Fluvial sequence stratigraphy

Sequence: autogenic fan succession
(Heward, 1978)
Smooth sequence boundaries produced by lateral migration of valleys due to slow rates of base level change

• After Holbrook (2011)
<table>
<thead>
<tr>
<th>Grp</th>
<th>Time scale of process (a)</th>
<th>Examples of processes</th>
<th>Instantaneous sedimentation rate (m/ka)</th>
<th>Fluvial, deltaic depositional units</th>
<th>Rank and characteristics of bounding surfaces</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$10^{-6}$</td>
<td>Burst-sweep cycle</td>
<td></td>
<td>Lamina</td>
<td>0th-order, lamination surface</td>
</tr>
<tr>
<td>2</td>
<td>$10^{-5}$ - $10^{-4}$</td>
<td>Bedform migration</td>
<td>$10^5$</td>
<td>Ripple (microform)</td>
<td>1st-order, set bounding surface</td>
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<tr>
<td>3</td>
<td>$10^{-3}$</td>
<td>Bedform migration</td>
<td>$10^5$</td>
<td>Diurnal dune increment, reactivation surface</td>
<td>1st-order, set bounding surface</td>
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<tr>
<td>4</td>
<td>$10^{-2}$ - $10^{-1}$</td>
<td>Bedform migration</td>
<td>$10^4$</td>
<td>Dune (mesoform)</td>
<td>2nd-order, coset bounding surface</td>
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<tr>
<td>5</td>
<td>$10^0$ - $10^{-1}$</td>
<td>Seasonal events, 10-year flood</td>
<td>$10^{2-3}$</td>
<td>Macroform growth increment</td>
<td>3rd-order, dipping 5-20° in direction of accretion</td>
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<tr>
<td>6</td>
<td>$10^2$ - $10^3$</td>
<td>100-year flood, channel and bar migration</td>
<td>$10^{2-3}$</td>
<td>Macroform, e.g., point bar, levee, splay immature paleosol</td>
<td>4th-order, convex-up macroform top, minor channel scour, flat surface bounding floodplain elements</td>
</tr>
<tr>
<td>7</td>
<td>$10^3$ - $10^4$</td>
<td>Long-term geomorphic processes, e.g., channel avulsion</td>
<td>$10^0$ - $10^1$</td>
<td>Channel, delta lobe, mature paleosol</td>
<td>5th-order, flat to concave-up channel base</td>
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<tr>
<td>8</td>
<td>$10^4$ - $10^5$</td>
<td>5th-order (Milankovitch) cycles, response to fault pulse</td>
<td>$10^{-1}$</td>
<td>Channel belt, alluvial fan, minor sequence</td>
<td>6th-order, flat, regionally extensive, or base of incised valley</td>
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<tr>
<td>9</td>
<td>$10^5$ - $10^6$</td>
<td>4th-order (Milankovitch) cycles, response to fault pulse</td>
<td>$10^{-1}$ - $10^{-2}$</td>
<td>Major dep. system, fan tract, sequence</td>
<td>7th-order, sequence boundary; flat, regionally extensive, or base of incised valley</td>
</tr>
<tr>
<td>10</td>
<td>$10^6$ - $10^7$</td>
<td>3rd-order cycles, Tectonic and</td>
<td>$10^{-1}$ - $10^{-2}$</td>
<td>Basin-fill complex</td>
<td>8th-order, regional disconformity</td>
</tr>
</tbody>
</table>
• After Miall (2006)
Heward, 1978b

Gloppen & Steel, 1981

This Paper,
Section 2,
198-218 m
• Autogenic controls on fan development

Fig. 10.1. Generalized model of autogenic fan development, based on experimental work on small, artificial fans. A Apex incision results from source-area erosion and leads to deposition near the toe; B the channel backfills and the locus of sedimentation (the intersection point of channel slope with the fan surface) moves up to the midfan region; C channel is obliterated by backfilling, and flow is dispersed from near the apex in all directions; D oversteepening of the apex occurs again, and incision along a steep flank of the fan leads to renewed entrenchment; E, F depositional backfilling commences in a new part of the fan. (Schumm et al. 1987)
Architecture of channel avulsion

Fig. 10.2. Architectural cross section through the upper part of a fan, transverse to fan axis, showing the development of a fifth-order lithosome (see also Figs. 4.3 and 10.1). 1 Trenching; 2 lateral migration and filling of trench; 3 backfilling of trench; 4 dispersion of flow; 5 abandonment of active part of fan, with development of pedogenic modifications and initiation of renewed trenching elsewhere; 6 cross section through resulting fifth-order lithosome, showing architectural features and types of bounding surface. (DeCelles et al. 1991)
• How can sea-level marginal marine system tracts be directly linked to fluvial systems that express strong and complex influence of more terrestrial variables (e.g. climate, tectonics)
Climate control on fluvial architecture

• High frequency climate change in the hinterland causes important changes in run-off and denudation rate.
Leeder-Allen-Bridge model (LAB)

• Sedimentation rates (used for proxies of subsidence rates) are a main controlling factor on stacking patterns.
• Inverse relationship between stacking density and sedimentation rates (this model does not consider avulsion frequency)
• Sheet like deposits (high stacking density)=low sedimentation rates
High sed rates: thick sediment in the channel + flood plain = ribbon like geometry
Low sed rates: less sediment is deposited in between avulsion events and so channels are more easily interconnected
But what about avulsion? Assumption: avulsion takes place only when the channel belt aggrades critical relief $h$ above the flood plane.
Significance of channel-belt clustering in alluvial basins

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Clustering is all about autogenic controls....
Third, Fourth and Fifth order cycles

- 3rd: 1-10 My
- 4th: 0.2-0.5 My
- 5th: 0.01-0.2 My

- Fourth and Fifth cycles are related to orbital changes (Milankovitch cycles):
  - Precession: wobble of the Earth’s axis (19,000 - 23,000yr)
  - Obliquity: tilt of the Earth’s axis (41,000yr)
  - Eccentricity: Earths’ orbit change (100,000- 400,000yr)
4th and 5th order cycles: Milankovitch cycles

OBLIQUITY: the tilt of Earth's axis changes in a 41 Ka cycle

21.5° - 24.4°

Plane of the ecliptic

PRECESSION: wobble of Earth's axis has a 19 to 23 Ka cycle

projection of Earth's axis of rotation

circle of precession

equator

normal to ecliptic plane

ECCENTRICITY: Earth's orbit changes shape in the plane of the ecliptic in ~100 Ka and ~400 Ka cycles
Trubi marls (<5Ma): pelagic foraminiferal marls on top of the Messinian (ca. 7-5 Ma), Italy
First (200-500 My) and second order (10-100 My) cycles

Sloss cycles (sequences) in N America
Stable isotopes
(all represented in part per mil: δ; refer to pg. 540 of Boggs)

• δ ¹⁸O: heavy (oceans are rich in this δ ¹⁸O during glacial periods)
• δ ¹⁶O: light (ice caps are rich in δ ¹⁶O and oceans are rich in δ ¹⁶O during interglacial periods when ice caps melt)
• Examples from the continents:
  – Uplift (δ ¹⁸O trends towards more negative values)
  – Aridification (δ ¹⁸O trends towards more positive values)
Climate and cyclicity
Pliocene
(5.3 to 1.8 Ma)

- Subtle warming trend until ~3.2 Ma;
- Halted by increase in Northern Hemisphere Glaciation;
- Increased frequency and amplitude of isotope signals;
- Increased significance of obliquity (41 kyr cycle).
- Closing of the Isthmus of Panama (3-5 Ma)
- Messinian Salinity Crisis (ca. 5 Ma)
• Greenhouse state (warm)
• Icehouse state (cold)
Example of tectonic controls on channel behavior

<table>
<thead>
<tr>
<th>a. Uplift ↑</th>
<th>b. Subsidence ↓</th>
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</thead>
<tbody>
<tr>
<td><strong>Slope deformation and adjustment</strong></td>
<td><strong>Channel pattern</strong></td>
</tr>
<tr>
<td><img src="image1" alt="Uplift schematic" /></td>
<td><img src="image2" alt="Reticulate" /></td>
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<tr>
<td><img src="image5" alt="Uplift schematic" /></td>
<td><img src="image6" alt="Reticulate" /></td>
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<tr>
<td><img src="image9" alt="Uplift schematic" /></td>
<td><img src="image10" alt="Cutoff" /></td>
</tr>
<tr>
<td><img src="image13" alt="Uplift schematic" /></td>
<td><img src="image14" alt="Sinuous - or island - braided" /></td>
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</tbody>
</table>