SHALLOW STRATIGRAPHIC CONTROLS ON SURFACE WATER-GROUNDWATER MIXING AND GEOCHEMICAL FATE IN THE BENTHIC ZONE OF AN ESTUARY

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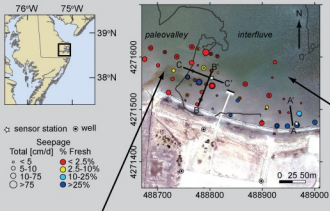
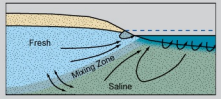
HOW DOES STRATIGRAPHY INFLUENCE SHALLOW SURFACE WATER-GROUNDWATER MIXING AND THE FATE OF REDOX-SENSITIVE SOLUTES DISCHARGING TO AN ESTUARY?

1 SITE: INDIAN RIVER BAY, DELAWARE (USA)



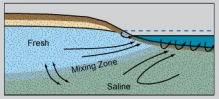
Left: Fresh groundwater discharges rapidly near the shoreline between paleovalleys (in interfluves) and broadly along paleovalley margins farther from shore (seepage data courtesy of Chris Russoniello). Transects for shallow benthic profiles target the interfluve and paleovalley margins.

Interfluve Conceptual Model

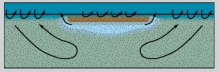


Above: Shore-perpendicular view beneath interfluve. Fresh groundwater discharge is greatest near shore.

Paleovalley Conceptual Model



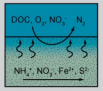
Left: Shore-perpendicular view beneath paleovalley. An impermeable peat layer fills the top of the paleovalley and prevents fresh groundwater discharge near shore.



Left: Shore-parallel view. Fresh groundwater upwells along paleovalley margins farther offshore.

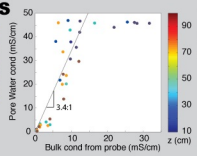
Shallow stratigraphy can affect geochemical processes near the sediment-water interface through three mechanisms:

1) vertical fluid fluxes (net and gross)
2) deeper groundwater chemistry (associated with lateral flow paths)
3) local, shallow reactions



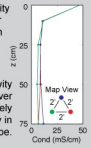
2 METHODS: RESISTIVITY PROBE, PORE WATER SAMPLES, & SEEPAGE METERS

Above: Resistivity probe for profiling bulk conductivity along transects.



Left: Pore water conductivity was generally 3.4x greater than bulk conductivity from probe measurements.

Right: Bulk conductivity profiles varied laterally over small scales (~2'), likely reflecting heterogeneity in porosity and sediment type.



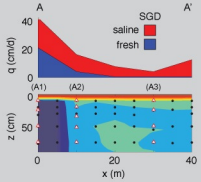
Left: Pore water samples were extracted from steel tubing with a screened interval of 3 cm using a peristaltic pump.

Right: Seepage meters were deployed at 10-m intervals along transects.

Right: Bags were pre-filled with 2L of water and deployed for 2 hours. Final masses and conductivities were recorded to determine fluxes of fresh and saline groundwater.

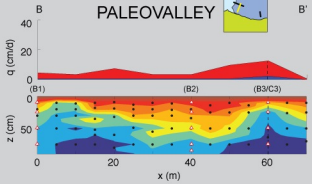
3 BENTHIC FLUXES AND CHEMISTRY

INTERFLUVE



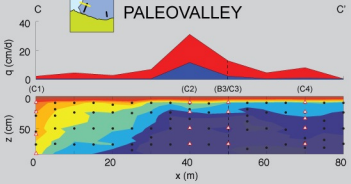
INTERFLUVE: Nearshore, fresh groundwater discharge is greatest, and bulk conductivity is low at each sampling depth. The sharp gradient in bulk conductivity at the sediment-water interface indicates that vertical transport is dominated by advection. Fresh groundwater discharge decays rapidly with distance offshore (10-20 m), and bulk conductivity increases at all depths.

PROXIMAL TO PALEOVALLEY



PALEOVALLEY (SHORE-PERPENDICULAR): Discharging groundwater is saline, and shallow bulk conductivity is generally elevated. Broad vertical gradients in conductivity suggest that diffusion and dispersion strongly influence transport across the sediment-water interface. No consistent trends in discharge or bulk conductivity occur parallel to the paleochannel margin.

PROXIMAL TO PALEOVALLEY

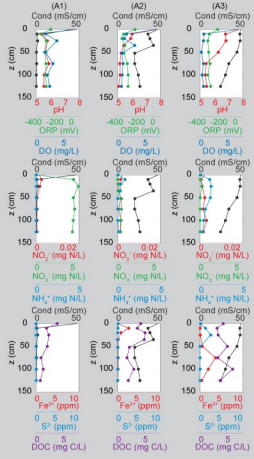


PALEOVALLEY (SHORE-PARALLEL): Within shallow paleovalley deposits (peat), bulk conductivity is elevated, groundwater discharge rates are low, and diffusion dominates transport across the sediment-water interface. Maximum fresh groundwater discharge occurs beyond the paleovalley margin, where shallow bulk conductivity is low. Moderate vertical gradients in bulk conductivity near the margin suggest that advection and dispersion both influence transport.

INTERFLUVE: The nearshore zone of rapid upwelling lacks vertical gradients in pH or redox potential--pH gradients develop farther offshore. DO generally declines with offshore distance.

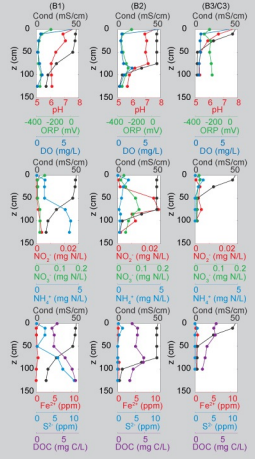
Nitrate is highest nearshore and is transported conservatively there. Offshore, shallow ammonium increases, likely due to decomposition of organic matter in marine sediments.

Iron and sulfide are low nearshore and increase offshore due to microbial respiration. Iron is elevated in offshore brackish groundwater where sulfide is low. DOC is generally higher offshore.



Local increases in ammonium and sulfide are likely due to sulfate reduction and anaerobic oxidation of organic matter.

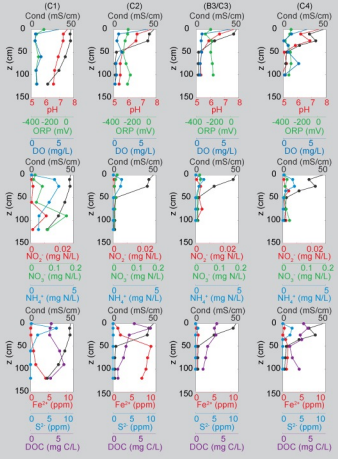
Local increases in dissolved iron may be due to microbial oxidation of organic matter.



PALEOVALLEY: Pore water near peat is generally more reducing and basic.

Nitrate is much lower near palleovalley deposits (Transects B/C) than in the interfluve (Transect A). Ammonium is greatest near peat deposits and shallow decomposing marine organic matter.

Sulfide is great near peat layers (nearshore and beneath paleovalley). Iron is locally elevated in fresher terrestrially-derived groundwater where sulfide is low. DOC is greatest near peat layers (nearshore and within paleovalley).



CONCLUSIONS:

1) PALEOVALLEYS INFLUENCE THE RATE OF SUBMARINE GROUNDWATER DISCHARGE TO ESTUARIES AND THE BALANCE OF ADVECTIVE-DISPERSIVE TRANSPORT ACROSS THE SEDIMENT-WATER INTERFACE.
2) BETWEEN PALEOVALLEYS, RAPIDLY DISCHARGING GROUNDWATER TRANSPORTS NITRATE CONSERVATIVELY FROM THE TERRESTRIAL AQUIFER THROUGH THE BENTHIC LAYER TO THE ESTUARY.
3) IN PALEOVALLEYS, PEAT LIMITS ADVECTIVE SOLUTE TRANSPORT TO THE ESTUARY. PEAT MAY BE A LOCAL SOURCE OF DOC, AMMONIUM, AND SULFIDE.
4) BENEATH PALEOVALLEYS, GROUNDWATER FLOWS SLOWLY OVER LONGER DISTANCES, BECOMES MORE REDUCING, AND DISCHARGES DIFFUSIVELY NEAR PALEOVALLEY MARGINS OFFSHORE. THERE, AMMONIUM AND SULFIDE ARE TRANSPORTED NON-CONSERVATIVELY THROUGH THE BENTHIC LAYER BEFORE DISCHARGING TO SURFACE WATER.

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