Chesapeake Bay Seminar Series

Shelf sedimentary processes in the Adriatic Sea and beyond: potential linkages to Chesapeake Bay sediment dynamics

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Speaker Introduction by Professor Bill Dennison
Shelf Sedimentary Processes in the Adriatic Sea and Beyond: Potential Linkages to Chesapeake Bay Sediment Dynamics

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Motivation: Why study sediments?

Spatial and temporal scales of sedimentation

Radioisotope primer

Case study: the Adriatic Sea
• Po River flood event
• Formation and maintenance of shelf deposits
• Impact of human activities (dam construction)

Potential applications to Chesapeake Bay sedimentation
Motivation

- Nutrients and pollutants are delivered to the marine environment via particles
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• **Uniformitarianism**: “the present is the key to the past”
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• **Temporal** variations in sedimentation:
  - **Episodic** – flood events
  - **Seasonal** – changes in physical-oceanographic energetics and river discharge
  - **Decadal** – human-induced changes
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- Contrasting styles of sedimentation: **point-** (Po River) and **line-source** (Apennine Rivers) sedimentation

- Contrasting shelf sedimentary deposits: **delta** (Po River) and **subaqueous clinoform** (Apennine Rivers)
Long-term stratigraphy

Sediment transport

Sediment source

Coastal and shelf

Fluvial systems

Terrestrial geomorphology

Spatial Deeper water

Temporal Longer timescale

Upper slope and Submarine canyon

Lower slope and rise Submarine fan

Long-term stratigraphy

Preservation of strata

Short-term deposition

Creation of strata

Sediment transport

Dispersal of sediment

character of material

Schematic from B. Mullenbach
Scales of Research

Temporal
- seconds to months
- less than 100 years

Spatial
- less than 1 meter
- less than a few meters

Currents (mean and tidal), waves (surface and internal), gravity-driven sediment flows

Nepheloid layers

Physical and biological structures

Figure provided by B. Mullenbach
Sedimentological Toolbox

**Field:**
- Box, kasten coring
- Sedimentary structures (x-radiography)

**Laboratory:**
- Grain size
- Naturally occurring radioisotopes
Radioisotopes as Particle Tracers

Short-term deposition (~100 days)
- $^{234}\text{Th}$ ($t_{1/2} = 24.1 \text{ d}$)
- $^{7}\text{Be}$ ($t_{1/2} = 53.3 \text{ d}$)

Long-term accumulation (~100 years)
- $^{210}\text{Pb}$ ($t_{1/2} = 22.3 \text{ y}$)
- $^{137}\text{Cs}$ ($t_{1/2} = 30.7 \text{ y}$)
Atmospheric Production: $^7\text{Be}$, $^{137}\text{Cs}$

Nitrogen Oxygen $^7\text{Be}$ (53.3 days) $^{137}\text{Cs}$ (30.7 y)
$^{238}\text{U}$-series Radioisotopes ($^{234}\text{Th}$, $^{210}\text{Pb}$)

$^{238}\text{U} \rightarrow ^{222}\text{Rn} \rightarrow ^{210}\text{Pb}$ (22.3 y)

$^{238}\text{U} \rightarrow ^{234}\text{Th}$ (24.1 d) $\rightarrow ^{210}\text{Pb}$ (22.3 y)

“Excess”

$^{238}\text{U} \rightarrow ^{234}\text{Th} \rightarrow ^{210}\text{Pb}$

“Supported”

$^{238}\text{U} \rightarrow ^{234}\text{Th}$

$4.5 \times 10^9$ y

$24.1$ d

$2.33 \times 10^5$ y

$8.3 \times 10^4$ y

$1590$ y

$3.83$ d

$22.3$ y

stable
Radioisotopes as Particle Tracers

Short-term deposition (~100 days)
- $^{234}\text{Th}$ ($t_{1/2}=24.1$ d): produced in water column
- $^{7}\text{Be}$ ($t_{1/2}=53.3$ d): indicator of terrigenous sediment

Long-term accumulation (~100 years)
- $^{210}\text{Pb}$ ($t_{1/2}=22.3$ y): used to estimate 100-y accumulation rates
- $^{137}\text{Cs}$ ($t_{1/2}=30.7$ y): independent check on $^{210}\text{Pb}$-derived rates
Case study: Adriatic Sea
Winds and Circulation

J. Doyle, J. Pullen  NRL-Monterey

Bora

Surface Circulation
Winds
Circulation
Gyre

Scirocco

Artegiani et al. (1997)

Figure courtesy of Rich Signell, SACLANT/USGS

J. Doyle, J. Pullen  NRL-Monterey

Figure courtesy of Rich Signell, SACLANT/USGS
Distributaries: Percent of Average Suspended Sediment Load (Nelson, 1970)

**Total = 15x10^6 t/y**

- Goro = 8%
- Donzella = 11%
- Maistra = 1%
- Tolle = 7%
- **Pila = 74%**

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**Total: 30x10^6 t/y**

<table>
<thead>
<tr>
<th>River</th>
<th>Load</th>
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<tbody>
<tr>
<td>Metauro</td>
<td>0.7 (x10^6 t/y)</td>
</tr>
<tr>
<td>Chienti</td>
<td>1.4</td>
</tr>
<tr>
<td>Aso</td>
<td>0.3</td>
</tr>
<tr>
<td>Tronto</td>
<td>1.1</td>
</tr>
<tr>
<td>Pescara</td>
<td>1.1</td>
</tr>
<tr>
<td>Biferno</td>
<td>2.2</td>
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Frignani et al., in press
River Hydrographs and Waves

Figure provided by Andrea Ogston
(modified from Fain et al., in press)
Flood Sediment Characteristics

Po River

Base of flood layer?

Physical Stratification

Uniform \(^{7}\)Be Activities

Fine Grain Size

Eel River

\(^{7}\)Be (dpm/g) \(^{210}\)Pb\(_{xs}\) (dpm/g) Clay (wt %)

Station U70

ND

Figure modified from Sommerfield et al., 1999
December 2000
• Uniform 7Be profile indicates rapid deposition
• Depth of 234Th ($t_{1/2}=24.1$ days) extends below 7Be ($t_{1/2}=53.3$ days)
• Depth of 7Be corresponds with coarse silt layer in x-radiographs

June 2001
• 7Be decays with depth as a result of mixing
• 234Th penetration depth significantly less than 7Be
2000 Flood Deposit

Coarse Silt Layer – $^7$Be penetration depth

Base of flood deposit

Figure by Rob Wheatcroft
Po: deposit adjacent to river mouth; quiescent

Eel: deposit offshore and downstream of river mouth; energetic
Flood Signature in $^{210}$Pb Profiles

- **Clay Content (Weight %)**
- **Depth (cm)**
- **Total $^{210}$Pb Activity (dpm/g)**

- **2000 Flood**
- **D18**

- **Clay content**
- **clay-normalized $^{210}$Pb activity**
Sediment Accumulation near the Po Delta

- **Total $^{210}$Pb Activity (dpm/g)**
  - 0.1 0.5 1.0 5.0 0 50 100 150 200 250
  - Depth (cm)

- **Total $^{137}$Cs Activity (dpm/g)**
  - 0.1 0.5 1.0 5.0 0 50 100 150 200 250
  - Depth (cm)

- **Grain Size (weight %)**
  - Sand
  - Silt
  - Clay

- **X-radiograph**
  - Depth (cm)

- **Chernobyl? (1986)**
  - 62.5 mm/y
  - 56.7 mm/y

- **Depth (cm)**
  - 0 15 30
Appearance of Chernobyl Radiation in Po River $^{137}$Cs Profiles
Sediment Accumulation – South of Po Delta

**J25**
- Total $^{210}$Pb Activity (dpm/g)
- Grain size (weight %)
- Depth (cm)
- Rate: 7.9 mm/y

**Q15**
- Total $^{210}$Pb Activity (dpm/g)
- Grain size (weight %)
- Rate: 3.3 mm/y
Shelf Sedimentary Deposits

Delta Plain  Delta Front  Prodelta

Accumulation Rate

Limit of sediment supply

Modified from Walsh et al., 2004

http://gulfsci.usgs.gov/missriv/aerials.html
Deltas and Clinoforms

Limit of sediment supply

Sea-level location for shelf clinoforms

Sea-level location for river deltas

Delta Plain
Topset
Delta Front
Foreset
Prodelta
Bottomset

Accumulation Rate

Physical limit on accumulation

Modified from Walsh et al., 2004
Deltas and Clinoforms

1) Equal Sediment Supply

Delta | Clinoform | Mid-shelf mud | Delta
Increasing Oceanographic Energy

2) Equal Oceanographic Energy

Mid-shelf mud | Clinoform | Delta
Increasing Sediment Supply

Sea-level location for shelf clinoforms

Sea-level location for river deltas

Modified from Walsh et al., 2004
**Timing of Floods and Storms**

**Po River:**
- Large river basin (70x10³ km²)
- Relatively low energy
- River flow and storms not correlated

**Apennine Rivers:**
- Small river basins (0.5-3.3x10³ km²)
- Relatively low energy
- River flow and storms somewhat correlated

**Eel River**
- Small river basin (9x10³ km²)
- Relatively high energy
- River flow and storms correlated
Across-shelf Trend near the Tronto River

Figure provided by Anna Correggiari
Across-shelf Trend near the Chienti River

Figure provided by Anna Correggiari
Anthropogenic Influence

- Increase in dam construction on Apennine Rivers following WWII led to a decrease in sediment supply and accumulation rates over the last ~50 years.
- Observed in $^{210}$Pb profiles and by comparing $^{210}$Pb and $^{137}$Cs rates.
- Contrasts with Eel River observations, where deforestation and an increase in precipitation led to an increase in sediment supply and accumulation rates.
How can these tools be applied to Chesapeake Bay sedimentation?
Recent Chesapeake Bay Floods

Figure from Eyes on the Bay website (http://mddnr.chesapeakebay.net/eyesonthebay/rainy_days.cfm)

Picture from IAN Image Library (http://ian.umces.edu/imagelibrary/)
Other Applications to Estuarine (Chesapeake Bay) Sedimentation

• Sediment source ($^{234}$Th/$^{7}$Be ratio)

• Suspended-sediment age or fraction of new sediment in suspension ($^{7}$Be/$^{210}$Pb ratio)

• Changes in sedimentation related to land-use changes
Summary

1. Naturally occurring radioisotopes are good tracers of sedimentation on time scales ranging from events to seasonal and decadal changes.

2. Flood sediment has a distinct signature (uniform $^7$Be, low $^{210}$Pb activities, fine grain size, physical stratification) that can be recognized in the seabed.

3. Sedimentary deposit formation and maintenance is largely controlled by event sedimentation and the physical oceanographic energetics at the time of emplacement.

4. Humans can have a big impact on sedimentary processes.
Acknowledgements

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Questions?