Isotopic sediment fingerprinting to correlate land use changes and erosion

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Students: Oberlin College - Dominic Fiallo, Gabriela Garcia, Joseph Martin, Yue Qiu, Adrian Singleton, Sylvia Woodmansee
University of Vermont - Thomas Neilson, Veronica Sosa Gonzalez

Thomas Neilson - long term erosion rates

Project goals:
* Characterize background erosion rates using 10Be in fluvial sediment
* Understand erosion rates in the context of modern land use
* Understand erosion rates in the context of modern sediment yield

Methods:
* In situ 10Be analysis of 54 samples collected in summer 2013 (Fig. 1)
* Network analysis tracking sediment as it moves downstream
* Correlation analysis of erosion rates and geomorphic parameters

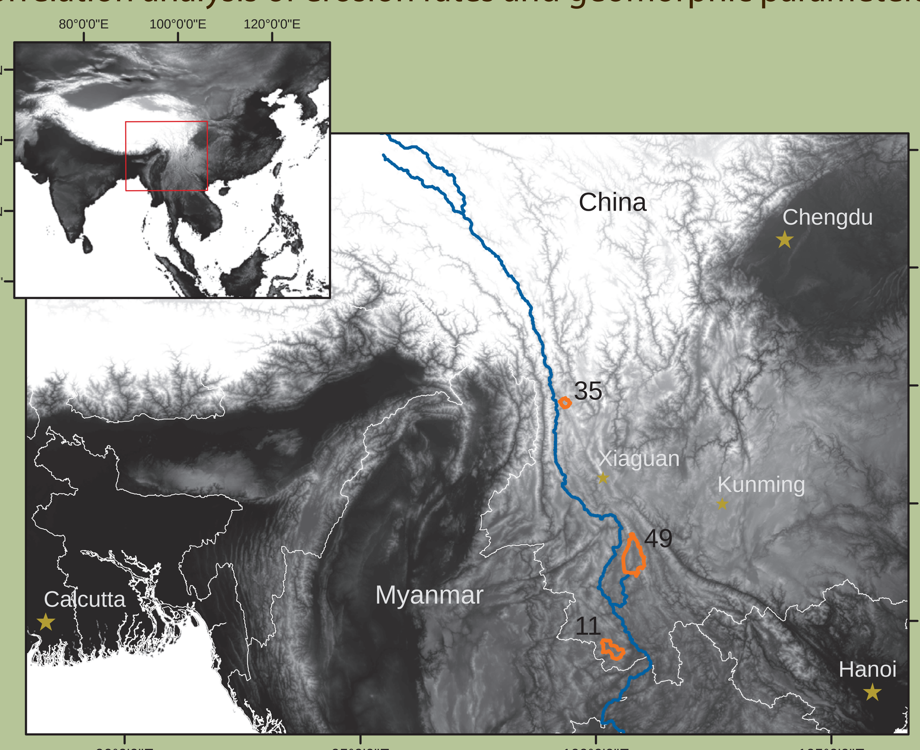


Figure 1: We sampled at 54 sites in 3 watersheds (in orange) in May 2013. Watersheds are all tributaries to the Mekong.

Preliminary results:
* Erosion rates range from 12 ± 1 to 195 ± 18 m/My
* Slope is the strongest regressor with all samples ($r2 = 0.37$, $p < 0.001$)
* No correlation with size, elevation, mean annual precipitation
* Erosion rates for individual watersheds correlate less well with slope
* Network analysis of samples upstream and downstream of confluences suggest using 10Be data to estimate sediment yield is inaccurate (44% under to 92% over actual yields)

Yue Qiu - Sediment yield, ^{137}Cs, ^{210}Pb, and land use

Project goals:
* Connect patterns in sediment yield to land use changes and policies
* Explore patterns in short-lived radionuclide activity in sediments and historical and current land use for one small watershed (basin 35, Fig. 1)

Methods:
* ^{137}Cs and ^{210}Pb analysis of detrital sediments
* Land use/land cover analysis from historic satellite images
* Analysis of Chinese sediment yield and discharge data

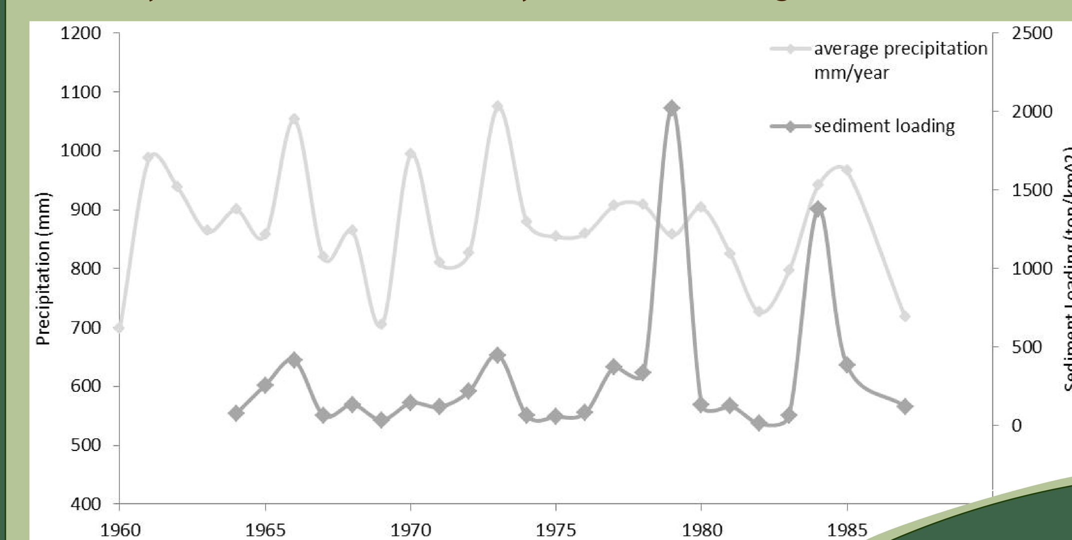


Figure 2: Sediment yield generally tracks with rainfall except for high sediment yield in 1979 and 1984.

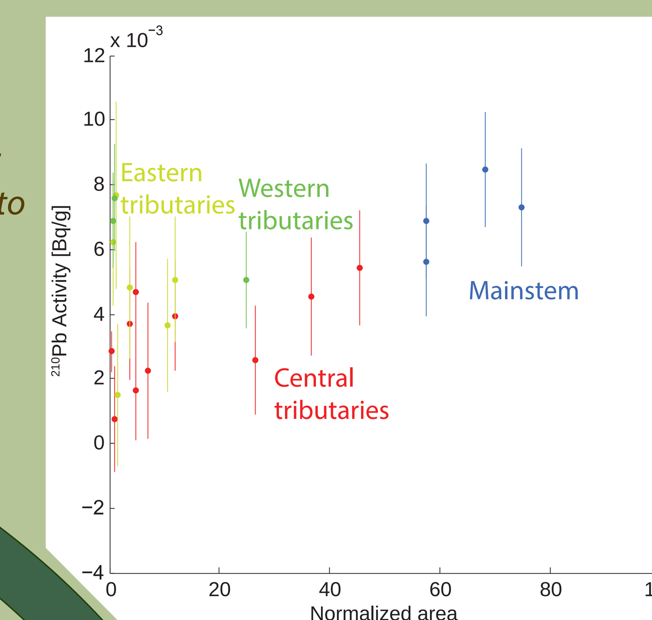
Preliminary results:
* ^{137}Cs is only found in two high, mountainous watersheds which have been pasture for the entire study period
* ^{210}Pb activity does not correlate with land use, slope, or elevation
* Two peaks in sediment yield do not correlate with rainfall and may be related to land use policies (Fig. 2)

Dominic Fiallo and Gabriela Garcia - Network analysis of ^{137}Cs and ^{210}Pb in one watershed

Project goals:
* To determine how short-lived radionuclide activity changes throughout one watershed (basin 49, Fig. 1)
* To connect the network analysis of ^{137}Cs and ^{210}Pb activity to qualitative changes in land use

Methods:
* ^{137}Cs and ^{210}Pb analysis of detrital sediments
* Qualitative analysis of land use from field photos and Google Earth
* Network analysis of ^{137}Cs and ^{210}Pb activity

Figure 3: The central tributaries have statistically significantly lower ^{210}Pb activity than the eastern or western tributaries or the mainstem. This may be due to intensive farming, including tobacco plantations, in the central tributaries.

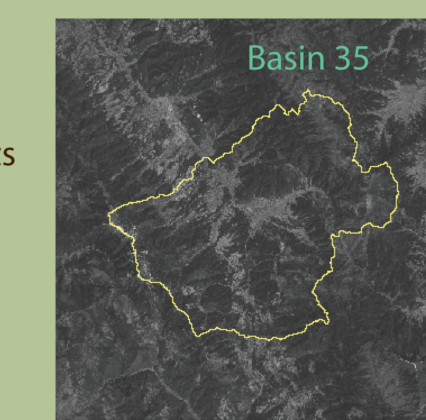


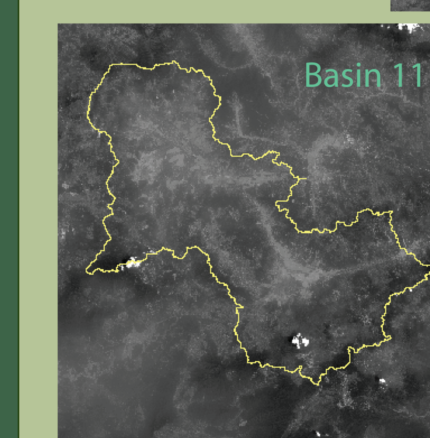
Preliminary results:
* Central tributaries have the lowest activity
* Low activity may be related to land use
* Mainstem sediment appears to be sourced mainly from eastern and western tributaries

Joseph Martin - GIS and remote sensing

Project goals:
* Characterize land use for 3 basins sampled in 2013 (Fig. 1) into forested, cultivated, and bare earth
* Define watersheds for samples collected in 2014
* Characterize land use for samples collected in 2014 into forested, cultivated, and bare earth

Methods:
Land use classification steps
* Acquire clear satellite imagery
* Calculate radiances and correct for atmospheric effects
* Use the ENVI Feature Extraction module for land use classification
* Check land use classification against global land use datasets (such as GLOBcover) and field photos to assess accuracy





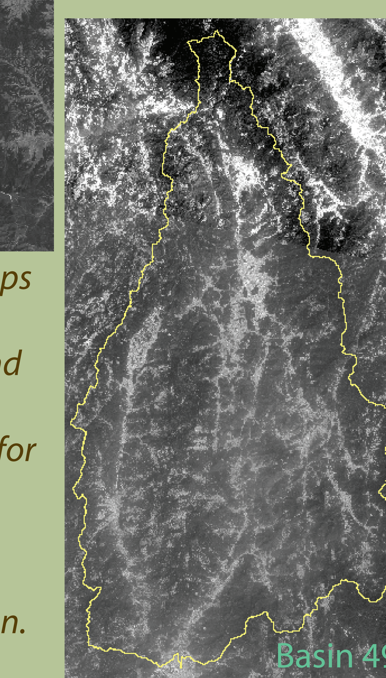


Figure 4: These maps show the panchromatic band of the Landsat 8 image being used for land use classification. See figure 1 for basin locations in Yunnan.

Drainage basin extraction
* Acquire high resolution DEMs (ASTER GDEM or HydroSHEDS)
* Correct DEMs for errors (including sinks and internal drainages)
* Calculate flow direction and determine basin outlets
* Calculate drainage basins using ArcGIS watershed tool

Overview

Overarching project goals:
* Determine relationships among land use, sediment yield, and type of erosion for gauged watersheds in Yunnan
* Determine the effects of grain size and mineralogy on fallout radionuclide retention in sediments
* Determine the differences between monsoon and dry season sediments to better understand erosion type and patterns in Yunnan

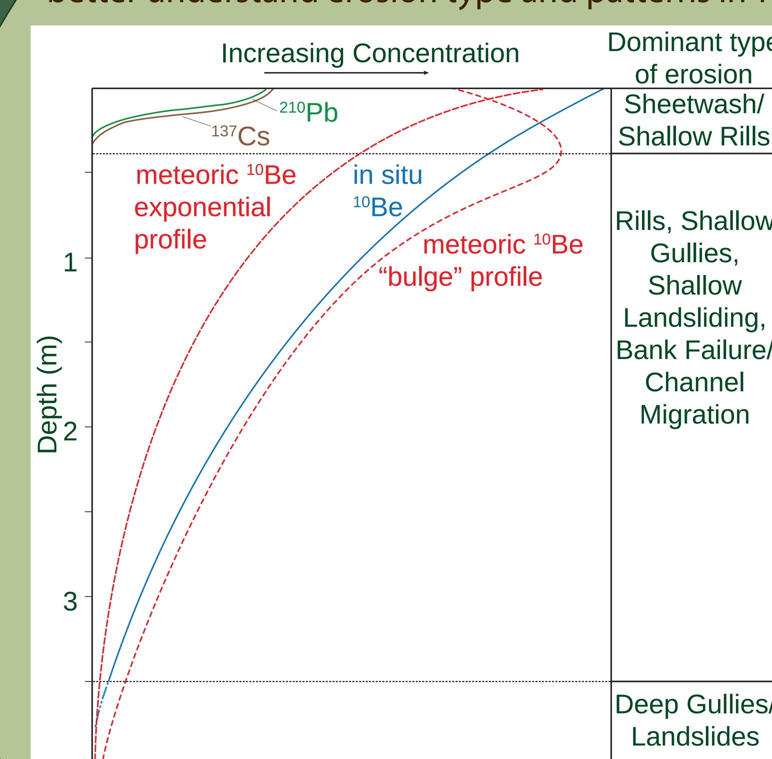


Figure 13: Using a combination of the four isotopes shown in this figure allows us to fingerprint type and depth of erosion better than using any single system. We will correlate the nuclide fingerprint of each sample to the upstream land use to determine land use effects on type of erosion.

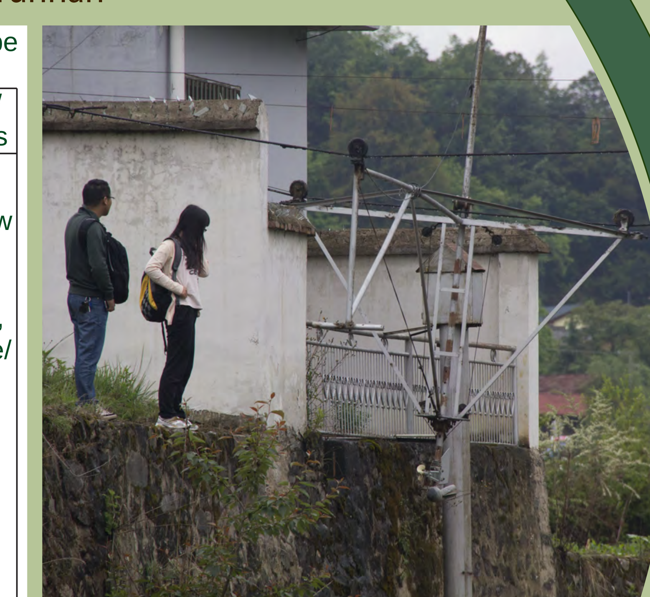
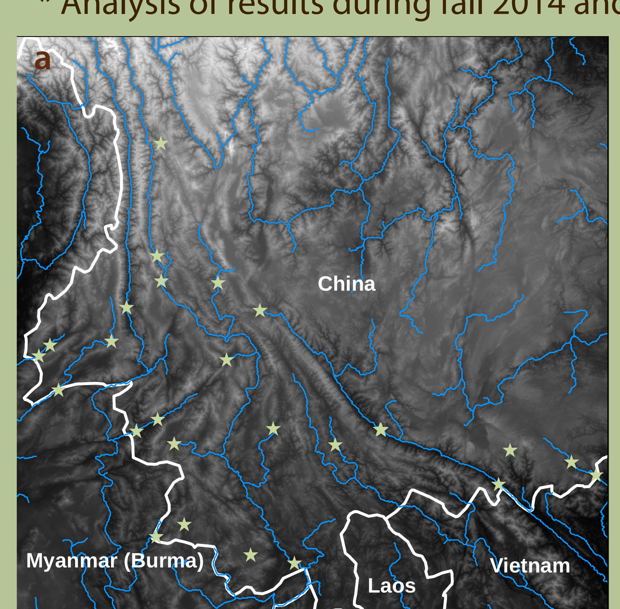


Figure 14: This project takes advantage of an unusually complete record of sediment yield and discharge for 26 gauging stations in Yunnan (such as the one shown) with at least 5 years of daily discharge and sediment concentration data. Field work was completed in 2013 and 2014.

Veronica Sosa Gonzalez - Sediment yield, erosion depth, and long-term erosion rates

Project goals:
* Compare modern sediment yield with long-term erosion rates at 26 Chinese hydrology stations (Fig. 5)
* Use 4-isotope system to fingerprint depth of erosion (Fig. 13)
* Correlate depth of erosion to upstream land use

Methods
* Collected samples in January 2014
* Samples are being analyzed for ^{137}Cs, ^{210}Pb, meteoric ^{10}Be, and *in situ* ^{10}Be during summer and fall 2014
* Analysis of results during fall 2014 and spring 2015



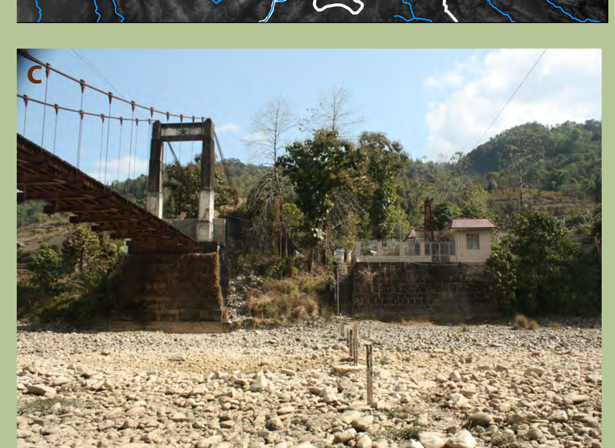


Figure 5: (a) Samples (stars); (b) High water labels at a hydrology station; (c) A hydrology station; (d) Sieving sediments at a sample site.

Dominic Fiallo - Monsoon vs dry season sediment sources

Project goals:
* Use isotopes and mineralogy to determine differences in sediment source during the wet and dry season

Methods:
* At all sample sites we collected in channel (dry season) and overbank (wet season) deposits
* ^{137}Cs and ^{210}Pb analysis of paired (in channel and overbank) samples
* XRD analysis of paired samples

Figure 6: Dom with the Oberlin XRD during training to use the machine

Preliminary results:
* Dry and wet season sediment sources often differ (Fig. 7)

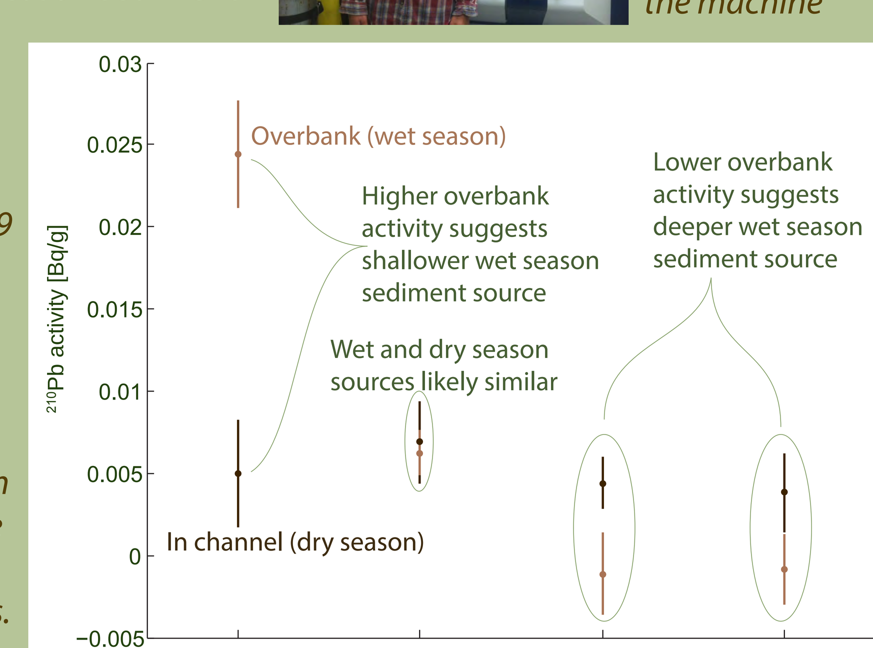


Figure 7: Basins 49 and 15 show deeper sediment sourcing during monsoons compared with dry seasons. Basin 35 has no change and basin 11 has shallower sources.

Adrian Singleton - Grain size and mineralogy effects on nuclide retention

Project goal:
* Determine the effects of grain size and mineralogy on retention of fallout radionuclides in sediment

Methods:
* Measure meteoric ^{10}Be, ^{137}Cs, and ^{210}Pb in 5 grain size fractions from 6 in channel sites sampled during the 2014 field season (Fig. 8)
* Natural delivery experiment to see how 5 different sheet silicates, 5 grain sizes of quartz, and 5 grain sizes of natural river sediment accumulate fallout radionuclides (^{7}Be and ^{210}Pb) (Fig. 9)

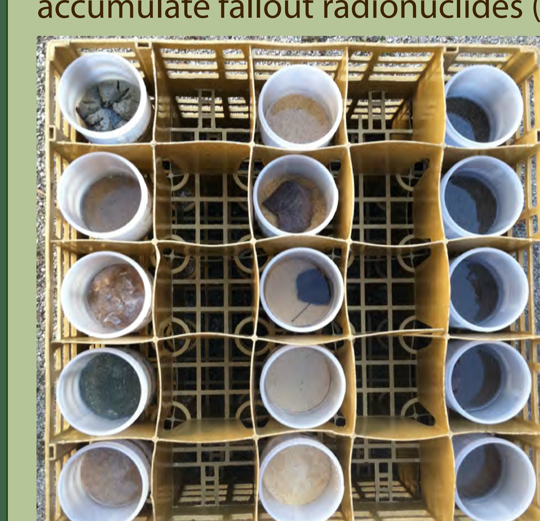
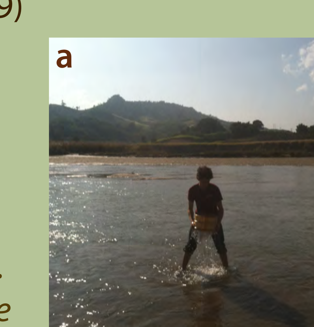
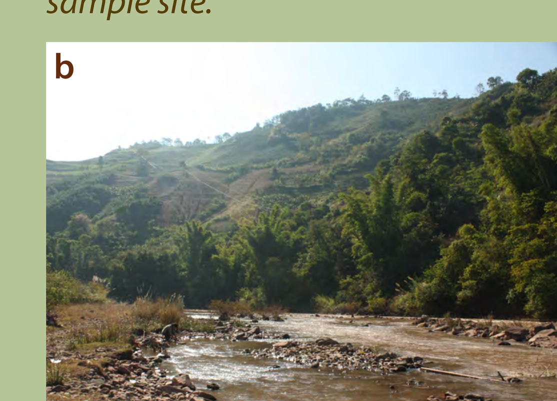


Figure 9: Natural delivery experiment. Samples are exposed for one month then brought inside for counting. Rainwater is also collected and measured.

Figure 8: (a) Sampling for grain size experiment in the field in January 2014. (b) A grain size sample site.





Sylvia Woodmansee - Drainage tiles and erosion

Project goals:
* Determine the effects of drainage tiles on depth of erosion in the Vermilion watershed, northern Ohio

Methods:
* Analyze samples collected by Jenny Bower (OC '13) for ^{137}Cs (Fig. 10)
* Model drainage tile locations using soil type and land cover (completed by Jenny Bower (OC '13) (Fig. 11)
* Determine sample mineralogy using XRD (Fig. 12)

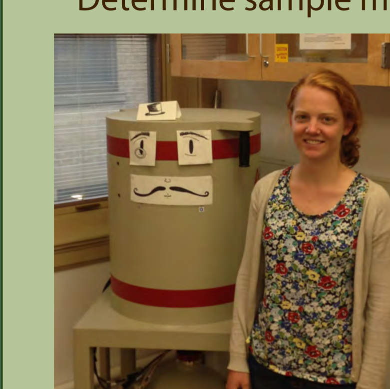


Figure 10: Sylvia with our germanium detector, Harbin. Harbin is named because the detector has to stay cold with LN2 and Harbin is a very cold city in China where Amanda used to live.

Preliminary results:
* ^{137}Cs activity is correlated with drainage tile density, suggesting that drainage tiles promote shallower (surface) erosion.

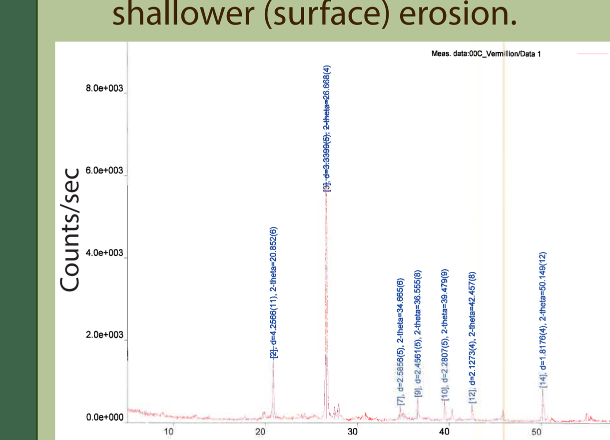


Figure 12: Preliminary XRD data for one sample. We expect areas with more tiles to have more weathered material.

Note: Although Jenny has graduated, she is involved in this project and it is in collaboration with her.

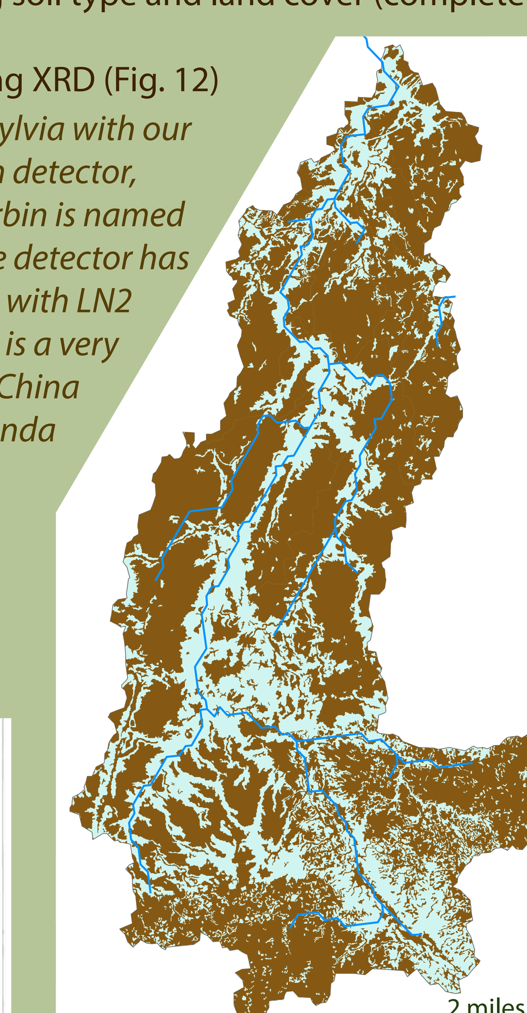


Figure 11: Modeled drainage tile locations (brown) in the study area. Drainage tiles are modeled as places with agricultural land use and soils classified as "prime farmland if drained".