LINKING LONG-TERM SEDIMENT DYNAMICS AND AQUATIC HABITAT IN THE COLUMBIA RIVER WATERSHED

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RESEARCH CONTEXT

Long-term, basin-wide (e.g. landscape scale) sediment yield data can **provide context** for anadromous fish restoration and habitat monitoring efforts in the Columbia River watershed.

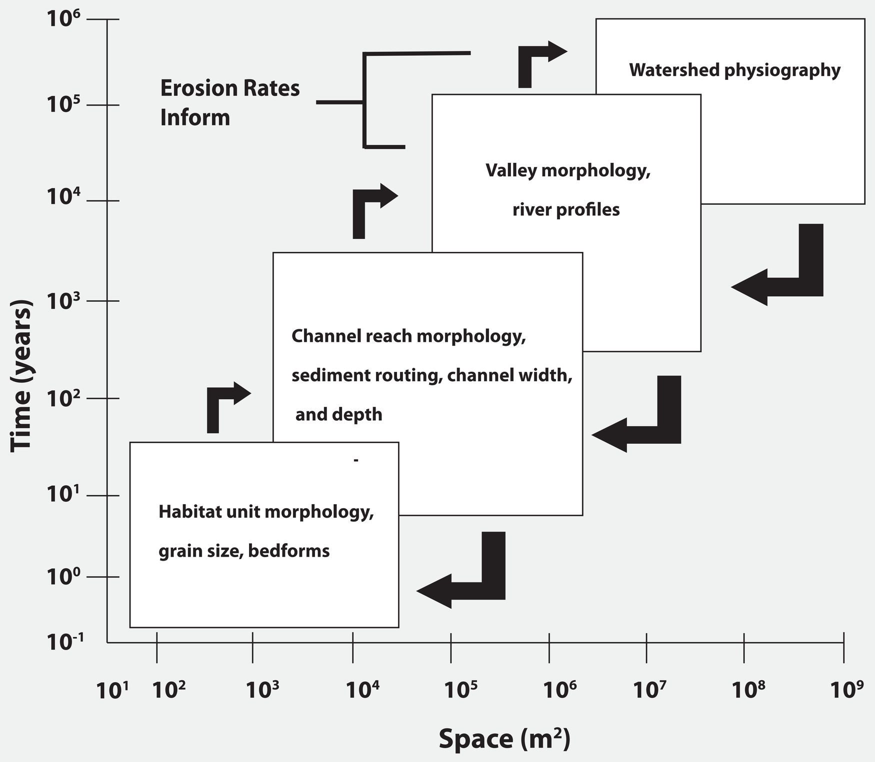


Figure 1: Relationships between spatial and temporal scales over which geology and geomorphology influence aspects of salmonid habitat. Boxes indicate the nested spatial and temporal hierarchy of landscape organization and the black arrows denote the dynamic exchange between ecology and geomorphology with variable widths symbolizing interaction strength (Modified from Montgomery, 2004)

BROAD RESEARCH QUESTIONS…

1. How do long-term rates of sediment supply vary spatially and temporally throughout the Columbia River watershed?

2. How have human activities influenced (amplified or dampened) processes of erosion and sediment transport?

3. At what scales do long-term and near-term erosion rates influence aquatic habitat metrics?

…IN A BROAD AND DIVERSE LANDSCAPE

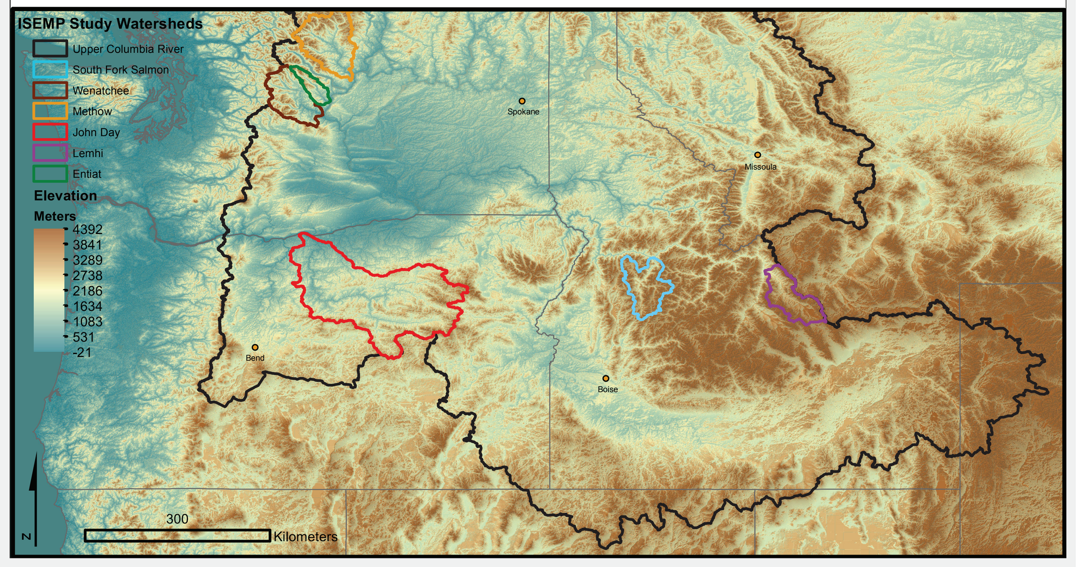


Figure 2: A portion of the Columbia River watershed with ISEMP sub-basins of interest highlighted with colored polygons. Cosmogenic and OSL sampling will take place in a sub-set of these basins.

STUDY DESIGN

I am using a combination of GIS analysis and rapid geomorphic assessments to **locate natural and anthropogenic experiments within sub-basins of the Columbia River** that I can sample to address my research questions.

Samples include:
Cosmogenics
- Active channel alluvium
- Terrace deposits

Optically Stimulated Luminesence (OSL)
- Terrace deposits

Carbon-14
- Terrace deposits

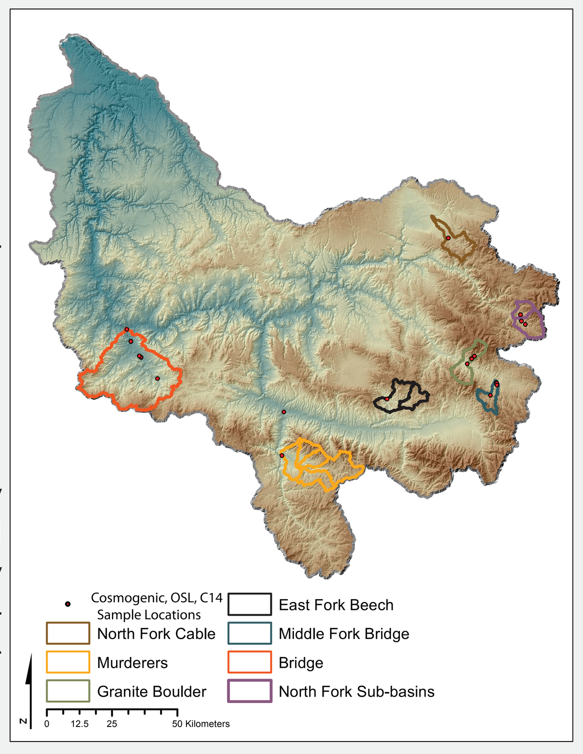


Figure 3: DEM of the John Day sub-basin located in central Oregon shown at left. Study basins are highlighted and existing sample locations are indicated with red dots

METHODS: RAPID GEOMORPHIC ASSESSMENTS

Fluvial Audits (Sear et al, 1995)

Qualitative basin scale assessment of the **location and type of sediment supply, transport and storage** within basins of interest:

- Sediment size, distribution
- Valley and Channel Width
- Gradient
- Sinousity
- Channel reach morphology
- Habitat unit morphology

INFORMS → **Cosmogenics Sampling**

METHODS: COSMOGENIC NUCLIDES AND BASIN-WIDE EROSION RATES (BWER)

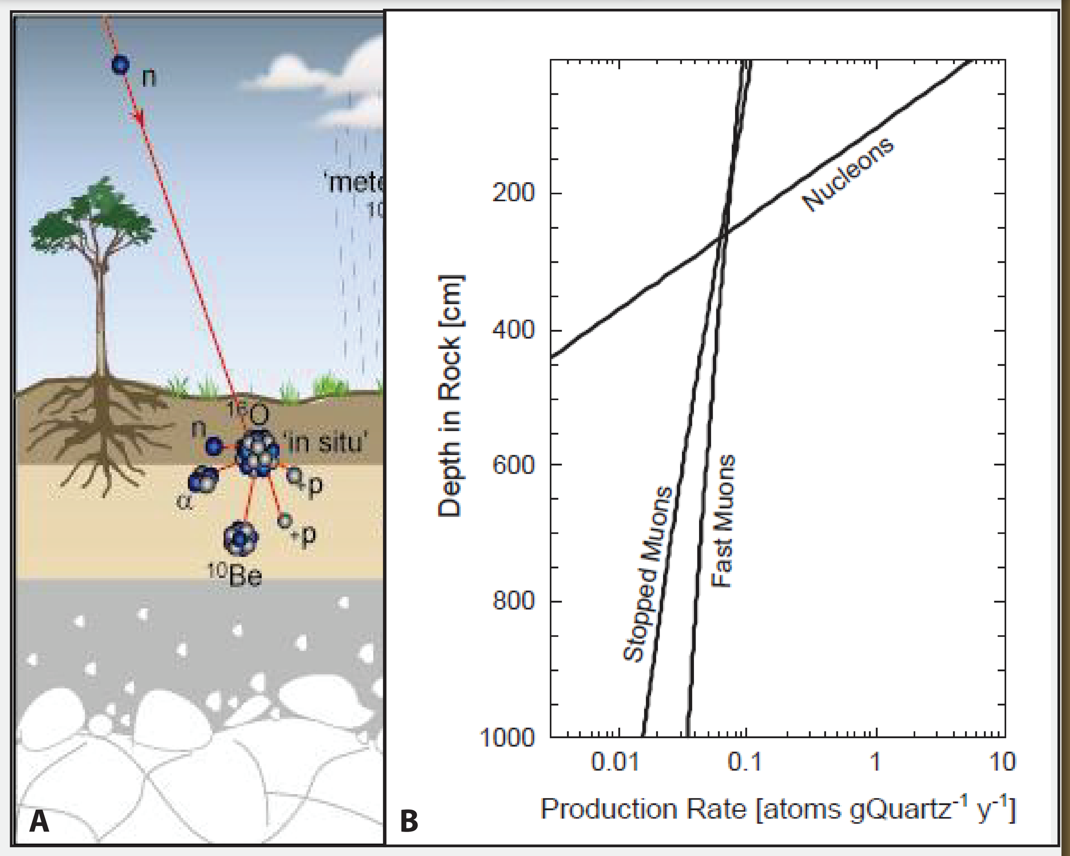


Figure 4: Top left **(A),** high-energy sub-atomic particle reacting with an oxygen isotope in quartz near the earths surface creating the long-lived radioactive isotope Be-10. Production and decay of Be-10 is well contrained and concentration measurement allows for surface exposure dating. Top right **(B)**, depth dependency of different components of high energy sub-atomic particles attenuating with depth. The majority of nuclide production takes place by nucleons near the earths surface.

METHODS: BASIN-WIDE EROSION RATES , 'LET NATURE DO THE AVERAGING'

Sediment at the outlet of a catchment is assumed to be an **aggregate of grains** originating from all different regions of the upstream area. These sediments are eroded at different rates from different source areas, and inherit different nuclide concentrations. Thorough mixing of grains through hillslope and fluvial transport processes homogenizes nuclides in the downstream sediment load.

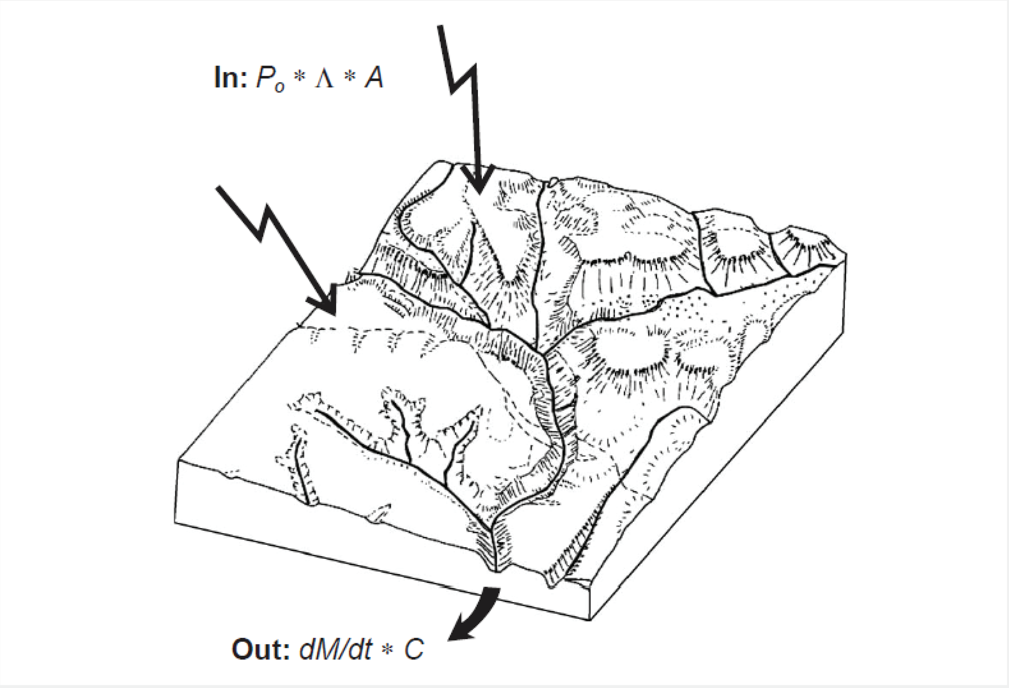


Figure 5: Nuclides are produced in a catchment with area A, **In,** P_o, nuclide production rate, atoms g $^{-1}$ y $^{-1}$. Λ , cosmic ray attenuation **length.** Fluvial sediment is exported **Out,** and assuming the inbound nuclide flux by production equals the outbound flux by erosion mass flux, dM/dT can be calculated by C, nuclide concentration, atoms g $^{-1}$. (Modified from Von-Blanckenburg, 2005)

WHY NOT USE AN EROSION MODEL?

'Erosion is most rapid where the slope is the steepest.'
– G.K. Gilbert (1877)

- Cosmogenics have shown that this is not always true. Slope and climate are not always good predictors for long-term erosion rates.
- Hack (1960) asserts that over time landscapes tend toward a dynamic equilibrium in which slopes are adjusted to attain uniform erosion. For any given erosion rate, harder rocks form steeper slopes, softer rocks form gentler slopes.

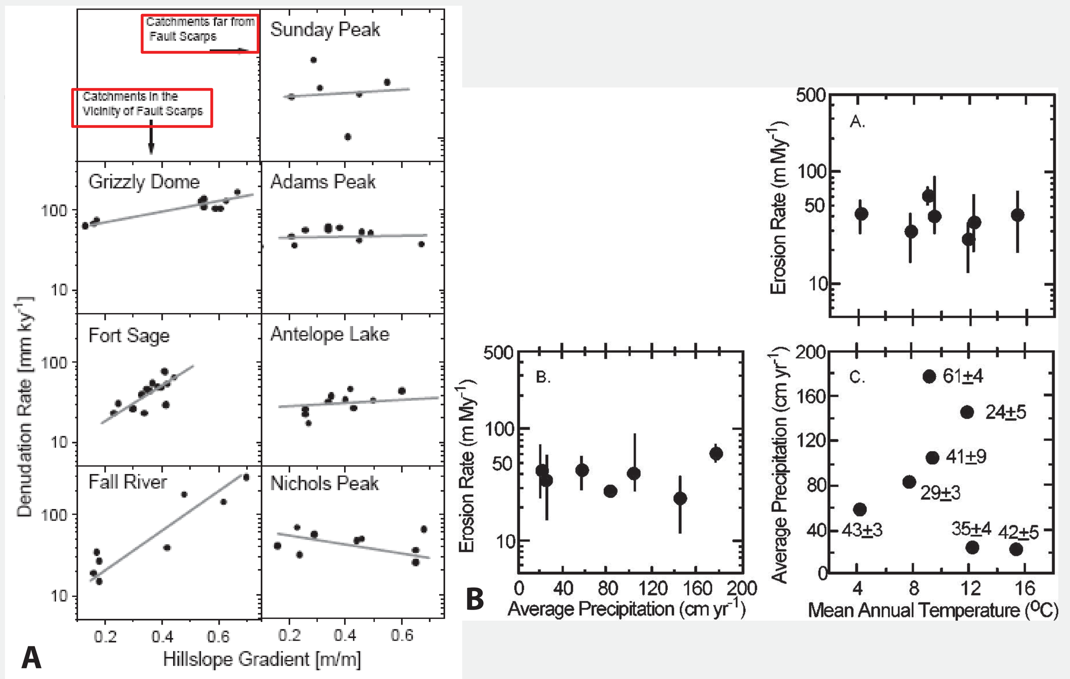


Figure 6: A. Cosmogenic nuclide derived erosion rates as a function of hillslope gradient. The 3 catchments on the left, hillslope gradient and erosion rate are strongly correlated and erosion increases with viscinity to an active fault scarp. In contrast, the catchments at right show no correlation between hillslope gradient and erosion rate. These catchments are located far from an active fault scarp and appear to be in a geomorphic steady state. **B.** Climate has no relationship with long-term erosion rates. These catchments are also located in the Sierra Nevada, CA. (Modified from Von-Blanckenburg, 2005 and Riebe et al, 2001)

SPECIFIC RESEARCH OBJECTIVES

1. **Compile database of basin-wide erosion rates** from cosmogenics and other sources throughout the Columbia. (Kirchner et al, 2001; Portenga and Bierman, 2011; Kirchner et al, Moon et al, 2011; and others)

2. Locate sub-basins with reliable short-term sediment yield data to **compare erosion rates through time**. Quantify magnitude of anthropogenic perturbation.

3. **Correlate variability in millennial scale BWER to observable reach-scale features from Fluvial Audits.**
High BWER = greater abundance of a particular reach-type ?
Or.. sediment classification (source, transfer or deposition reaches)?

MILLENNIAL SCALE EROSION RATES ACROSS THE COLUMBIA RIVER WATERSHED

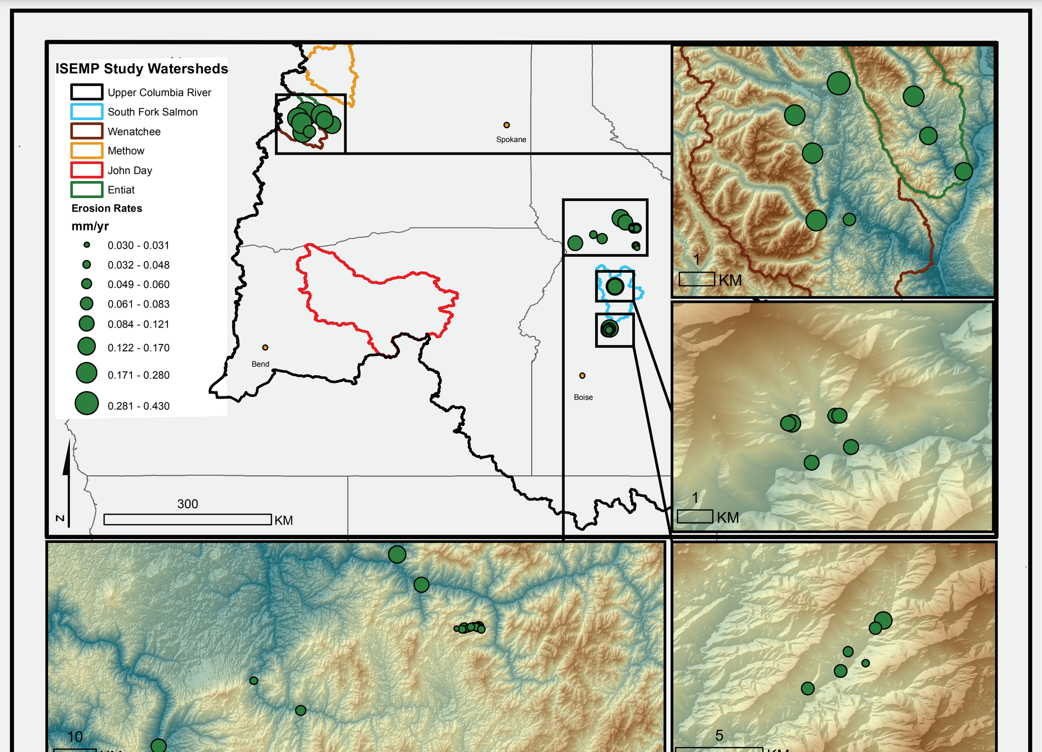


Figure 7: A portion of the Columbia River watershed with millennial scale BWERs shown in green. Inset top right are BWER from the Wenatchee and Entiat sub-basins (Moon et al., 2011). The remaining inset boxes are BWER from central Idaho mountainous catchments (Kirchner et. al., 2001).

STUDY SITE: SKOOKUM CREEK, OREGON

Methods:
Fluvial audit, BWER, sediment yield gauge data

Analysis:
Compare erosion rates over the **decadal** and **millennial scales** using existing sediment yield gauge data and cosmogenically derived basin-wide erosion rates.

- Quantify magnitude of anthropogenic perturbation.
- Correlate to Fluvial Audit

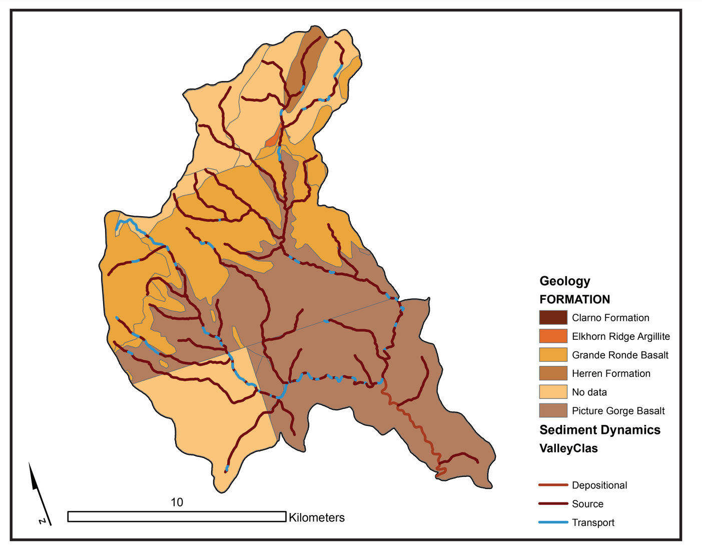


Figure 8: Geologic map of study basin. Also shown is a broad scale classification of sediment dynamics developed by Beechie and Imaki at NOAA fisheries.

STUDY SITE: BRIDGE CREEK, OREGON

- **Highly incised channel**
- **Large-scale restoration project underway by ISEMP**

Methods:
Fluvial audit, field mapping, BWER (active channel and terraces), OSL and C14 dating of terraces

Analysis:
Compare millennial scale erosion rates from active channel and dated terraces

- Constrain timing of recent incision (anthropogenic?)
- Correlate to Fluvial Audit

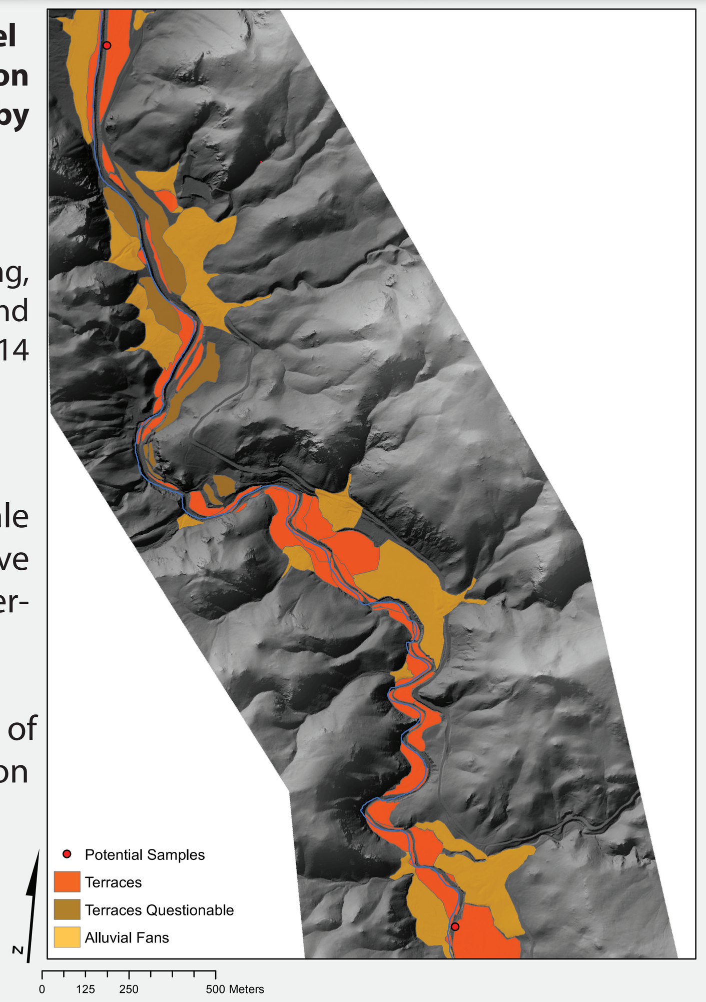
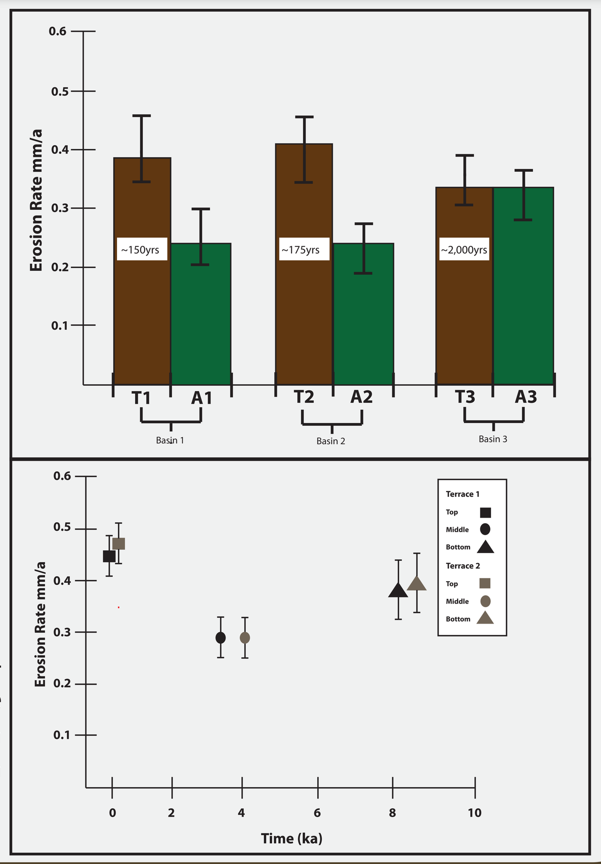


Figure 9: Locations of coarse-grained terraces and fine-grained alluvial fans shown above. Red dots are locations of OSL, C14 and cosmogenic samples.

ANALYSIS

Figure 10: Right, mock figure comparing millennial scale erosion rates between active alluvium and dated terraces from 3 sub-basins within the John Day watershed, Oregon.

Figure 11: Right, mock figure showing the differences in millenial scale erosion rates during the depostion of 2 terraces in Bridge Creek John Day watershed, Oregon.



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