Implications for Tectonic Control on Paleogeography and Sediment Dispersal Pathway: Integrated U-Pb Detrital Zircon Age-Analysis of the Paleogene Missouri River Headwater System, SW Montana*

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Abstract

Cenozoic intermontane basins in southwest Montana lie within the Sevier-Laramide orogenic belt and constitute many of the basins within the Northern Basin and Range (B&R) province. Paleogene fluvial deposits within the intermontane basins record basin evolution and sediment dispersal pathways across the post-contractile Cordilleran fold-thrust belt. Recent work has demonstrated that structurally controlled fluvial incision served to establish an interconnected drainage system and develop intermontane-scale paleovalleys prior to B&R extension. In adjacent regions to the south and west of the uppermost modern Missouri River, paleotributaries to the paleo-Missouri River were essentially identical to those of the modern system. The sediment dispersal pattern is similar to that which is typical of modern fold-thrust belts. Resultant outflow was northward into the upper paleo-Missouri River and beyond, into the northeastern continental basin region.

A newly documented large-scale Eocene fluvial conglomerate (cobble to boulder) in the Beaverhead Basin demonstrates northward paleoflow and serves as evidence for a major influx of detritus to the paleo-Missouri River system from previously undocumented tributaries in the far southwest, near the Montana-Idaho border. Paleocurrent data document that the Grasshopper and Medicine Lodge basins were contiguous with the Horse Prairie Basin, similar to the modern, with net outflow eastward toward the modern Beaverhead Canyon. That paleodrainage configuration is further supported by using detrital zircon U-Pb ages and conglomerate clasts as provenance indicators and tracers. Composition of conglomerate constituents and detrital zircon ages from trunk fluvial outcrops suggest a paleodrainage link between the paleo-Beaverhead Basin and the southwestward Horse Prairie and Medicine Lodge paleobasins. Furthermore, these data indicate erosion of Meso-Proterozoic Belt Formation strata as a primary sediment source, with a minor to moderate supply of sediment from Archean basement, Cretaceous plutons, and early Paleogene volcanics. In addition, detrital zircon ages serve as an effective tracer of sediment derived from Cretaceous plutons in the southern Pioneer Mountains that was routed through separate drainages in the Grasshopper and Frying Pan basins.
The Frying Pan Basin discharge was eastward, directly into the Beaverhead Basin, whereas discharge from the southern basin system was most likely northward through the paleo-Clark River Canyon.
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ABSTRACT

BASIN INTERIOR: TRUNK FLUVIAL FACIES

1. Gravel: Red-Braided River:
   - Fluvial-ramp supported, planar-stratified deposits.
   - Fining-upward channel deposits.
   - Well-rounded clasts, up to 56 cm diameter.
   - Bedforms: ripples, up to 15 cm wavelength.
   - Sediment: sand, silt, clay.

2. Sand: Braided River:
   - Isolated channel bodies and tabular sandstones occur within thick, abundant overbank mudstone deposits.
   - Channel bodies consist of cyclically laminated clay and sand layers.
   - Clay: smectite, kaolinite, illite.
   - Sand: sub-rounded to rounded, 2-5 cm diameter.
   - Overbank mudstone: 3-4 m thick.
   - Channel width: 56 m.

3. Mud: Deltaic Fluvial Facies:
   - Wide-spread estuarine mudstone;
   - Tabular sheet-like geometry.
   - Absent upper fluvial regime deposits.
   - Absent sediment deformation, hyperconcentrates.
   - Cyclical beds: up to 1 m in thickness.
   - Channel-form bedding; clasts up to 3 m in diameter.

BASIN MARGIN: ALLUVIAL FAN FACIES

1. Proximal alluvial fan deposits:
   - sheet flood breccia, up to 1 m thick.
   - Channelized sand waves, up to 1 m thick.
   - Pedimental knolls, 2-4 m high.
   - Sheet flow breccia: 1-2 m thick.
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2. Medial to distal alluvial fan deposits:
   - Isolated sandstone and breccia/conglomerate bodies encased within thick mudstone.
   - Coarse-grained facies include (1) scattered single bed and (2) channel-flood deposits.
   - Pedogenic alteration of mudstones indicates prolonged subaerial exposure between depositional events.

3. Erdoba Flow Breccia:
   - Wide-spread sheet flows; chaotic.
   - Mostly angular to sub-rounded clasts.
   - Texture: massive to tabular.

4. Channel-Bound Facies:
   - Tidal bound with coarser material.
   - Channel form bedding.
   - Poorly sorted, medium to coarse sandstone.
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Background

This diagram is modified from Lageson et al. (2001).

Key:

Additional Notes:
- Schwartz et al. (2011)
- This Study

Table:

<table>
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<tr>
<th>Region</th>
<th>Description</th>
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<td>Horse Prairie Basin</td>
<td>Paleorelief of western foothills; red beds; large-scale cross-stratification</td>
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<tr>
<td>Medicine Lodge Basin</td>
<td>Paleorelief of western foothills; red beds; large-scale cross-stratification</td>
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<tr>
<td>Sage Creek Basin</td>
<td>Paleorelief of western foothills; red beds; large-scale cross-stratification</td>
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<td>Grasshopper Basin</td>
<td>Paleorelief of western foothills; red beds; large-scale cross-stratification</td>
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<td>Upper Ruby Basin</td>
<td>Paleorelief of western foothills; red beds; large-scale cross-stratification</td>
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<tr>
<td>Frying Pan Basin</td>
<td>Paleorelief of western foothills; red beds; large-scale cross-stratification</td>
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Figures:
- Figures 1-4 in color
- Figures 5-10 in black and white
- Figures 11-15 in color

This page contains additional images and tables related to the study.
Paleodrainage & Detrital Zircon Provenance

Conglomerate Clast-Count Data & Sandstone Petrography

Kolmogorov-Smirnov (K-S) Testing

Detrital Zircon CDF

Potential Paleogene Source Rocks - Summary

Distribution of major ancient sources of Paleogene sediments. (Google Earth, 2013)
Eocene-Oligocene Geography and Drainage

1) Stratigraphy: Detrital zircon ages and stratigraphic position indicate Eocene to Early Miocene deposition.
2) Axial Depositional System: through-going, high energy braided streams (gravel and sand-bed).
3) Paleodrainage: Mostly similar to the modern Missouri headwater system. Net outflow eastward from Grasshopper Basin into the modern Beaverhead canyon, interconnected with the paleo-Beaverhead-Jefferson river system.
   - Paleodrainage divide between the paleo-Upper Beaverhead and Sage Creek Basins.
   - The modern upper Missouri River headwater system has a >34 m.y. history.
4) Provenance:
   a. Southern basins source areas:
      - Proterozoic Belt feldspathic quartzites; ~1.6, 2.5Ga detrital zircons --> Beaverhead and Tendoy Mtns.
      - Cretaceous granitic sand; ~70-75 Ma zircons --> Plutons in Pioneer Mountains
      - Lowland Creek & Dillon Volcanics; ~40-52Ma zircons --> Eastern Pioneers Mtns; locally abundant.
   b. Downstream changes in composition:
      - Sandstone:
         - Quartz rich (Upper Horse Prairie and Medicine Lodge Basins) to lithic-volcanic (Beaverhead Basin) due to alluvial input of early Paleogene volcanics from the Eastern Pioneer Mountains.
      - Conglomerate:
         - Progressive decrease in feldspathic Proterozoic quartzite clasts - due to dilution.
         - Increase in Archean, Paleozoic, & Mesozoic clasts – due to added presence of corresponding source rocks in stream-adjacent uplifts, and from material transported by adjoined channel systems
5) Paleogeography: Similar to adjacent northern basins (Schwartz & Schwartz, 2013), southwesternmost MT has mountainous terrain with ancient uplifts mostly coincident with the modern highlands (Beaverhead, Tendoy, Pioneer Mountains).
   - Development of the early Paleogene basins was result of Late K to early Eocene fluvial systems that carved intermontane-scale paleovalleys with reliefs of the 100-1000 m scale into the Sevier orogenic wedge.
   - The Paleogene terrain was likely modified and overprinted to some degree by Basin-and-Range (~16Ma) and Yellowstone hotspot trackway (~6Ma) uplift and extension.
   - Unlike modern configuration, ancient highlands existed along the western margin of the Sage Creek Basin.

1) Data in this study are most consistent with incisional model of basin origin with respect to the expected through-going drainage patterns and three-dimensional geography.
2) Supports a passive control on Paleogene dispersal pathways; preexisting Sevier-Laramide structural fabric
3) Integrated provenance data sets are imperative for provenance & paleodrainage assessments in geologically complex terrains

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