Provenance Of Modern Soils, Loess, Alluvium, and Limestone and Chert Bedrock of middle TN Assessed Using Zircon U-Pb Geochronology

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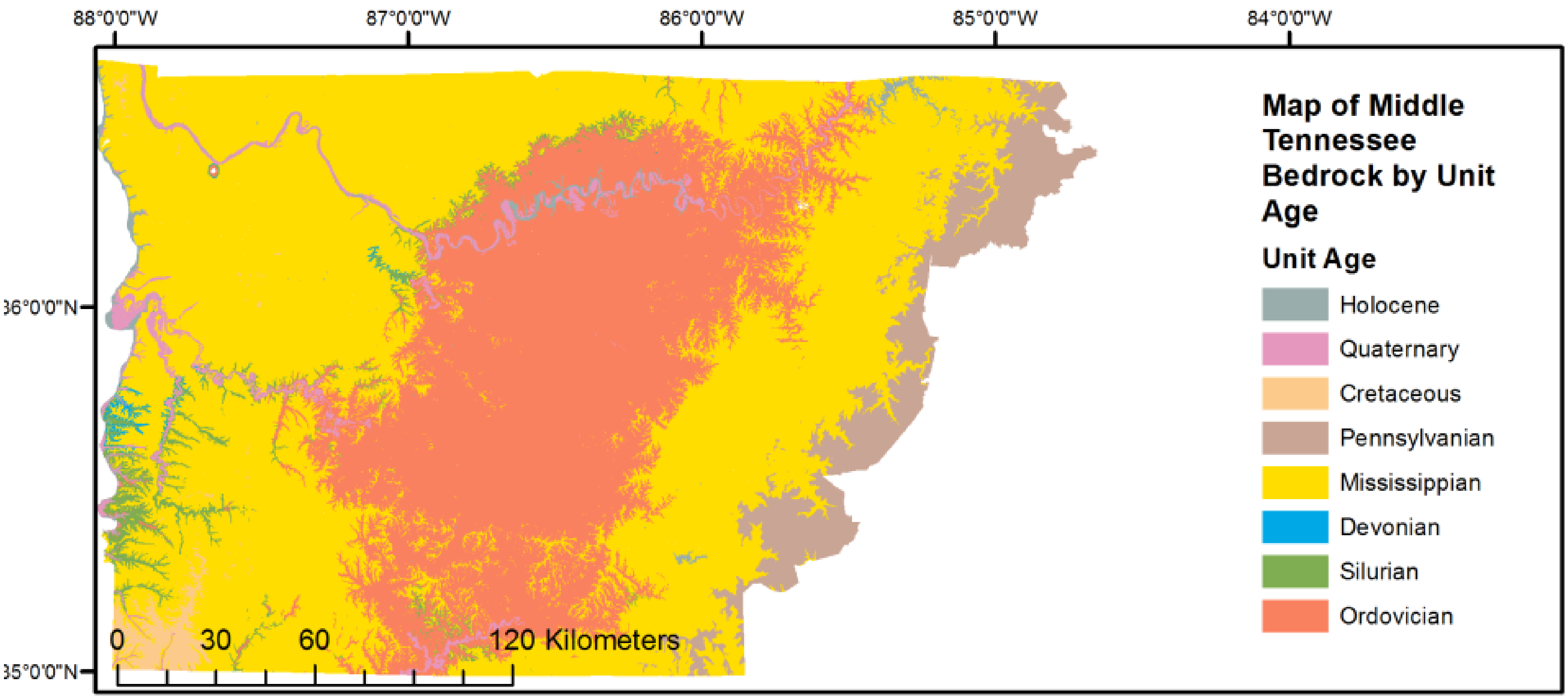
Soils Forming on Limestone – Why should we care?

- Carbonates comprise 10% of all surface-rocks
- 22% of Phanerozoic sedimentary rocks
- 17% of surface area of the USA—mostly in southeast
- But, despite all this, few studies of modern soil development on limestone

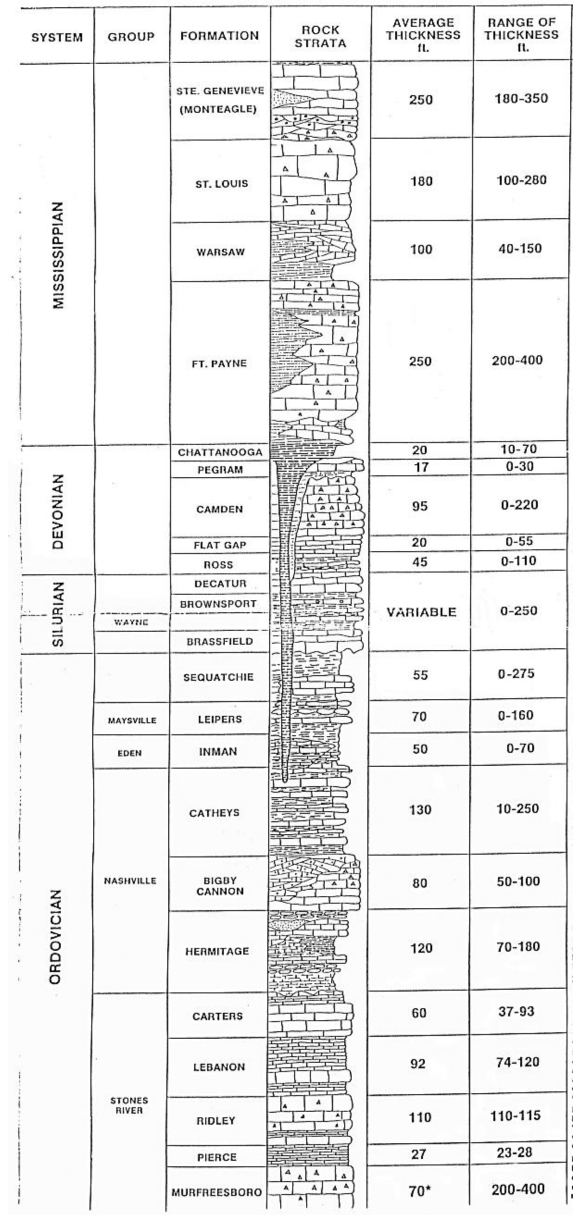
Research Objectives

- Recover and date zircon from limestone
- Test the use of zircon in tracing provenance of soils forming atop limestone
- Determine presence of external inputs such as:
  - Loess
  - Alluvium
- Characterize soil development in Middle TN

Middle Tennessee Geology

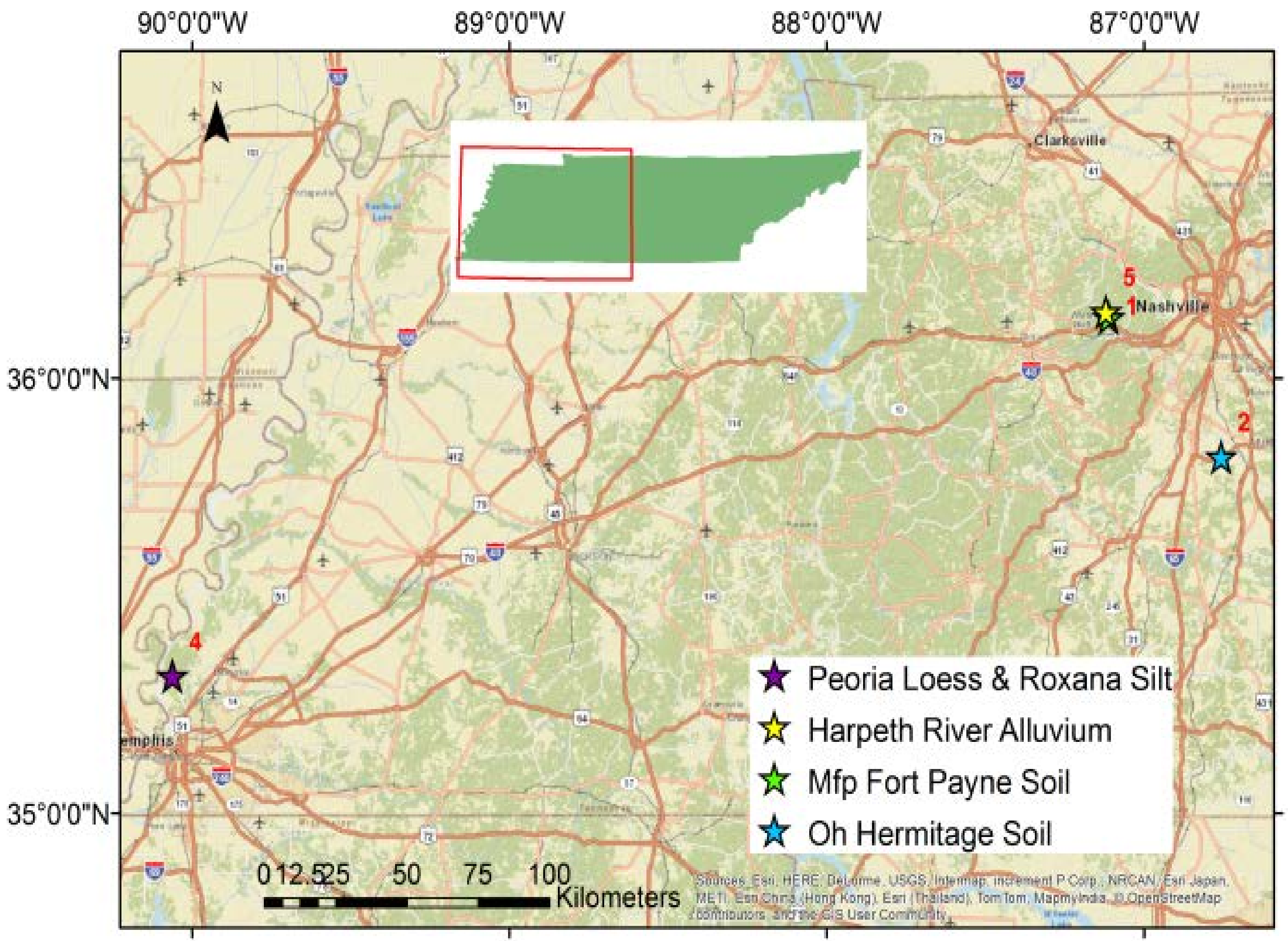


Middle Tennessee Geology



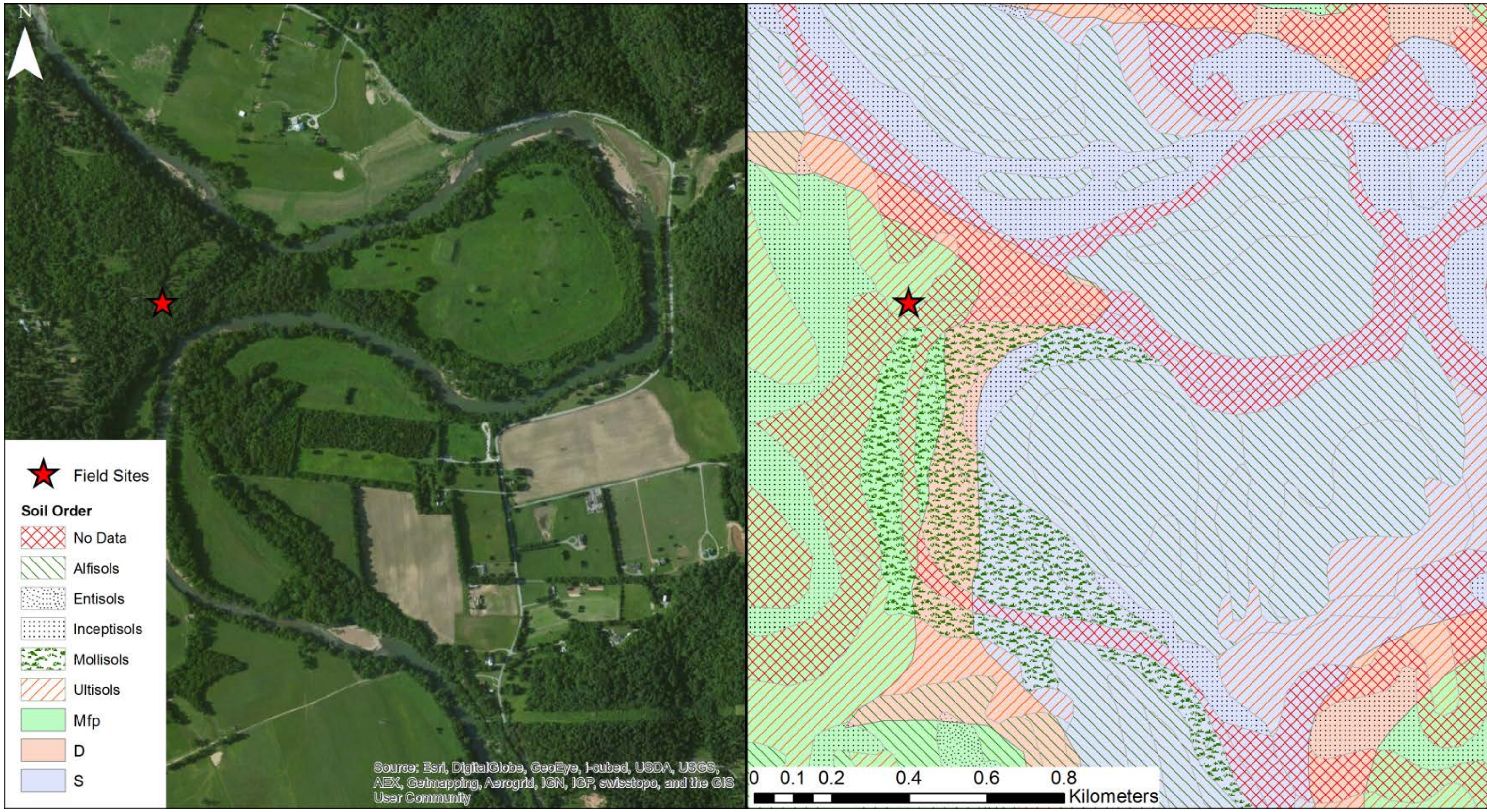
SYSTEM	GROUP	FORMATION	ROCK STRATA	AVERAGE THICKNESS ft.	RANGE OF THICKNESS ft.
MISSISSIPPIAN		STE. GENEVIEVE (MONTEAGLE)		250	180-350
		ST. LOUIS		180	100-280
		WARSAW		100	40-150
		FT. PAYNE		250	200-400
DEVONIAN		CHATTANOOGA		20	10-70
		PEGRAM		17	0-30
		CAMDEN		95	0-220
		FLAT GAP		20	0-55
		ROSS		45	0-110
SILURIAN		DECATUR		VARIABLE	0-250
		BROWNSPORT			
	WAYNE				
		BRASSFIELD			
ORDOVICIAN		SEQUATCHIE		55	0-275
	MAYSVILLE	LEIPERS		70	0-160
	EDEN	INMAN		50	0-70
	NASHVILLE	CATHEYS		130	10-250
		BIGBY CANNON		80	50-100
		HERMITAGE		120	70-180
	STONES RIVER	CARTERS		60	37-93
		LEBANON		92	74-120
		RIDLEY		110	110-115
		PIERCE		27	23-28
		MURFREESBORO		70*	200-400

Sample sites



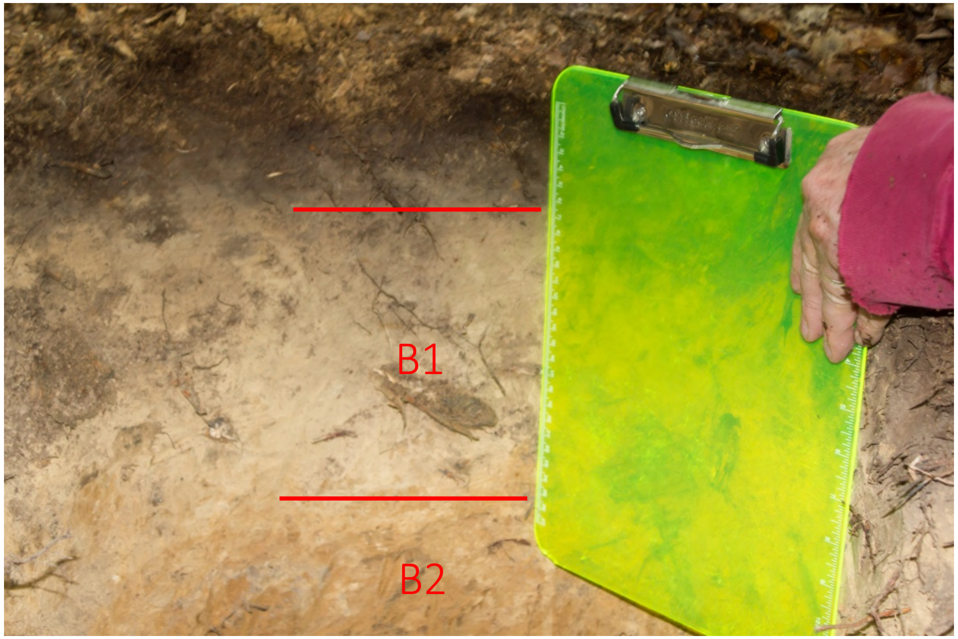
Field Site 1: Harpeth River Terrace

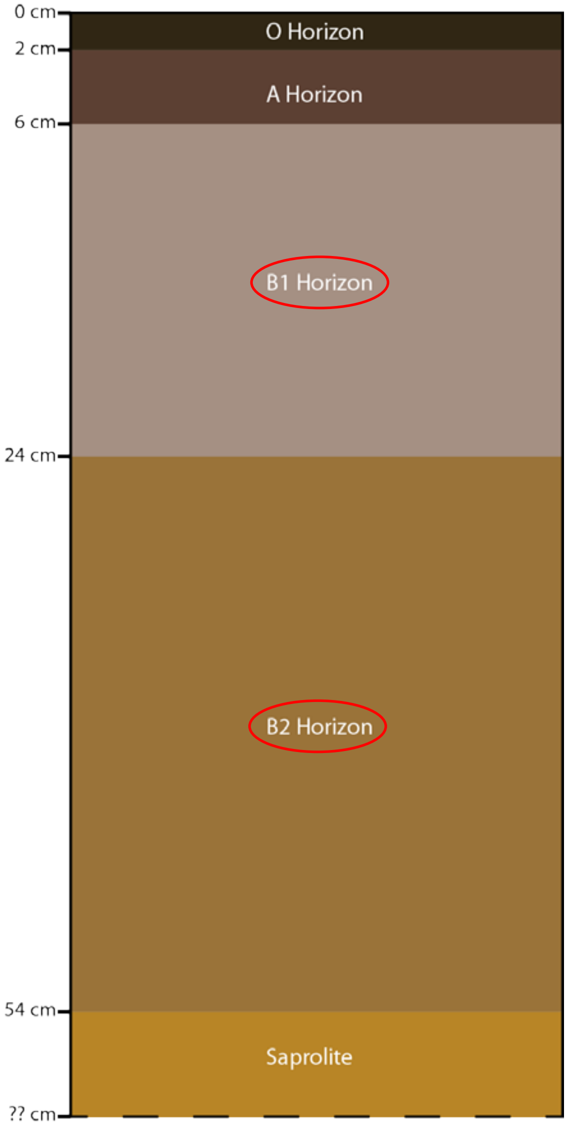
- Ultisols atop Sangamon age equivalent terrace (~128-75 ka)
- Fort Payne Fm. (Mfp) Mississippian cherty limestone***** bedrock (Wilson, 1990)



(Geological data from Nicholson et al., 2005; Soil data from NRCS, 2012)

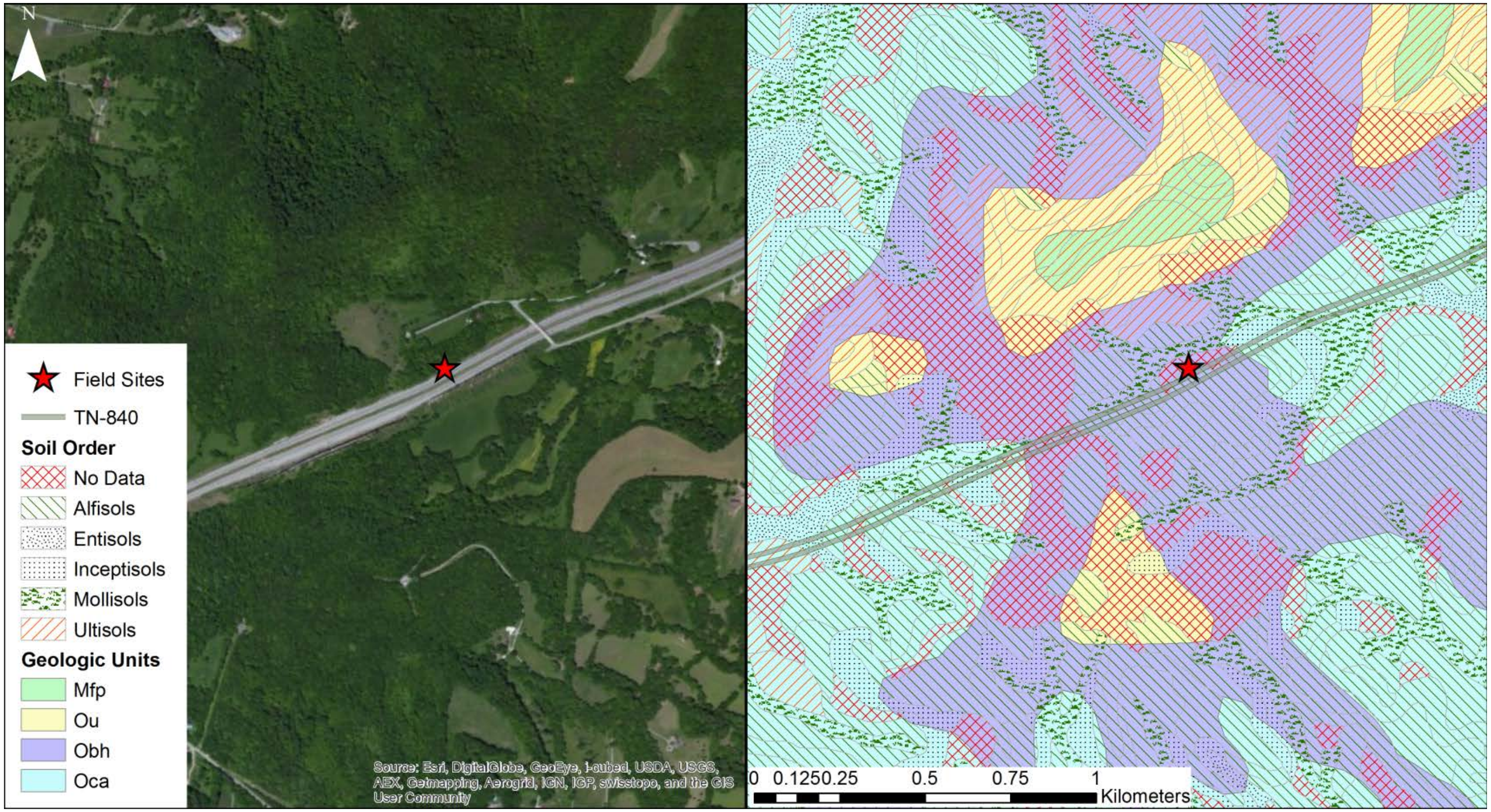
Sampling (Site 1)





Field Site 2: Highway Outcrop

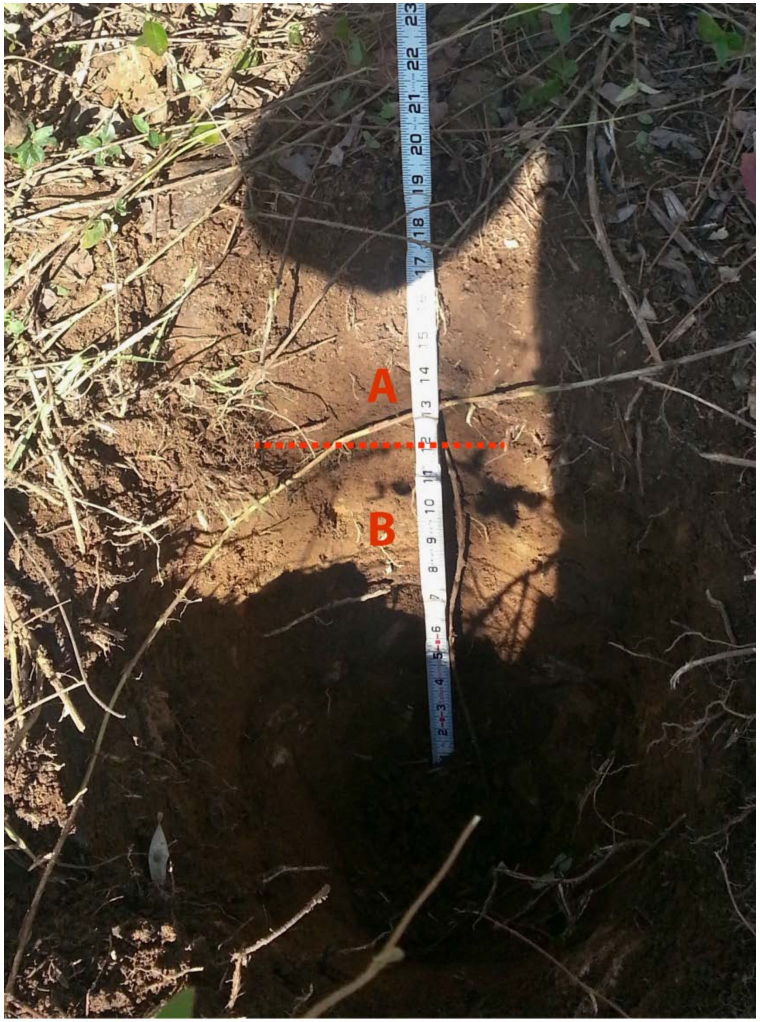
- Alfisol soils atop Hermitage Formation (Oh) bedrock



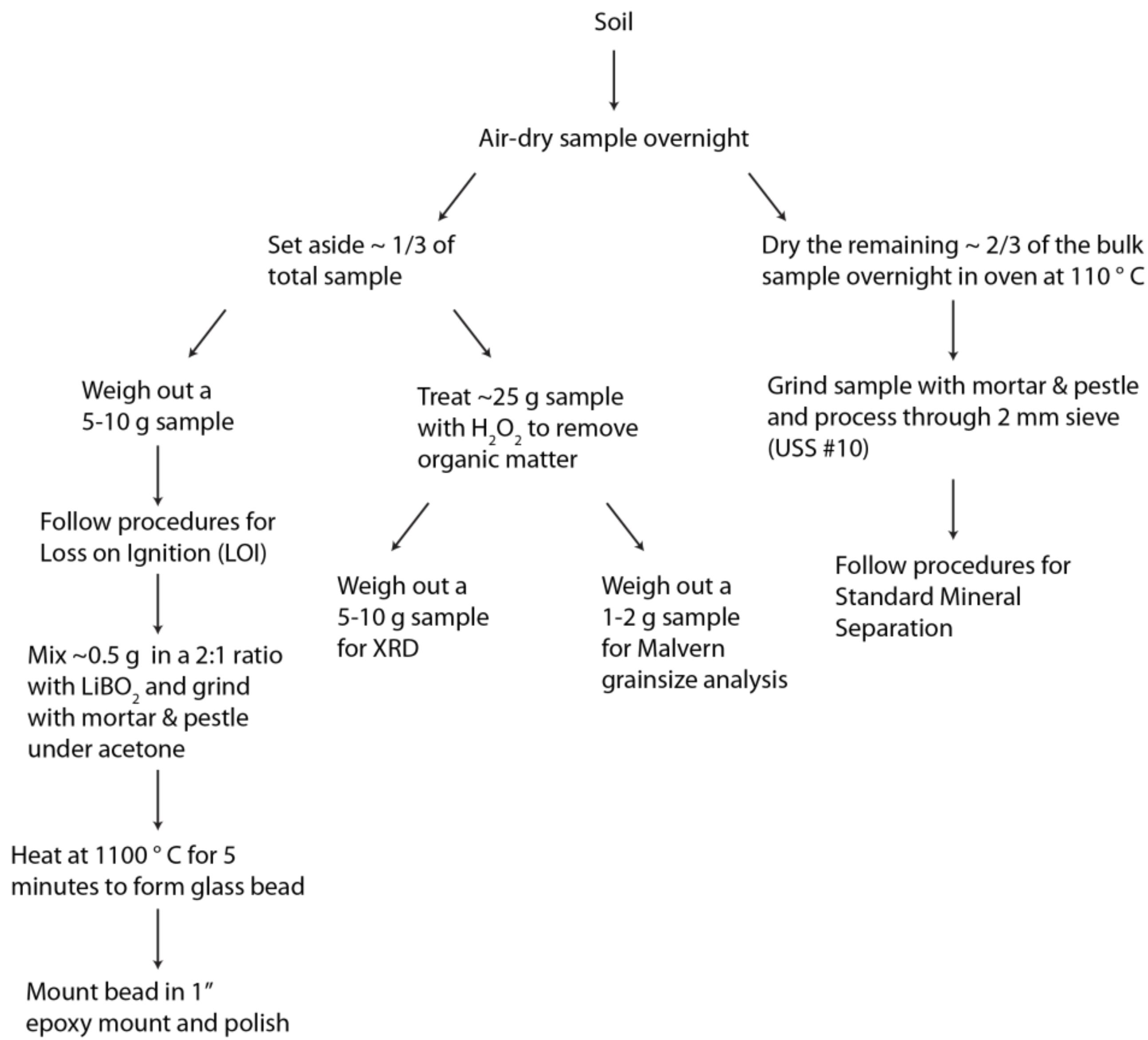
Field Site 2: Highway Outcrop

- Alfisol soils atop Hermitage Formation (Oh) bedrock

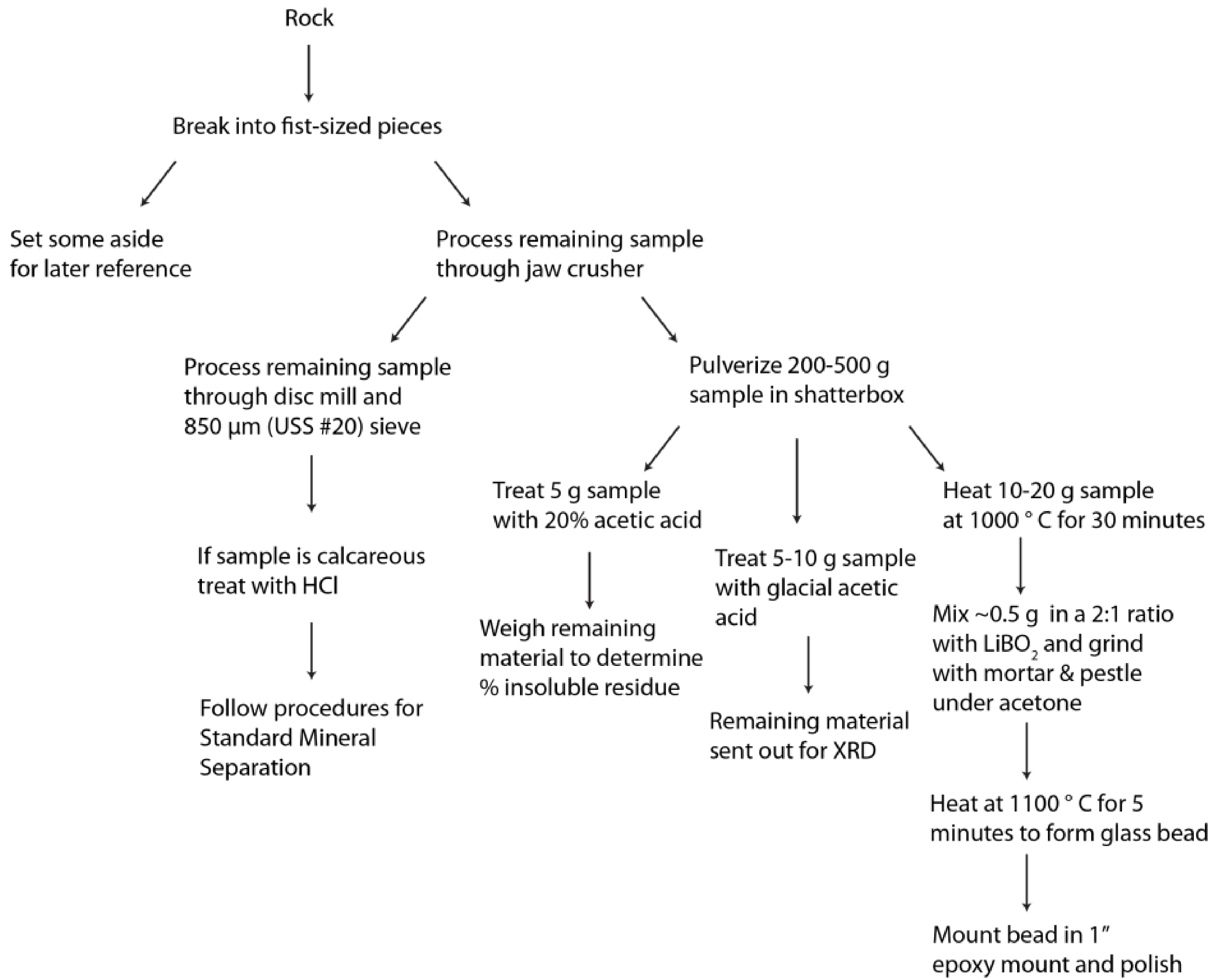
Sampling (Site 2)



Sample Preparation - Soil



Sample Preparation - Rock



Bulk Properties

Sample	Munsell Color	ρ (g/cm^3)	Mean grain size (µm)	Soil Texture (USDA)	% Insol. Residue	$\epsilon_{Zr,\,w}$	CIA
B1	10YR 6/3	1.5 ± 0.2	43	Silt	NA	0.81	73
B2	10YR 5/6	1.5 ± 0.2	19.9	Silt	NA	0.76	82
840W	7.5YR 5/4	1.8 ± 0.2	29.3	Silt Loam	NA	0.68	76
Mfp	10YR 7/6	2.2 ± 0.6	NA	NA	99%	NA	71
Oh	2.5Y 5/1	2.5 ± 0.1	NA	NA	28%	NA	80

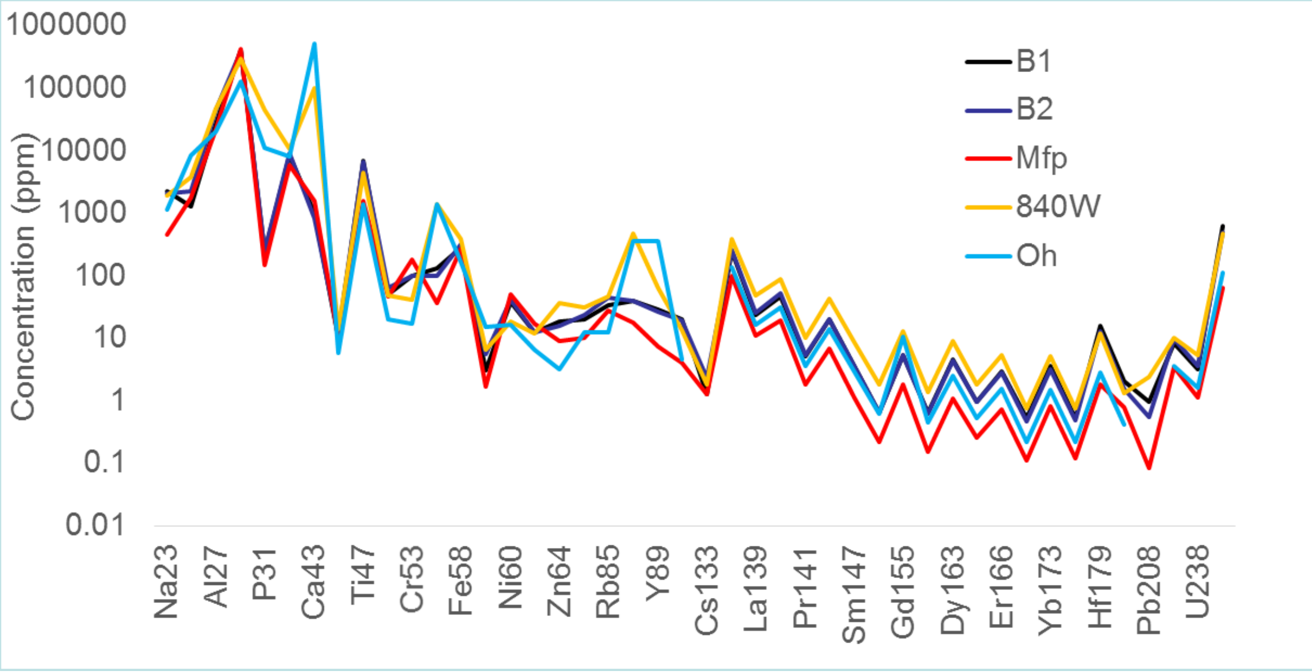
Major Element Concentrations

	B1	B2	Mfp	840W	Oh
Na2O	0.27	0.22	0.06	0.27	0
MgO	0.07	0.31	0.23	0.44	0.92
Al2O3	4.71	7.58	3.71	7.18	3.73
SiO2	90.83	86.29	92.54	62.50	27.84
P2O5	0	0	0	11.22	2.87
K2O	1.17	1.1	0.78	1.20	0.81
CaO	0.1	0.03	0.23	13.08	62.95
TiO2	1.11	1.04	0.19	0.63	0
FeO	1.73	3.44	2.26	3.48	0.88
O.C.	2.6	2.25	NA	2.2	NA
% Insol.	NA	NA	98.78	NA	27.69
CIA*	0.73	0.82	0.76	0.71	0.80

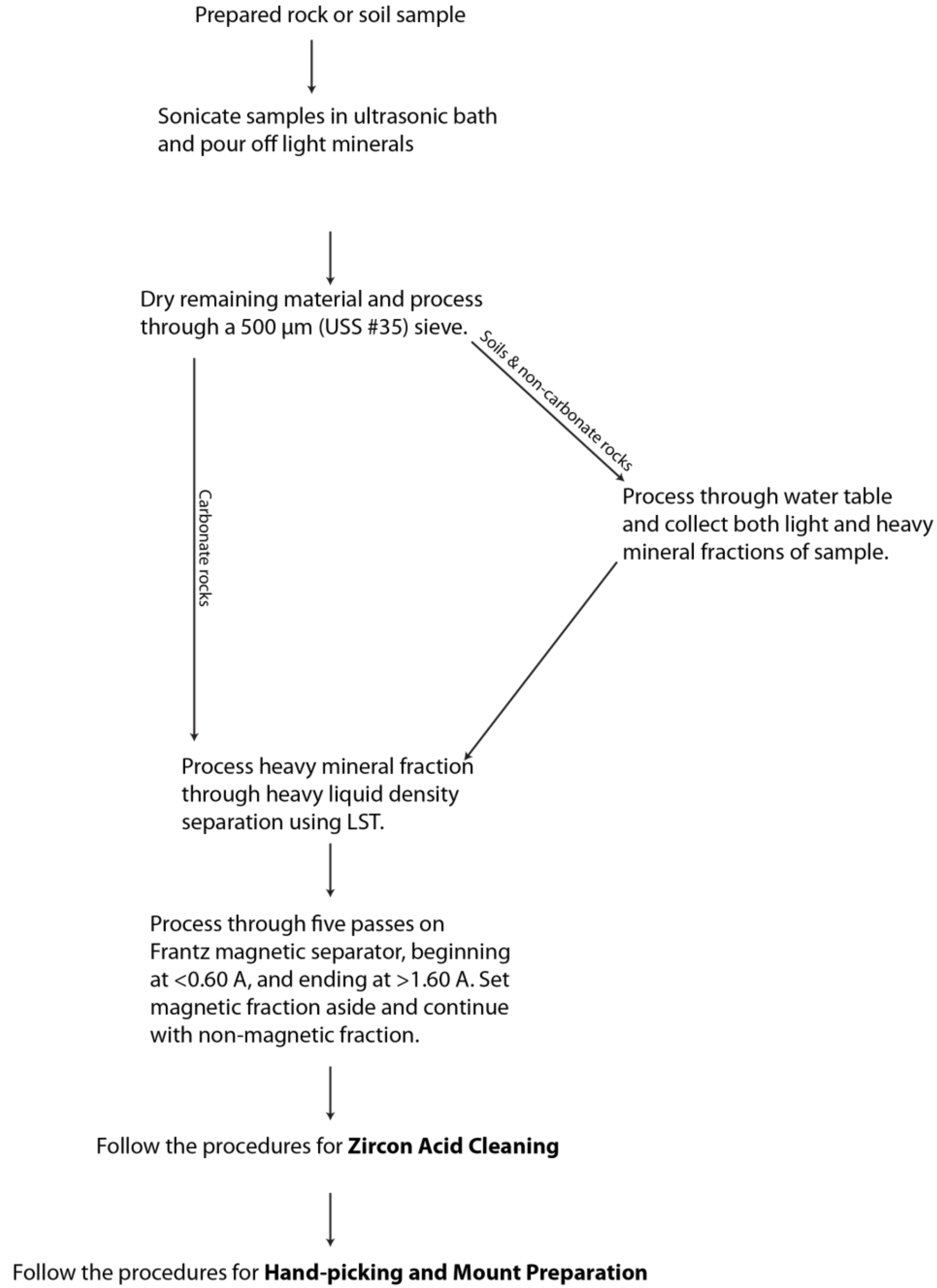
CIA = Al2O3/(Al2O3 + CaO + Na2O + K2O)
Where CaO* is the amount associated with the silicate fraction of the sample.

Trace Element Compositions

- Similar trace element signatures for soil bedrock pairs imply weathering of bedrock to form soil:
  - Hermitage formation bedrock (Oh) and 840W soil
  - Fort Payne bedrock (Mfp) and B1 and B2 horizons.

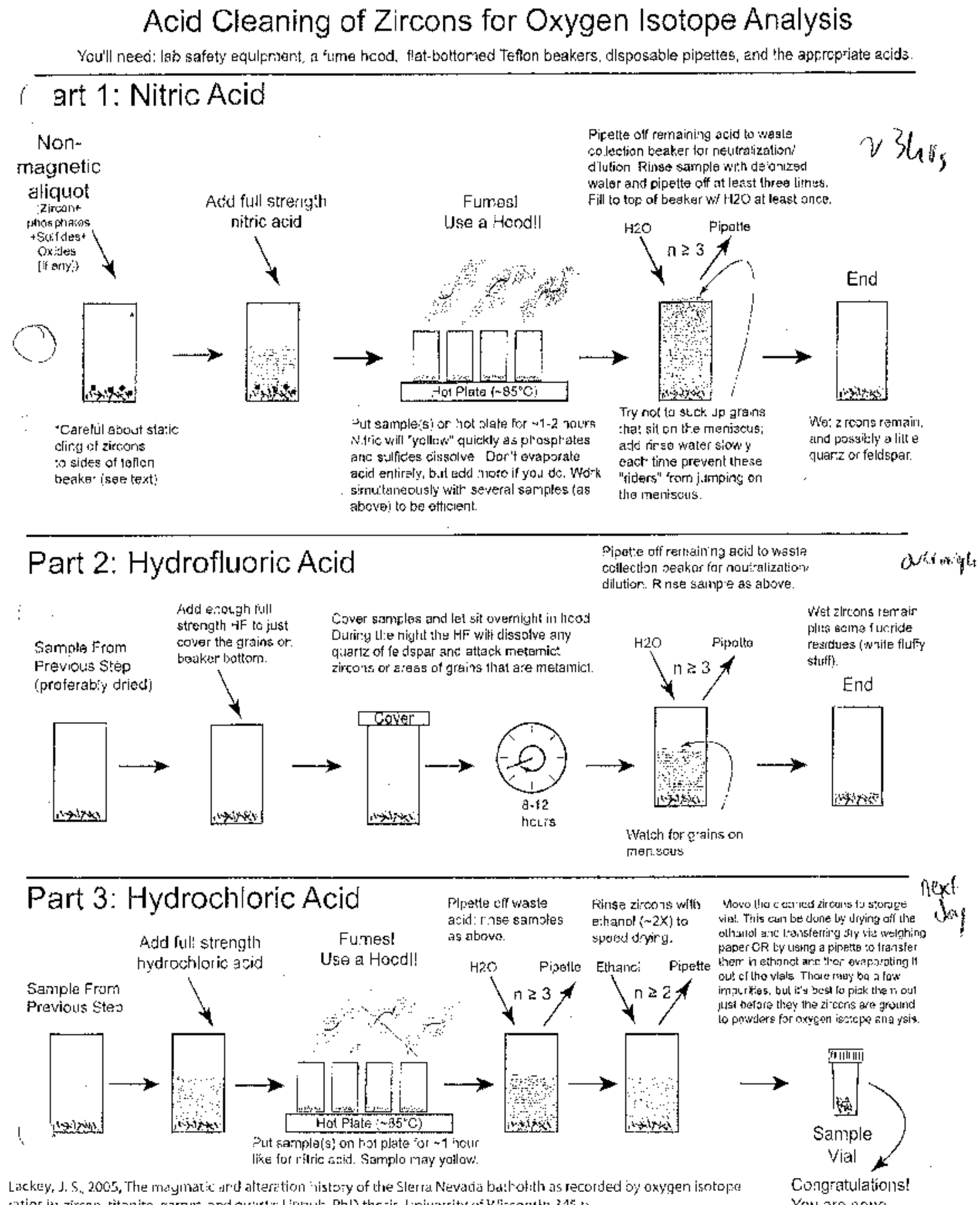


Mineral Separation Procedures



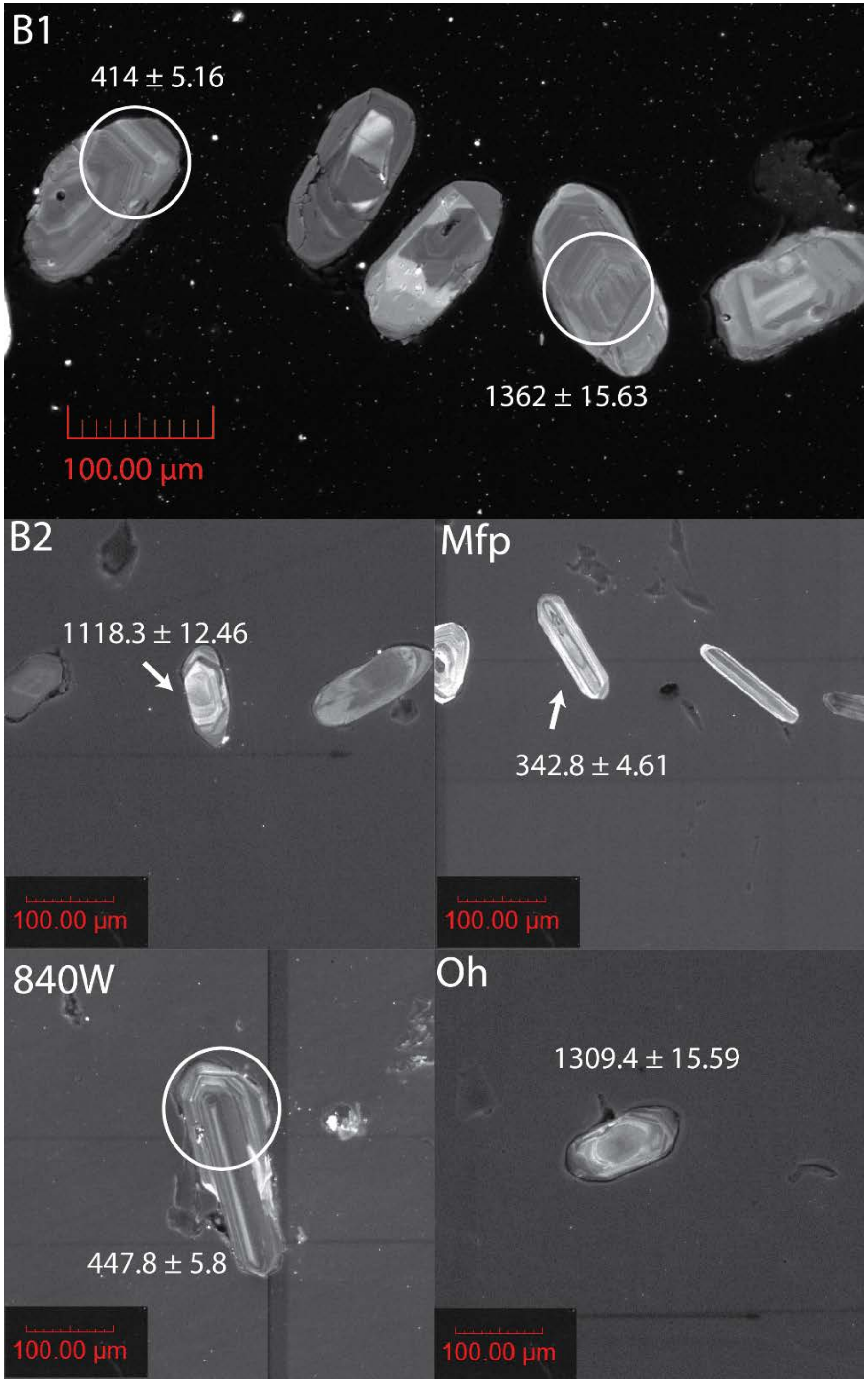
Zircon Acid Cleaning

- Removal of “junk” and metamict zircon
- Steps:
  - 10% HCl
  - 70% HNO_3
  - 40-45% HF
  - 10% HCl



Lackey (2005)

CL Images

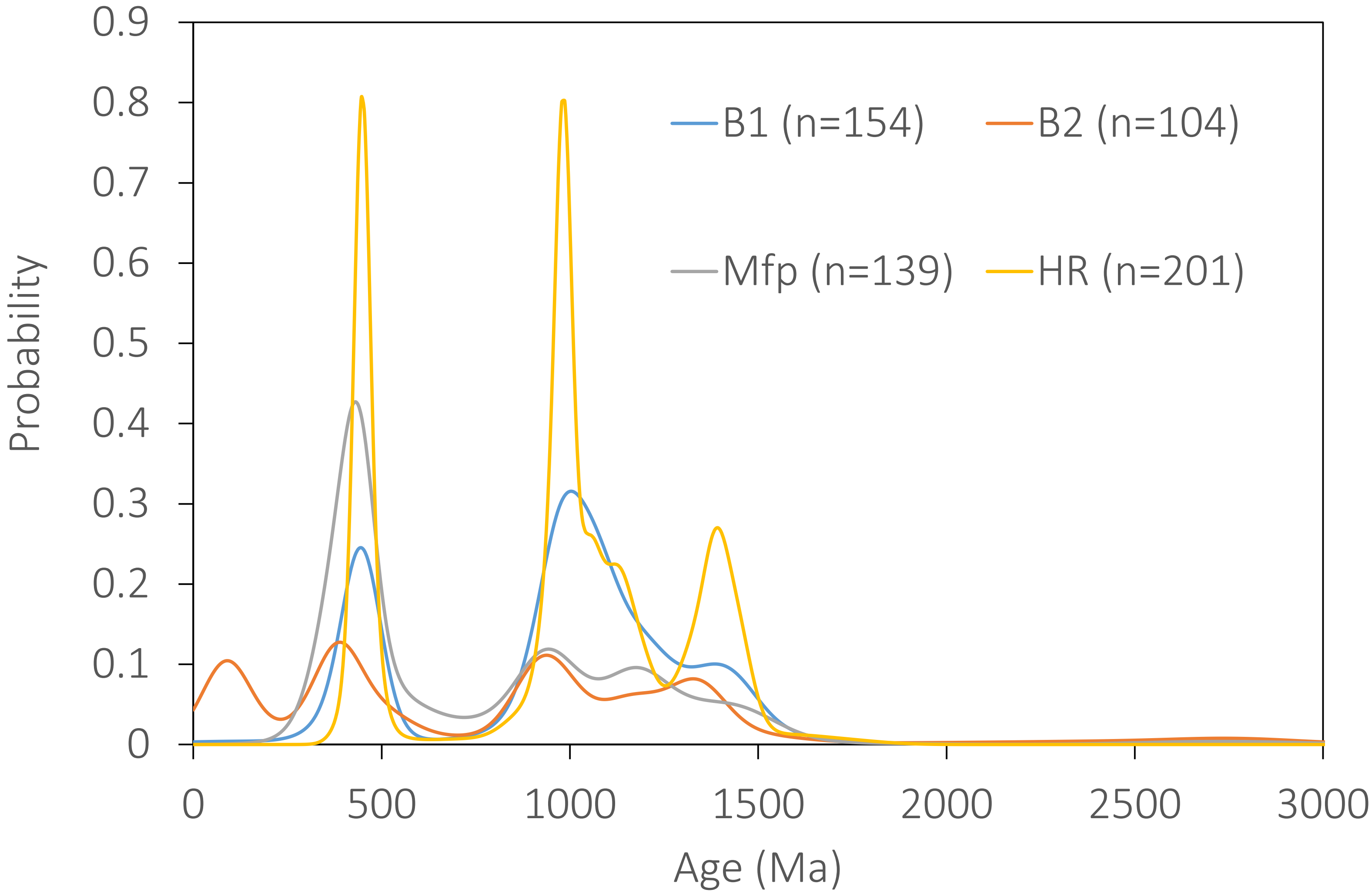


B1
414 ± 5.16
1362 ± 15.63
100.00 µm
B2
1118.3 ± 12.46
100.00 µm
Mfp
342.8 ± 4.61
100.00 µm
840W
447.8 ± 5.8
100.00 µm
Oh
1309.4 ± 15.59
100.00 µm

Procedures

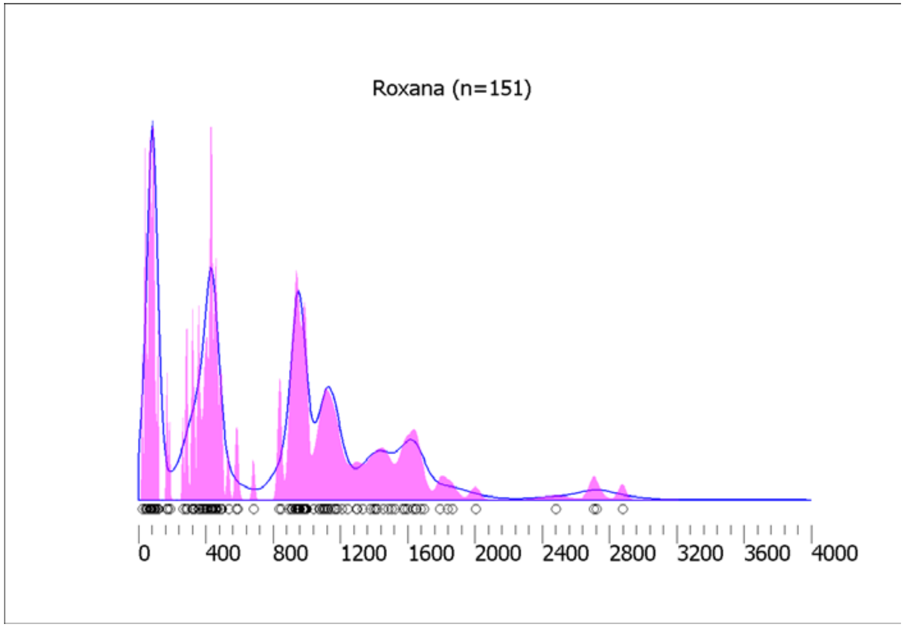
- ThermoFisher iCAP Qc quadrupole ICP-MS with CETAC autosampler and Photon Machine Excite 193nm excimer laser ablation system
- Filtering data:
  - for ages <1Ga, use $^{206}Pb/^{238}U$ age, $100*(^{206}Pb/^{238}U)/(^{207}Pb/^{235}U)$ should be within 90%-110%
  - for ages >1Ga, use the $^{207}Pb/^{206}Pb$ age, $100*(^{206}Pb/^{238}U)/(^{207}Pb/^{235}U)$ should be within 90%-110% and $100*(^{207}Pb/^{206}Pb)/(^{206}Pb/^{238}U)$ should be within 90%-110%.

Site 1 Age Spectra

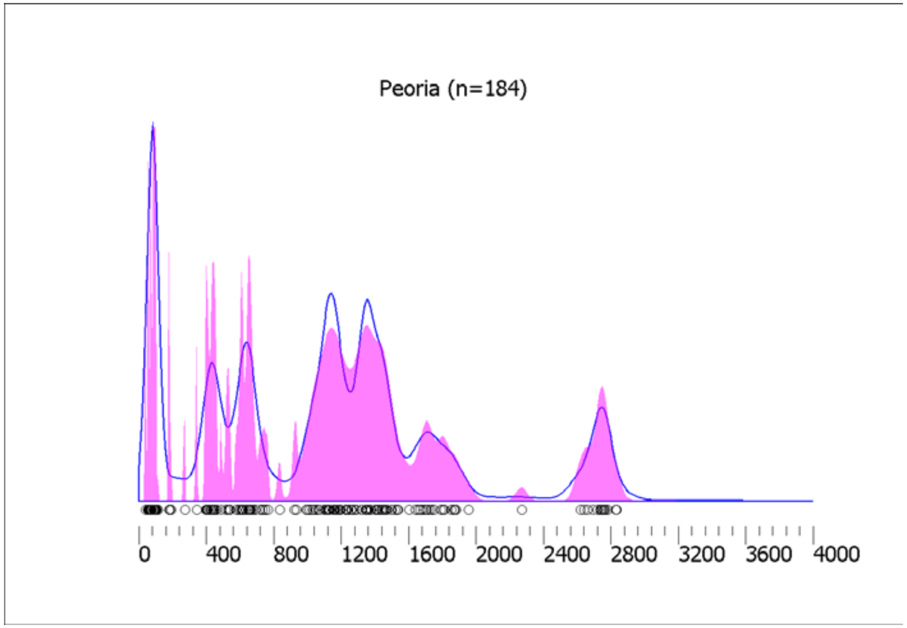


Loess samples

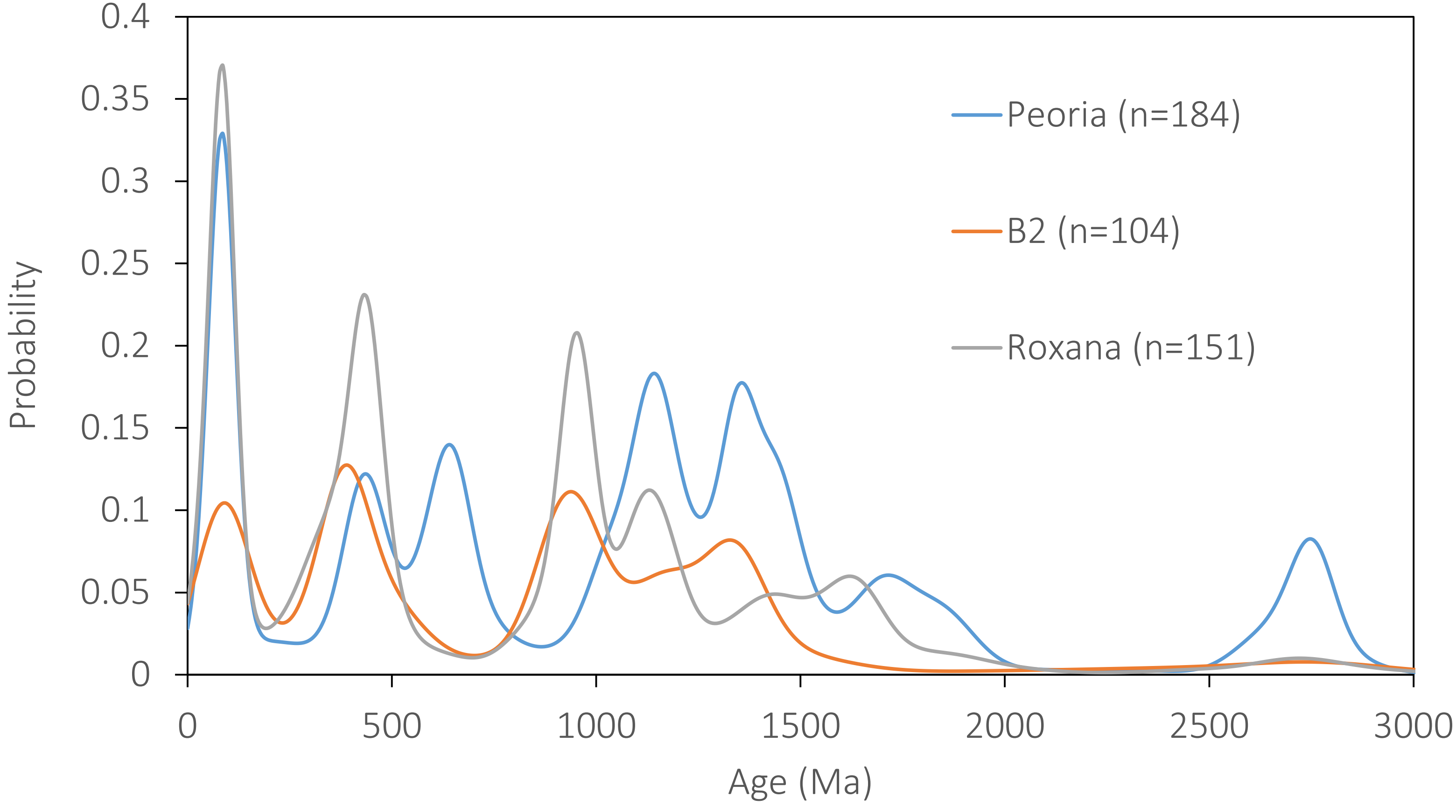
Roxana loess



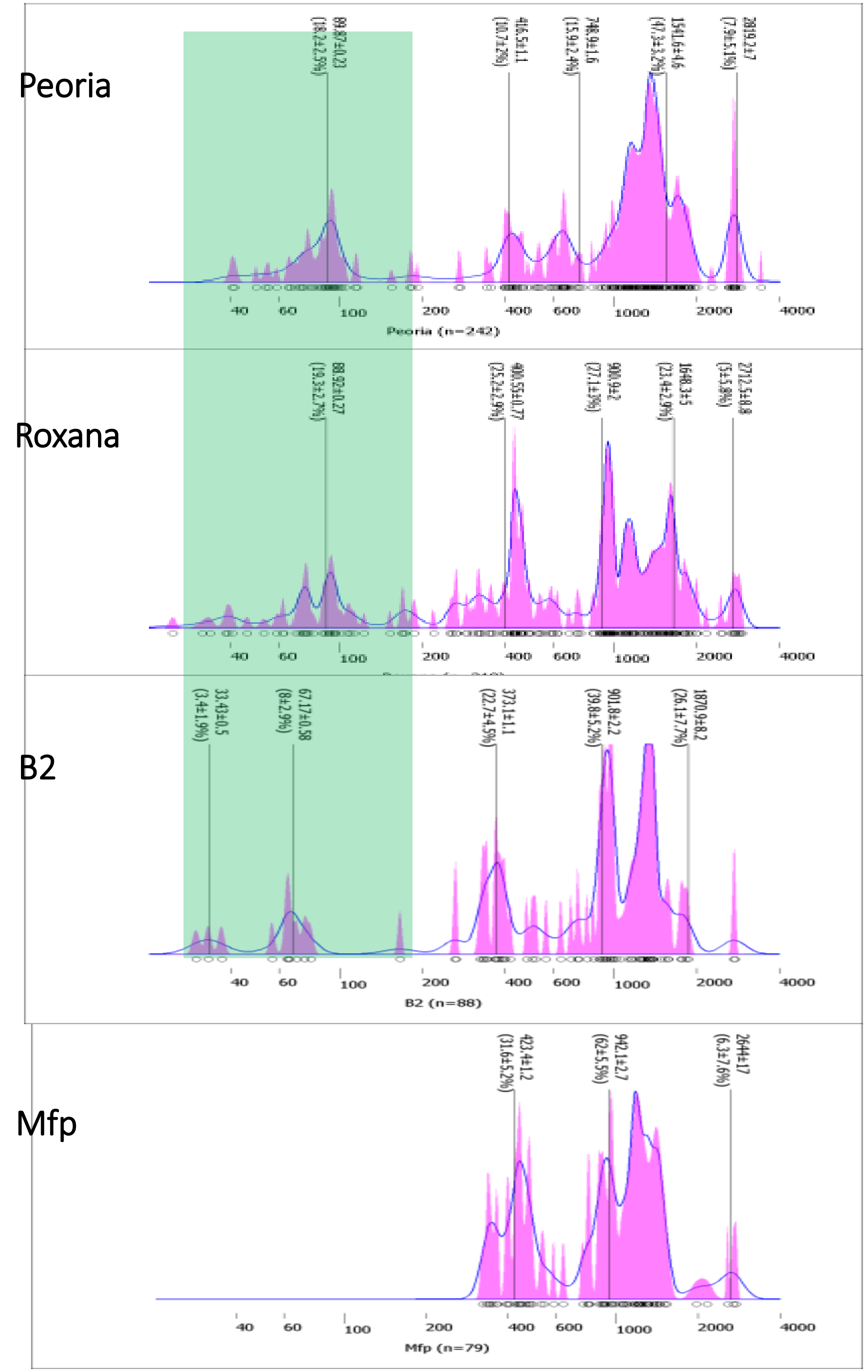
Peoria loess



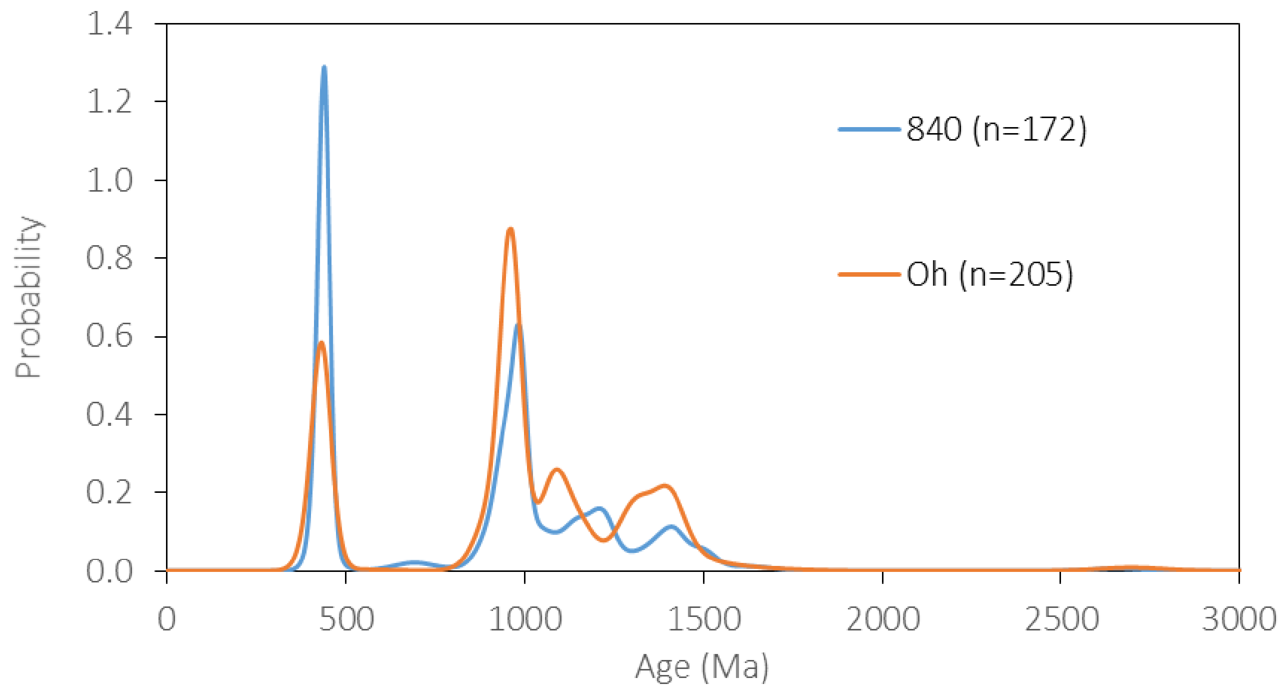
Input of loess to B2?

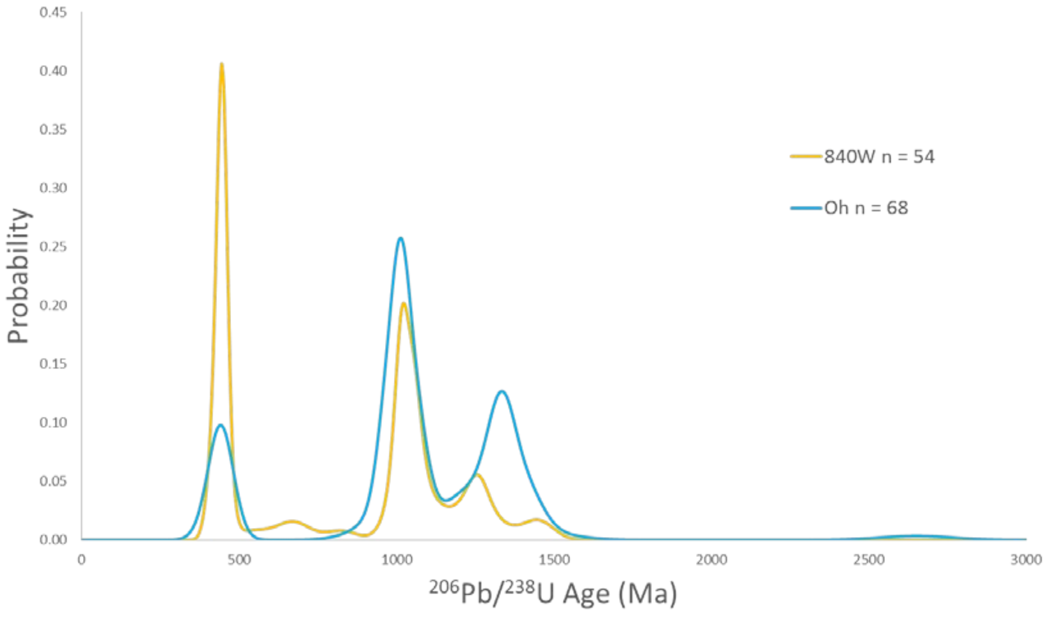


Input of loess to B2 soil



Site 2 Age Spectra





X-Ray Diffraction Results

Sample	Quartz	Plag	Apatite	Chlorite	Illite	Amphibole	Dolomite
Harpeth River	97	3					
B1	95	5					
B2	95	3		2			
Peoria loess	77	6		2	1	1	13
Roxana loess	97	3					
Mfp	>98						
840W	92	4	4				
Oh	78	4	8		10		

Conclusions

- Bedrock age peaks overlap with the Grenville, Taconic, and Acadian orogenies of eastern North America.
- Soil age peaks and other evidence require:
    - Above Fort Payne chert bedrock:
        - Input of Roxana +/- Peoria loess to form ultisol B2 soil horizon
        - Deposition of Harpeth River alluvium to form ultisol B1 horizon
    - Chemical weathering of Hermitage limestone bedrock to form 840 alfisol
- Zircon is recoverable from limestone
- Zircon U-Pb geochronology is an effective tool for determining provenance of soil and limestone