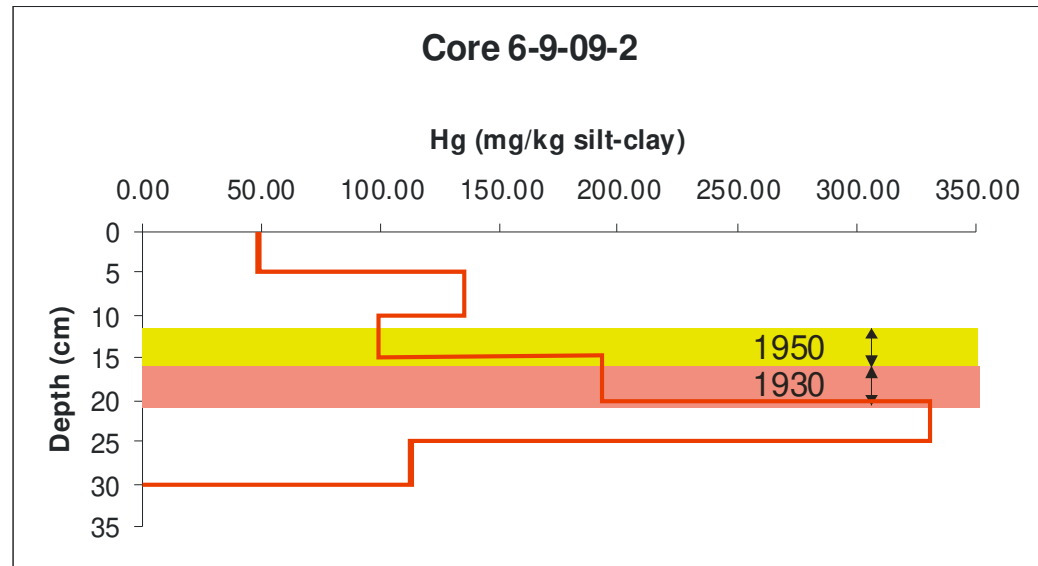
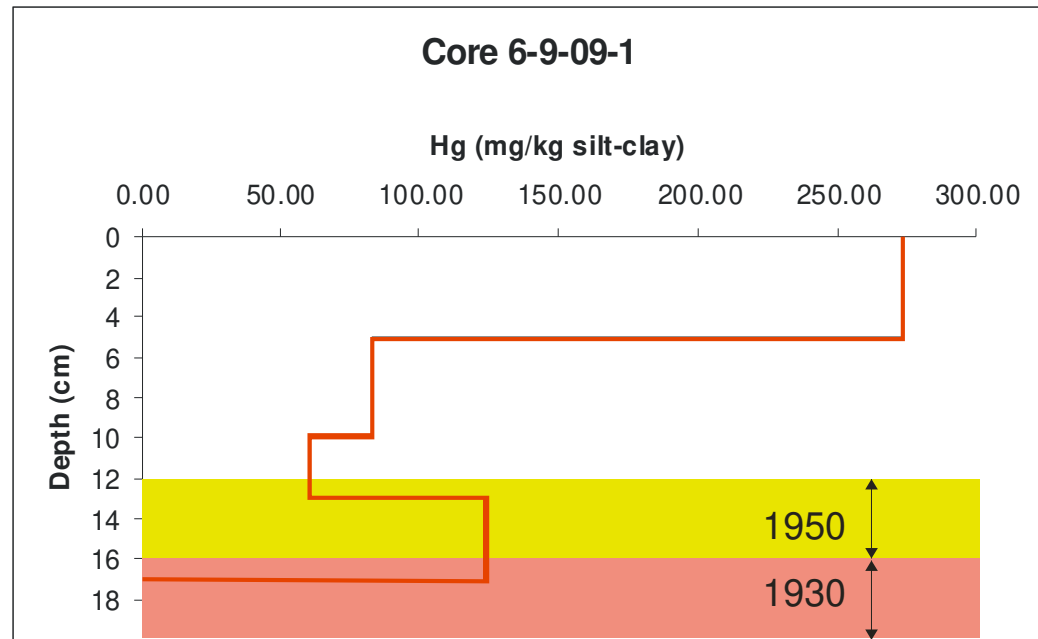


*Concentrations Normalized to % Mud*



*Hg concentrations in both cores MAY be high enough to date from release period, but difficult to compare analyses of bed material with analyses from finer sediments*

# Silt-Clay Normalized Concentrations with Release Period Estimate



# Summary

- We have successfully sampled and dated fine-grained sediments from 2 sites on the gravel bed of the South River
- Bed material from the two areas sampled is as much as 100 years old at depths of 25 cm!
- Hg in these deposits is likely to persist indefinitely
- Sediment ages suggest an apparent long term sediment accumulation rate of  $\sim 2$  mm/yr
  - Possibly related to slow lateral migration and point bar accumulation