Fluvial/Pond Environments, Features, and Identification
Time Scales of Fluvial Sedimentary Records

[extending the instrumented time period.....]

- Individual flood event
- Annual floods and seasons
- Decadal changes, human alterations, dams and such
- Historical post-Euro American settlement, climate
- Pre-European settlement, Native American
- Holocene climate
- Glacio-fluvial

Range in variability

Years

0.1  1.0  10  100  1,000  10,000  100,000
Modern geomorphic and watershed settings gives clues to where we expect to find deposition and sedimentary records.

“Base level” very important.
Erosion
Transfer
Deposition

Upland
Upland valley
Floodplain valley
Large River

Longitudinal Profiles

Magnitude

Distance downstream/drainage area

Texture of channel bed deposits and longitudinal profile

Fig. 2.6 Schematic diagram showing transitions in the fluvial system along a river profile. (Source: Mosley & Schumm 2001; reproduced with permission New Zealand Hydrological Society.)

From Perry and Taylor, 2007, Environmental Sedimentology, Chapter 2, Mountain environments by Jeff Warburton
Fig. 1.5 Hjulström’s (1935) graph showing the relationship between flow velocities and sediment grain size and the corresponding fields in which erosion, transport and deposition occur.

From Perry and Taylor, 2007 “Environmental Sedimentology”
Fig. 3.4 Continuum between principal planform types of rivers, illustrating the diversity of river channel types. Between the straight, meandering, anastomosed and braided types of planform are rivers that exhibit characteristics of at least two of these end-members. (After Bristow 1996.)
Alluvial vs. “Parent Material”

- Alluvial – formed by flowing water and deposited during recent times
- Rivers are called “alluvial” if the modern channel is surrounded (sides and bottom) by sediment that was deposited by modern channel processes (usually assumed to be the Holocene and Anthropocene...)
- Not all rivers are alluvial
- Important to know the difference between alluvial deposits and other types of deposition, including glacio-fluvial, glacio-lacustrine, and outwash
Alluvial deposits along a river

Modern point bar deposit along the Bad River, WI

Historical overbank vertical accretion deposits along the Bad River, WI
Parent materials along a river

Glacio-fluvial sand and shoreline deposits along the Bad River, WI (G

Glacio-lacustrine clay along the Bad River, WI (Marquette re-advance)
Where do we expect sedimentation or erosion?
Geomorphic process and related deposits

**Fig. 1.11** Processes and deposits associated with rock and sediment movement along a continuum of decreased concentration and increased internal disaggregation. (Adapted from Stow 1986.)

From Perry and Taylor, 2007, Environmental Sedimentology
Dominance of sediment transfer processes

Fig. 2.13 Schematic diagram showing the changing dominance of different sediment transfer processes with distance from the crater following the 1980 eruption of Mount St. Helens. Variation in dominant grain-size (mm) of the deposits with distance away from the crater is also shown. (Source: Scott 1988; Courtesy of U.S. Geological Survey.)

Gravity flows vs. fluvial flows

Fig. 2.10 Classification of mass movements and flows on steep slopes as a function of solid debris fraction and material type. (Source: Coussot & Meunier 1996; redrawn from Earth Science Reviews, Coussot, P. & Meunier, M. (1996) Recognition, classification and mechanical description of debris flows, 40, 209–27, with permission from Elsevier.)
Colluvium, slide, rockfall — a loose jumbled collection of unsorted rock and soil that collects at the foot of a steep slope

Colluvial boulder berm – poorly sorted, angular, coarse fragments

Old colluvial terrace exposed by stream erosion, Great Smoky Mountains, TN.
Debris (Sediment Gravity) Flows

- Moving loose mass of mud, sand, rock, soil, water, and air
- Moves under influence of gravity
- Poorly sorted mix of particle sizes that move independently within the flow
- 50% sand sized particles and larger
- Travel at <1 ft/yr to 100 mi/hr

http://geology.com/articles/debris-flow/
Debris (Sediment Gravity) Flows

Fig. 3.22 Mechanics of idealized uniform debris flow.

Fig. 3.23 (a) Idealized deposit of a debris flow. (b) Deposits of debris flows and turbulent water flows exposed in an ephemeral fan-head channel bank. (c) Boukley top to a debris flow that caused the demise of the house.
Mudflows

• Less coarse and more cohesive than a debris flow
• Large boulders are transported by matrix strength
• Lahar is a type of mudflow or debris flow that originates from volcano slopes
• Mudflows grade into hyperconcentrated streamflow where boulders are no longer able to be carried on top by matrix strength

Photo by AlexeyKZ [http://www.panoramio.com/photo/8882900](http://www.panoramio.com/photo/8882900); Mud Volcano, Sychliar, Azerbaijan
Water flows and sediment

- Suspended vs. moved along the bed
- Vertical vs. lateral accretion
- Channel vs. overbank

For particles in suspension:

Advection: passive transport of particles by the moving fluid

Diffusion: molecular agitation and small scale turbulent motions that move the particle randomly with respect to the overall motion of the fluid

Settling: vertical falling of particles through fluid under the action of gravity

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From Perry and Taylor, 2007, Environmental Sedimentology
Floodplain environments and sedimentary features

Fig. 1.1 Block diagram of landforms associated with a meandering river and its floodplain. Adapted from Allen (1965), and other sources. (Brown, 1997)
Typical “fining upwards” floodplain sequence with gravel/cobble at base

Channel bed deposits – imbricated boulders

“traditional hydraulics”

“New age energy vortex” in Oak Creek canyon, Sedona, AZ
Repeating channel geomorphic units

Figure 8.3 Riffle-pool formation in meandering alluvial rivers. Accentuation of erosion on the concave bank of meander bends produces pools. Riffles form at the inflection points between bends, where sediment is deposited in shallower parts of the channel. Point bars occur on the insides of the bend as secondary flow moves sediment onto the bar surface. Down-bar (around the bend) gradation in grain size is commonly observed on these bar surfaces. Oparau River, New Zealand. Photograph: K. Fryirs.
Lower stage plane beds – bedload sheets

![Image](bridge_2003)

**Fig. 4.7** (a) Low-relief bedwaves (bedload sheets) on gravel bar. Flow is from right to left. (b) Field example of deposits of a bed-load sheet or low-height dune (flow from left to right). Above lens cap is 80 mm of open-framework gravel that fines upward. The basal gravels are imbricated pebble clusters. The overlying finer gravels show pseudomation, indicating deposition on the lee face of the bedload sheet/low dune.

**Fig. 4.9** Pebble cluster with imbricated grains. Flow to right. Photo courtesy of Jim Best.

Bridge, 2003
Water flows, bedforms, and sedimentary structures

From Perry and Taylor, 2007, Environmental Sedimentology
Channel Bedforms and Structures

• Features of transverse bedforms – dunes and ripples

Fig. 4.1 Morphological features of transverse bed forms. Flow in x direction. (From Allen 1982.)
Channel Bedforms and Structures

- Features of dunes and ripples

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Simons et al., 1965
Dunes – height and length a function of water depth

Fig. 4.13 Height and length of dunes as a function of water depth, $d$ (redrawn from Allen 1982, by Leeder 1999).

Bridge, 2003
Fig. 4.49 Internal structures associated with chutes and pools (cp), antidunes (a), and upper stage plane bed (p), resulting from a reduction in flow velocity during aggradation (from Alexander et al. 2001). Top panel is parallel to flow direction (right to left), and is 1 m long. Bottom panel is normal to flow direction, and is 0.5 m across.
Turbulent flow over ripples and dunes

**Fig. 4.23** Variation in texture of cross strata due to passage of superimposed bed waves.

Bridge, 2003
Cross stratification example

Harms and Fahnestock, 1965

Fig. 9.—Stratigraphy and location of trenches at Vinton and Mesilla.
Point bar formation – lateral accretion

- Secondary flow around bends in meandering channels
- Lateral accretion as channel migrates
- Stacked sequences of gravel, sand, and silt
- Sequences angled toward direction of lateral progression
Sand stratification in a bar

Harms and Fahnestock, 1965

**Fig. 1.** Horizontally stratified sand (H) is overlain and underlain by small-scale trough cross-stratified sand (S). This sequence rests on large-scale trough cross-stratina (L). Section is perpendicular to current and is viewed from downstream. Ruler is 6 inches long.

**Fig. 2.** Same deposit as figure 1 alter sectioning parallel to the current direction. The distinct laminae in the horizontal strata have little to no dip. Upstream toward upper left. Ruler is 6 inches long.
Point bar deposits in sandy channels

Fig. 5.56 (a) Unit bar on a point bar of the Congaree River, South Carolina. Flow from right to left. The lee face of the unit bar is at the angle of repose. (b) Internal structure of the unit bar is composed mainly of medium-scale cross strata, formed by the dunes migrating over the unit bar. Angle-of-repose cross strata associated with the avalanche face of the unit bar occur only at the margin of the unit bar.
Point bar deposits in cores

Lateral accretion point bar deposit, Wolf River, WI
Typical flood sequences

**Fig. 4.54** Examples of depositional sedimentary sequences produced by water flows that change in time (over a single flood) and in space. Sequences are different for fine sands to muds, very coarse sands to silts, and pebble gravels to fine sands. Deposition is caused mainly by decreasing sediment transport rate (j) in the flow direction (x). This is also responsible for change in bed forms and sedimentary structures. Vertical changes in grain size and sedimentary structures are caused by temporal changes in sediment transport rate over the passage of a flood. Upper parts may be eroded subsequently. Thickness of flood-generated sequences is typically centimeters to meters.
Interpretation of paleo bankfull channels

Fig. 5.75 Sedimentological and wireline logs from the Travis Peak Formation, N. Appleby Field, with revised interpretation (redrawn from Tye 1991, by Bridge & Tye 2000). Reprinted by permission of the AAPG whose permission is required for further use. Recognition and proper interpretation of bar-top deposits is critical to accurate estimation of bankfull channel depth and channel belt width. Bankfull channel depth can also be estimated from the mean and standard deviation of medium-scale cross-set thickness.

Bridge, 2003
Buried channel deposit in cohesive overbank vertical accretion
Flood plains – zooming in

- marshes
- lakes
- drainage channels
- wind blown sediments

- active and abandoned channels
- crevasse channels and splays
- levees

Bridge, 2003
Floodplain building

- Mainly vertical accretion
- Not always constant deposition, especially in active channel area, erosion, ice
- Spatial extent variable, especially in forested floodplains
Flood deposits

Kickapoo Floodplain Scour and Deposition Produced by July 1-2, 1978 Flood (near Steuben, WI) 16,500 cfs, 100-yr

2 July 1978, 1 mi south of Readstown

Jim Knox photos
Section 25  T3N R2W, Little Platte River – Impact of 1 June 2000 Flood
Date of photos: 12 June 2000

Jim Knox photos
Historical Change in Flood Power, L. Platte River Tributary, SW Wisconsin

- post-1820 agricultural sedimentation
- Late Holocene channel sediment
- pre-agricultural surface soil
- boulders transported by August 2, 1972 flood

Jim Knox photos
Fine sediment (clay and silt deposited on the floodplain of the River Teme (tributary to the River Severn). These deposits were about 1 cm thick and located about 100 m from the channel. Tube is used to measure sedimentation.
Thick sandy overbank deposits near channel bank, River Ouseneear, York. Deposits were about 20 cm thick.
Woody debris and vegetation become part of the sediment record in overbank areas. Preservation is dependent on the oxidation state of the deposit. If above the water table and in sandy deposits, the woody material may decompose in decades.
Levees and crevasse splays

Figure 1. In the avulsion system, the levee of the river is breached (a), and water carrying sediments flows out onto the floodplain, forming crevasse splay deposits (b). Subsequently, a new river channel can be formed; however, the spread sediments can remain in the floodplain (c). Adapted from Assine (2003).

http://www.scielo.br/img/revistas/rbcs/v37n5/01f01.jpg
Levees and crevasse splays

Fig. 6.8 (a, b) Typical sandy levee/crevasse splay deposits showing planar strata overlain by small-scale cross strata (climbing-ripple type) with soft-sediment deformation structures. Brahmaputra River, Bangladesh. (c) Wedge-shaped sandstone bed (arrow), thinning to left, interpreted as a levee deposit. Devonian of New York State. (d) Channel margin with wedge of sandstone (levee deposit) thinning away to the right (arrow). Siwaliks of Pakistan.
Levees and crevasse splays

Halfway Creek crevasse splay 1938

- Thick sandy deposits over fine-grained vertical accretion deposits
- Planar beds but may also have cross strata from ripples/dunes across the surface
- Adjacent to active channel
Deltas and Alluvial Fans

Morphological classification of deltas based on the influence of river, tidal, and wave activity.

From Perry and Taylor, 2007, Environmental Sedimentology, Chapter 7, Delta environments by Peter French
Three types of deltas near Ashland, WI, Lake Superior

- Wave-dominated
- Fluvial-dominated
- Seiche-dominated
Delta anatomy

(Hakanson and Jansson, 2002)
Delta anatomy

From Perry and Taylor, 2007, Environmental Sedimentology, Chapter 7, Delta environments by Peter French
Sediment-rich delta
Deltaic environments of the Mississippi River

Fig. 7.11 Representation of delta lobe formation in the Mississippi delta. (Compiled and modified from E.C.F. Bird (2000) and Woodroffe (2003).)
Lacustrine sediment (Cohen, 2003, p. 187)

- Hi water content
- Mix of mineral and organic particles
- Varves represent seasonality of particle sources – repeated sequencing
- Laminae = < 1 cm
- Bed = < 1 cm

Figure 7.13. Late Pleistocene glaciolacustrine varves from the Severn River area, northern Ontario, Canada.
Lacustrine gyttja – eutrophic/mesotrophic lake

- High organic content
- High water content
- When exposed to air can shrink considerably
- Term gyttja confusing – typically used for organic-rich silts and clays
- Hakanson and Jansson, 2002 good reference
Erosion, transport, and sedimentation

Fig. 6.18. Erosion, transportation and deposition (= accumulation) velocities for different grain sizes. Possible values for various stages of consolidation, as given by the water content, are indicated (Postma 1967)
Impounded sediment, Neopit Millpond, Menominee Reservation, WI

Organic-rich silt/clay with very high water content over pre-dam peat (photo by Barb Lensch, NRCS) ~25% organic carbon
Balsam Row Impoundment, Wolf River, WI

CROSS SECTION T2

Fitzpatrick, 2005
Riparian wetland
Riparian wetland and wetland channel

Fort McCoy Stillwell Cr at 16th Ct cores 2008
Beaver dams – low sediment supply
North Shore Lake Superior, MN
Beaver pond deposits – fine-grained, low sedimentation rate, varying densities from wetting and drying.

Grand Portage Creek, MN North Shore Lake Superior
Beaver dams – high sediment supply
Beaver dams – high sediment supply

Large dumps of sand – vertical accretion – over wetland organic soils
Clumps of brushy material

_Bark River, WI South Shore Lake Superior_
Alluvial fans
Typical Valley Types in the Upper Great Lakes Region

- **Confined**
  - Confined headwater streams, potential large sediment source from slopes and incision, no sediment storage

- **Entrenched**
  - Unconfined valleys, entrenched meanders, high potential for landslides, limited sediment storage

- **None**
  - No valley, headwater channels, low slope, minimal sediment source

- **Alluvial**
  - Unconfined valleys, alluvial meanders, episodic sediment delivery, sediment storage

Longitudinal profile

Distance from headwaters to mouth
Tunnel valleys
Stop 1

Stop 2

Boardman River valley influenced by glacial-fluvial and glacio-lacustrine activity

Tunnel Valley: Large, Long, U-shaped valley originally cut under the glacial ice near the margin of continental ice sheets. Form by subglacial erosion from large volumes of meltwater
Figure 1 (a) Paired terraces. (b) Unpaired terraces. The terraces are numbered in the order in which they formed. Arrows indicate the lateral migration of the channel across its floodplain. Adapted from Huggen (2003).

Charlton, 2008
Terrace development

Figure 1.—Block diagrams illustrating the stages in development of a cut terrace (diagrams A and B) and a fill terrace (C, D, and E).

Powder River examples (Leopold and Miller, 1954)
Figure 5. — Generalized topographic and stratigraphic relationships in alluvial fills of the river valleys in eastern Wyoming.
Clear Creek cross section

Figure 12. — Cross section of valley of Clear Creek at Thomas's ranch near Ucross, Wyo. The three alluvial terraces can be seen.

Leopold’s basis for three terraces in western rivers (Leopold and Miller, 1954)

Figure 13. — Changes in content of calcium carbonate and in pH with depth in the Kaycee terrace alluvium at Thomas's ranch near Ucross Wyo. The stratigraphic units are shown in the profile at the right of the figure.
Criteria for correlating terraces

- Three terraces – Kaycee, Moorcroft, Lightning
- Terrace morphology
- Continuity
- Height
- Physiographic relation to other terraces
- Stratigraphy of underlying fills
- Relation to buried soils, unconformities, fossil zones, and other markers (maybe volcanic ash in other areas)
- May be underlain by different units, but similar surface age, soil development

Leopold’s basis for three terraces in western rivers
(Leopold and Miller, 1954)
Other interpretive features

- Continuity of stream process (all cutting or filling) – longitudinal extent, cause?
- Paired heights on either side of valley – less lateral migration, quick downcutting
- Progressive downcutting – no pairing, irregular heights more common
- Slope wash profiles give indication of minimum stream elevation

Leopold and Miller, 1954
North Fish Creek
Upper main stem
Valley cross section

DISTANCE ACROSS VALLEY (METERS)

EXPLANATION

- Sand
- Gravel
- Soil development

APPROXIMATE ALTITUDE (METERS)

Location
Fluvial terrace look a-likes

Grand Portage Creek, MN
Terrace deposits

Glacio-lacustrine diamicton
Grand Portage Creek, MN

Glacial Lake Algoma beach deposits over Glacial Lake Nipissing lacustrine deposits
Pigeon River, MN
Accelerated floodplain deposition

• Reconstruct long-term sediment loadings based on overbank sedimentation rates
• Combines channel position changes, radiometric dating, identification of buried soils

[Photo: photo by Bob Hansis]
Sand Creek, Kickapoo River Watershed (Happ, 1940)

Mill Creek, 10 mi^2, Platte River Watershed

Halfway Creek, 2005

Little Platte River, 150 mi^2

Jim Knox photos

c. 3100 yr BP

c. A.D. 1830
Tracking paleochannels – Driftless Area, SW WI

Fig. 3.14 Historical changes in channel morphology and hydraulics on the Shullsburg Branch tributary, Galena River system, USA. Accelerated overbank sedimentation from the beginning of Euro-American settlement in the 1820s increased progressively, resulting in increases of bank heights and facilitation of deeper flows with high shear stresses that led to bank erosion and channel expansion. After about 1950, overbank sedimentation decreased owing to smaller and less frequent floods as a result of improved upland land conservation practices. (After Knox 2001, fig. 9.)
Humans as geomorphic agents

_Fur Trade Village and fields – Grand Portage National Monument, MN 1700s to 1920s_

_Copyright © Robert Pavlowsky 2002_

_Mine tailings, 1890-1930, Blue River, Wisconsin_
Hydraulic mining sediment

- High quartz content
- Spheroidal shaped pebbles
- Sand lenses
- No cementation
- Some imbrication
- Some cross bedding
- Thick deposition
Channelization, Channel Evolution, and Floodplain Deposition

Stage I. Sinuous, Premodified

Stage II. Constructed

Stage III. Degradation

Stage IV. Degradation and Widening

Stage V. Aggradation and Widening

Stage VI. Quasi Equilibrium

$h_c = \text{critical bank height}$

$h = \text{direction of bank or bed movement}$

$h < h_c$

$h > h_c$
The Boardman River is not just poetry in motion; it has also played an important part in the economic development of the Grand Traverse area. Spanning over 130 miles, the Boardman River is the largest tributary leading into Grand Traverse Bay. During Traverse City’s logging years, log drivers used the Boardman River to float timber down to the mill. The Boardman River is named for Horace Boardman, who built the first sawmill on Kid’s Creek. It is also the birthplace of one of the most famous fishing flies in history. “The Adams,” a fishing fly developed in 1922, was developed specifically for catching the big brown trout and brook trout of the Boardman River.
Splash dams – a common occurrence on streams used for log drives

INTRODUCTION

Between 1884-1956, splash dams in Oregon were considered a practical and efficient means to transport timber to downstream mills. A splash dam would span the width of the stream, logs would be placed behind rising waters and then released by either large gates or dynamite (Photo 1). Anecdotal evidence has claimed that historic splash dam freshets considerably altered stream characteristics and salmon habitat (Lichatowich, 1995). In particular, the high velocity of water and logs scoured streams to bare bedrock. However, few scientific studies have examined whether a stream’s environmental legacy of splash dam practices can be detected today, nearly 50 years after its outlaw (Sedell, 1995). Splash dams were considered temporary structures, and
Questions?

Boardman River, Keystone Impoundment, Stop 1