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Geochemical Variability of Soils in the Maritime Provinces of Canada and the New England States of the United States

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U.S. Geological Survey

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The North American Soil Geochemistry Landscape Project (NASGLP)

- The NASGLP was developed as a joint Mexico, USA, and Canada project for characterizing the soil cover over North America.
- Goals of the NASGLP are:
  - develop a continental-scale framework for generating and managing geochemical and mineralogical data.
  - produce a continental array of soil data using consistent sampling and analytical protocols.
  - establish an archive of soil samples for future researchers
- In 2004 two transects (W-E and N-S) that crossed the US and Canada were conducted as a pilot study – results reported in a special issue of Applied Geochemistry, Vol. 24 (8), 2009.
- Spatial sampling in the US and Canada began in 2007 – Maritime provinces sampled by GSC and provincial surveys; New England states + New York sampled by USGS.

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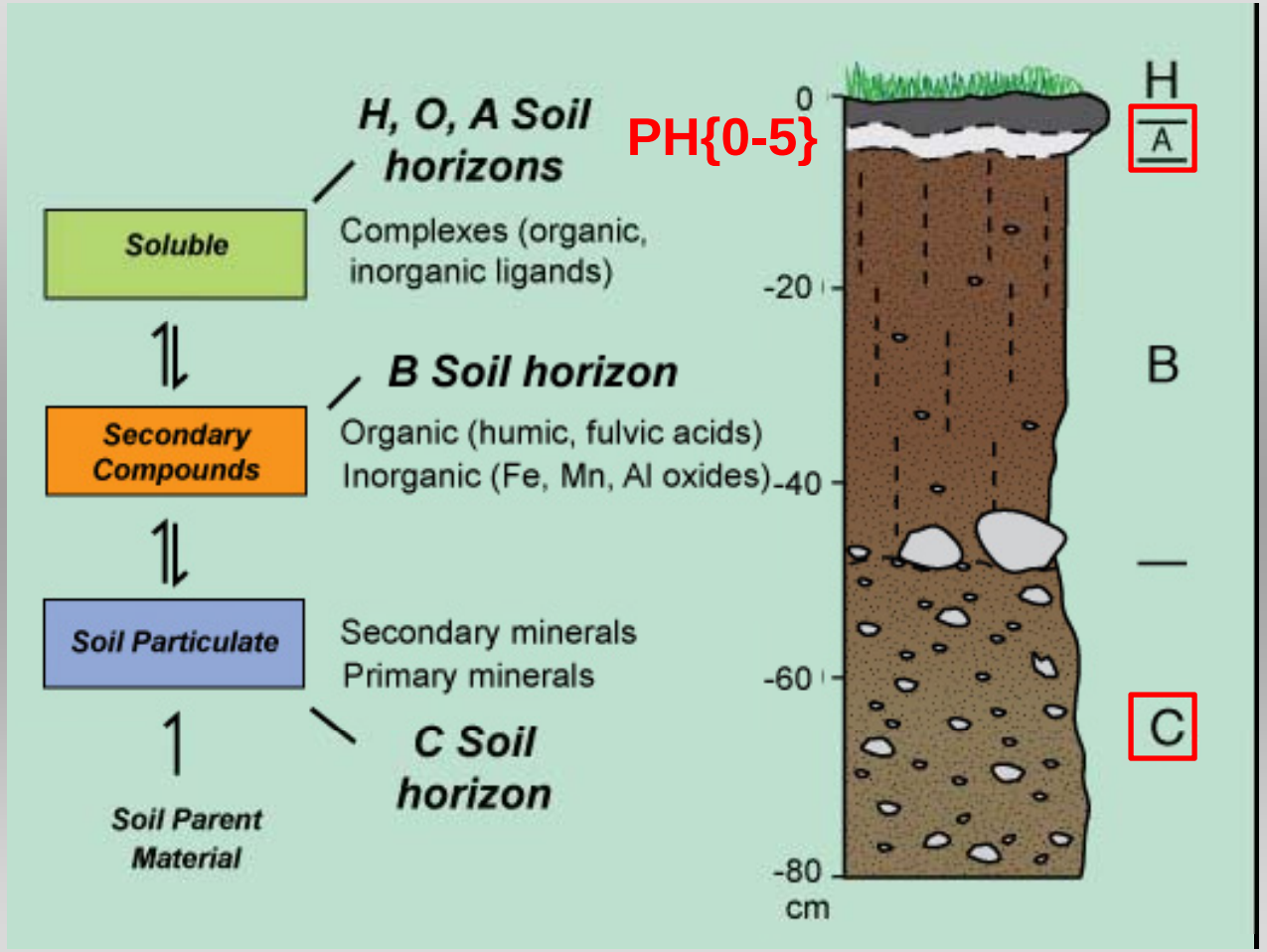
Soil Horizons



Three samples in this analysis

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Analytical Protocols

- Geochemical analysis of the 3 soil horizons (PH (0-5 cm depth), A & C horizons)
- Samples sieved to < 2 mm & milled to < 150 mm
- 4 acid digestion (HNO_3-HF-HCl-$HClO_4$)
- ICP-MS/ICP-AES instrumentation
- Hg – Cold Vapour AA (US samples)
- Hg – Aqua-Regia ICP-MS (CD samples)
- As – Hydride generation (US samples)
- As – 4 acid ICP-MS (CD samples)

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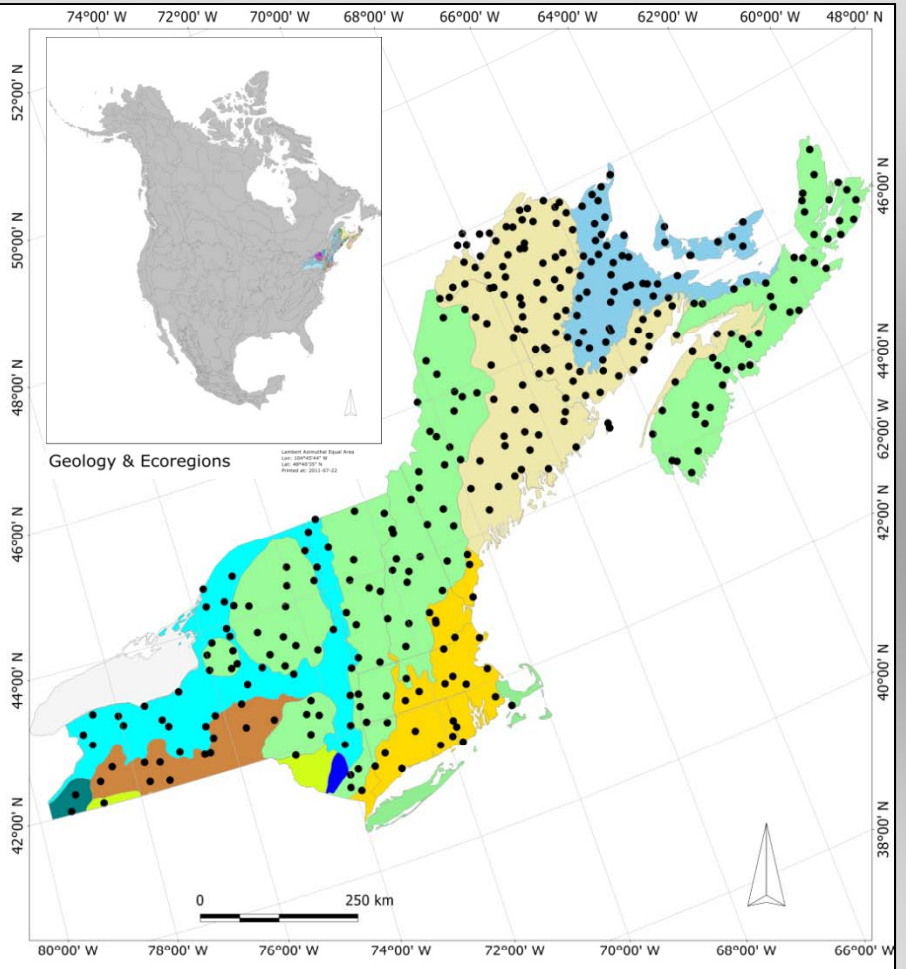
Sample Sites

~1 sample/1600 km^2 in US; double density in Canada

EcoRegions

- Atlantic Coastal Pine Barrens **(ACPB)**
- Eastern Great Lakes and **(EGLHL)** Hudson Lowlands
- Erie Drift Plain **(EDP)**
- Lake Erie Lowland **(LEL)**
- Maine/New Brunswick Plains and Hills **(MPH)**
- Maritime Lowlands **(ML)**
- North Central Appalachians **(NCA)**
- Northeastern Coastal Zone **(NECZ)**
- Northern Appalachian **(NAPU)** Plateau and Uplands
- Northern Appalachian and **(NAAMH)** Atlantic Maritime Highlands
- Ridge and Valley **(RV)**



Survey Design

Lambert Azimuthal Equal Area

Basic Questions

- What is the chemical and mineralogical variability in soil profile throughout different geological units and ecoregions?
- How can this be understood and visualized?
- What can a statistical analysis of the data tell us?

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Compositional Aspects of the Geochemistry

- Soil geochemistry (%, mg/kg) is compositional and subject to closure.
- Centered logratio (clr) and isometric logratio (ilr) transformations were used.
- Relationships in the data reveal processes of deposition, erosion, weathering and alteration (e.g., groundwater effects).

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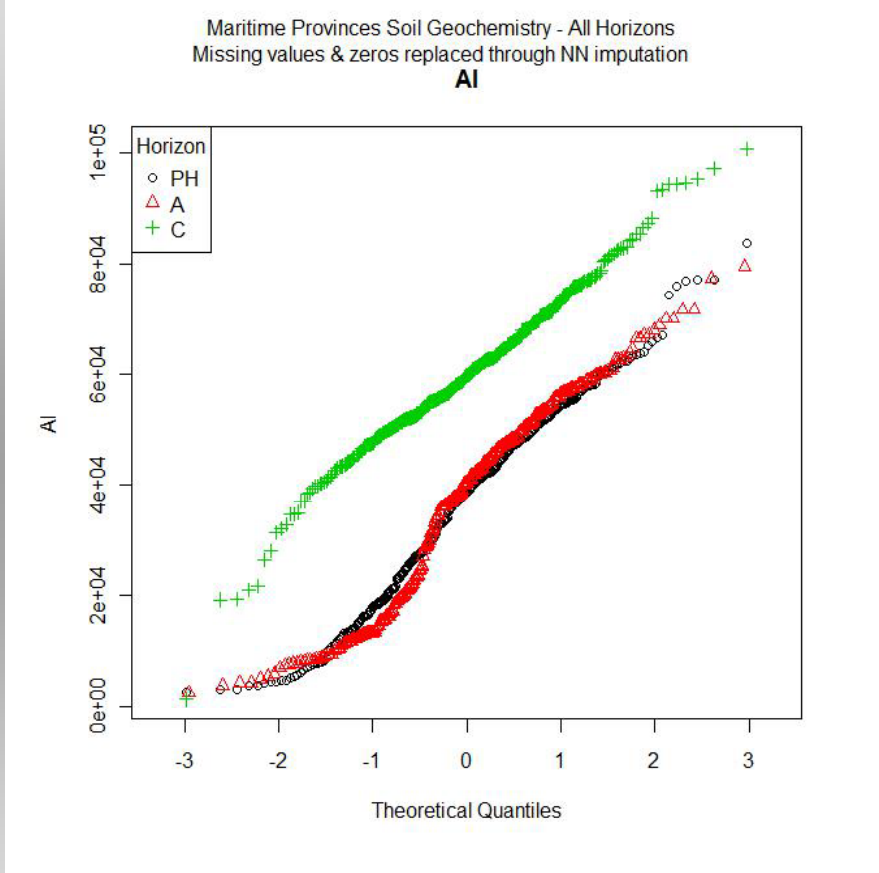
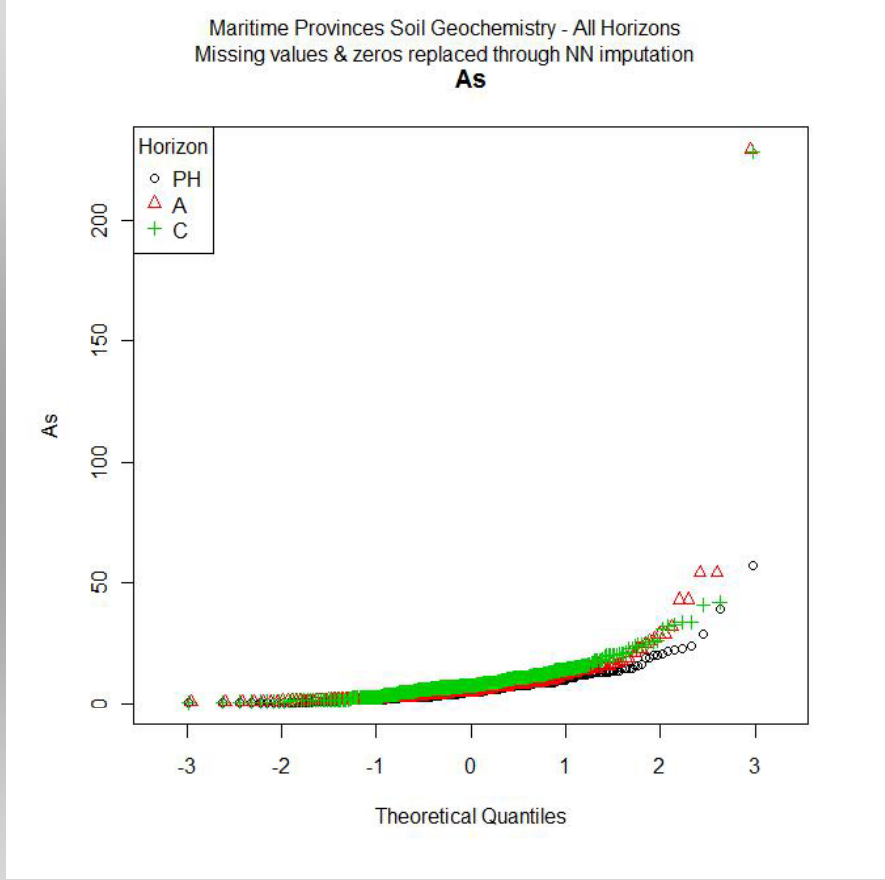
Quantile-Quantile Plots – Soil Geochemistry



Al dominant in C horizon



As nearly equal in all 3 horizons

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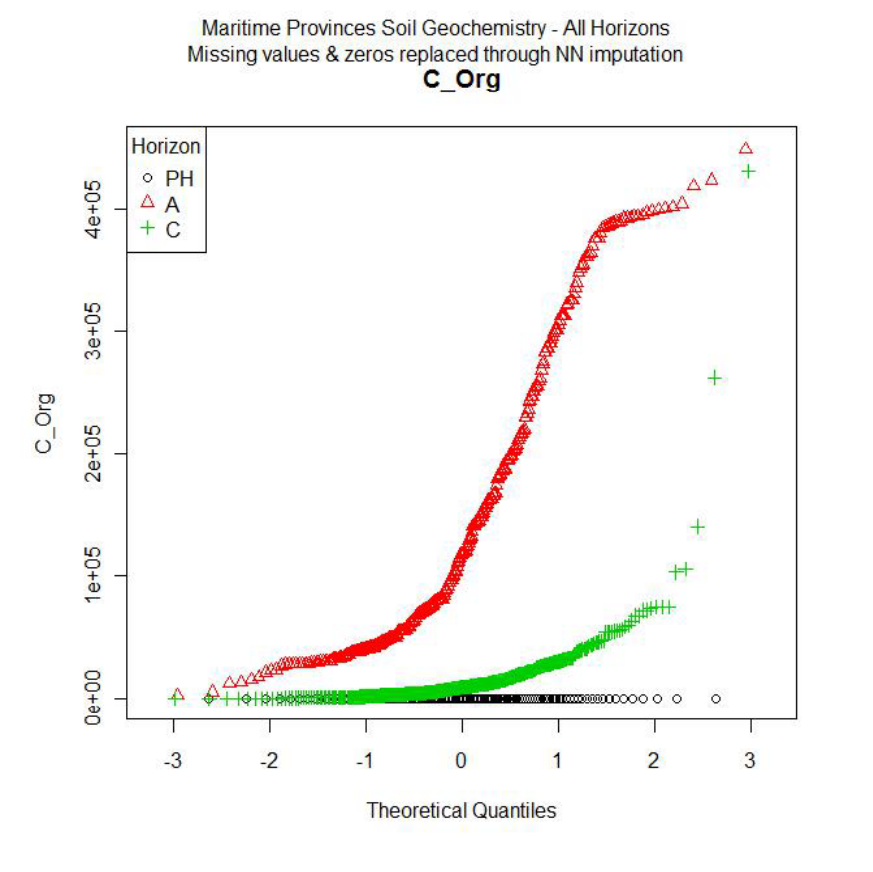
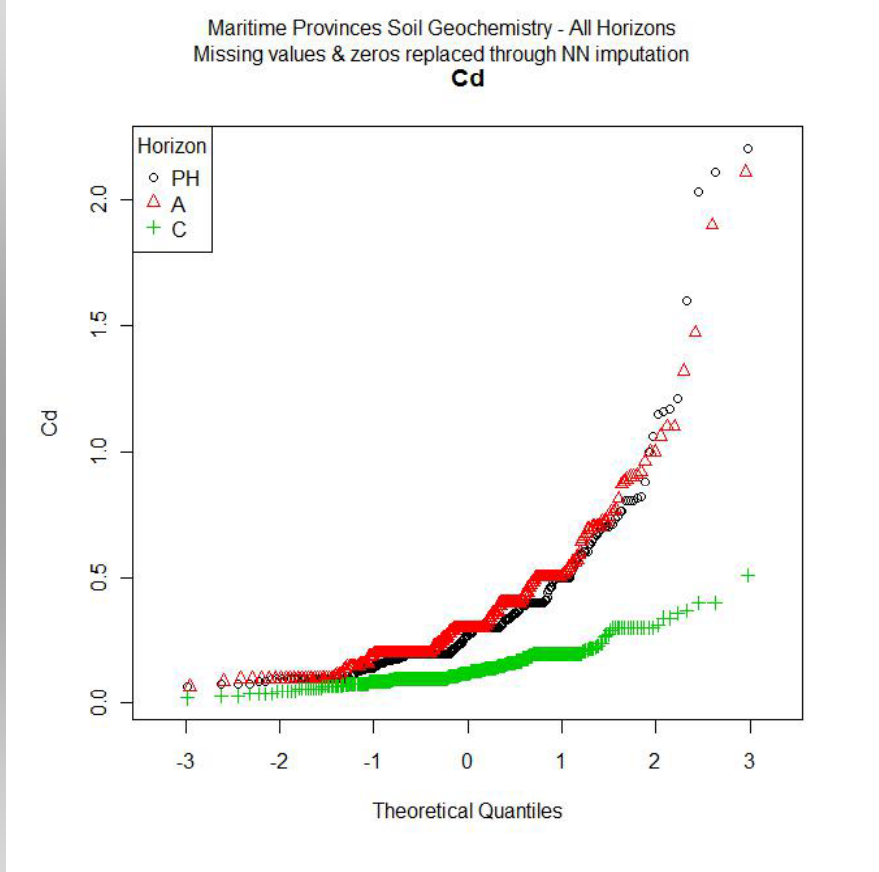
Quantile-Quantile Plots – Soil Geochemistry



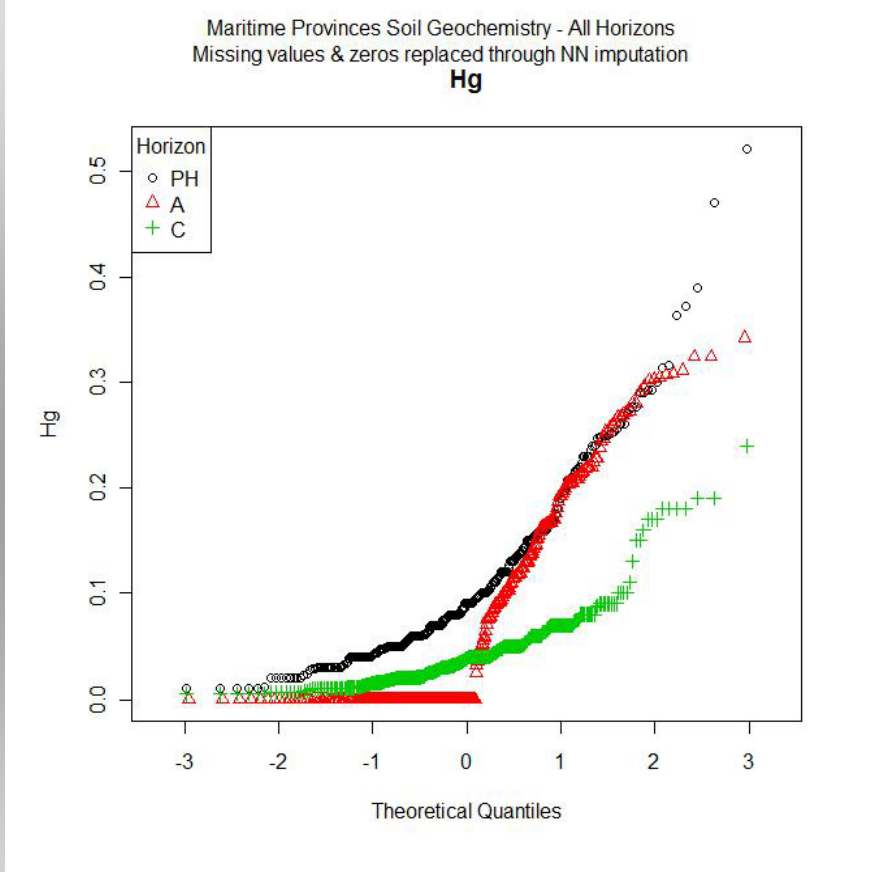
Organic carbon dominant in the A horizon



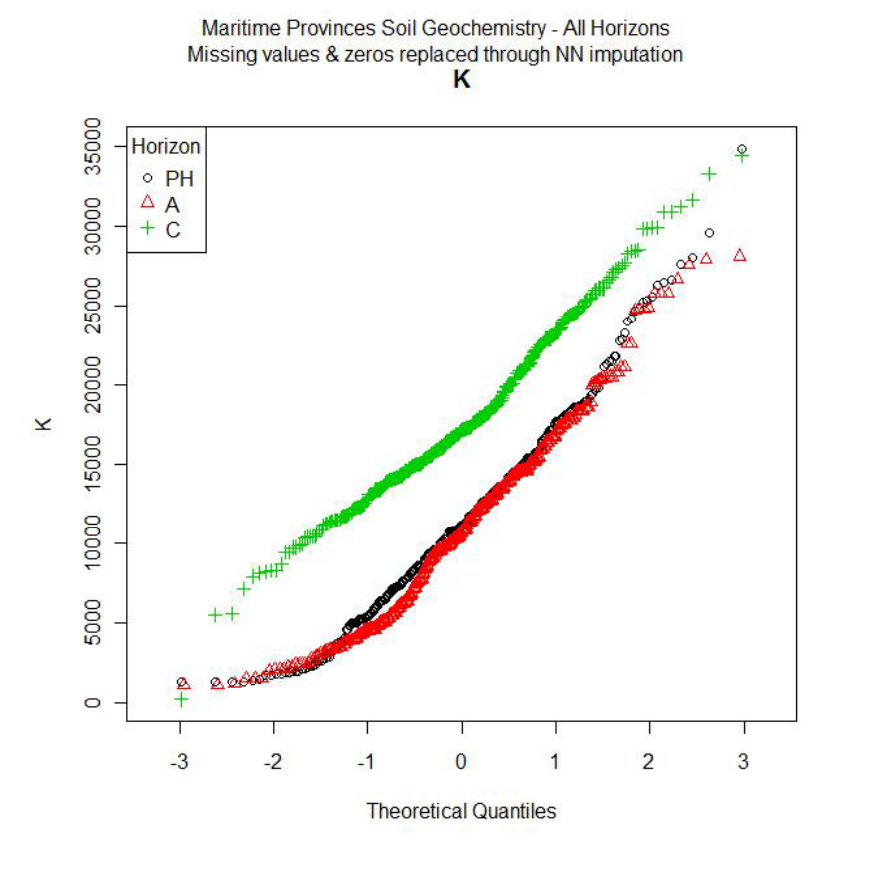
Cd dominant in the PH & A horizons

Carbon not determined in PH horizon

Quantile-Quantile Plots – Soil Geochemistry



Hg dominant in PH & A horizons



K dominant in the C horizon

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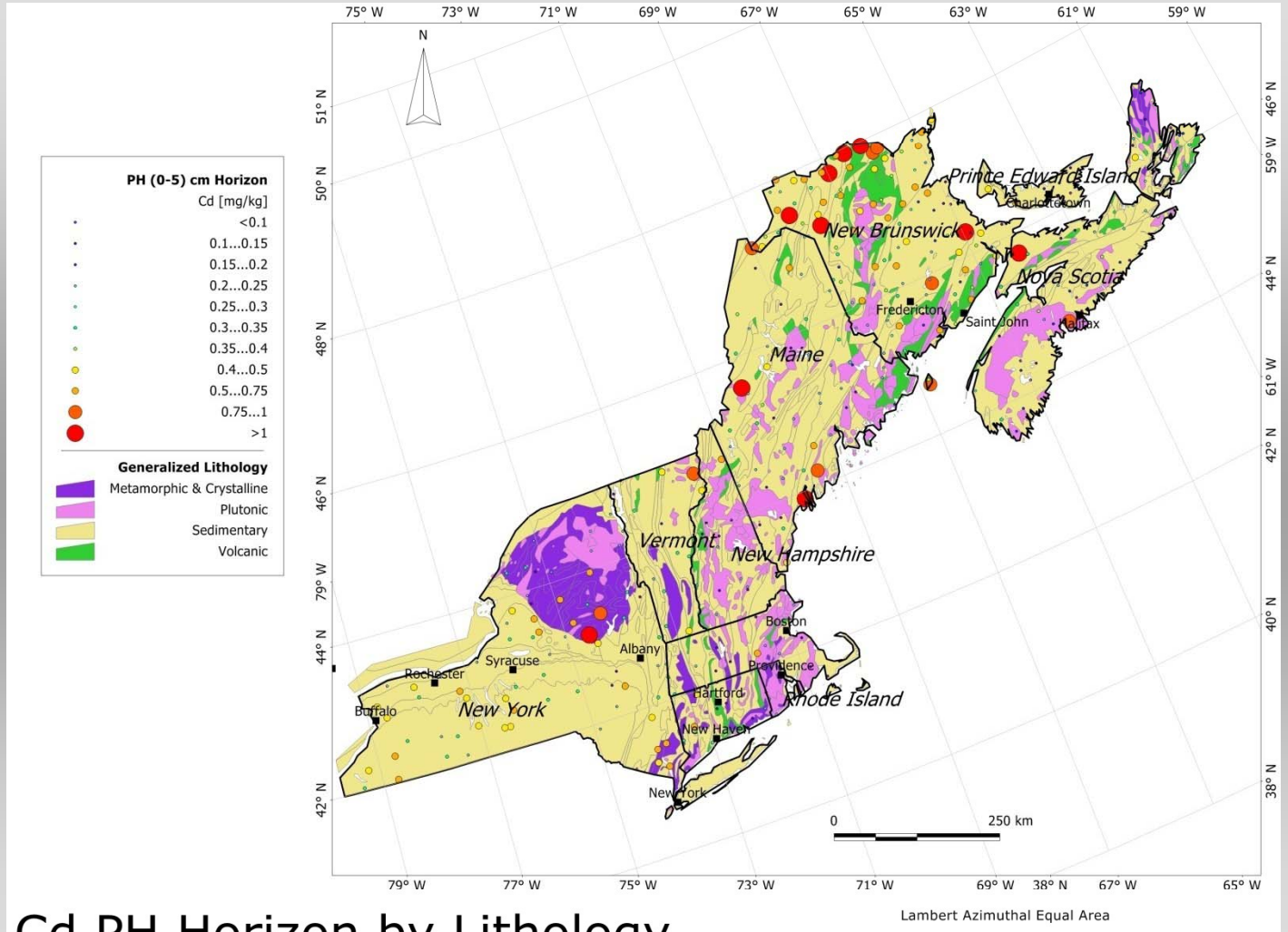
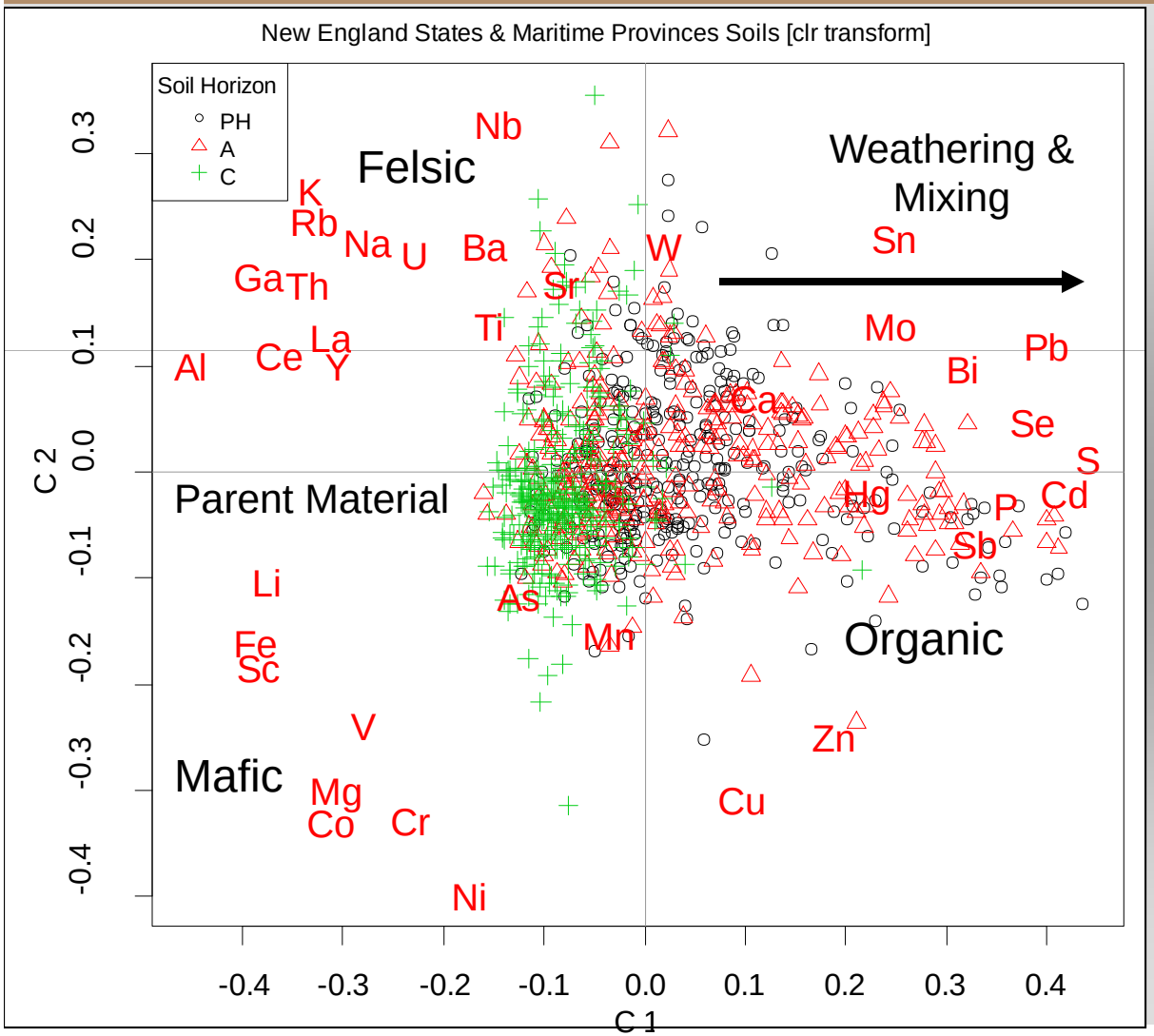
Cd – PH Horizon



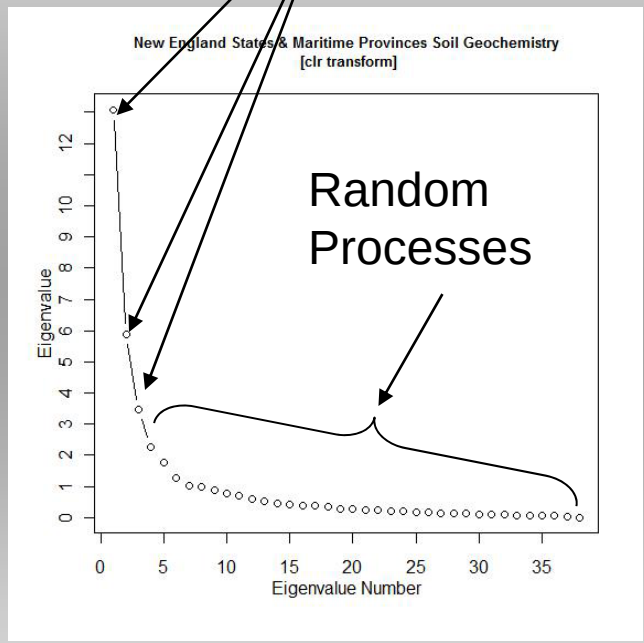
Cd PH Horizon by Lithology

Cd associated with organic material in the PH horizon

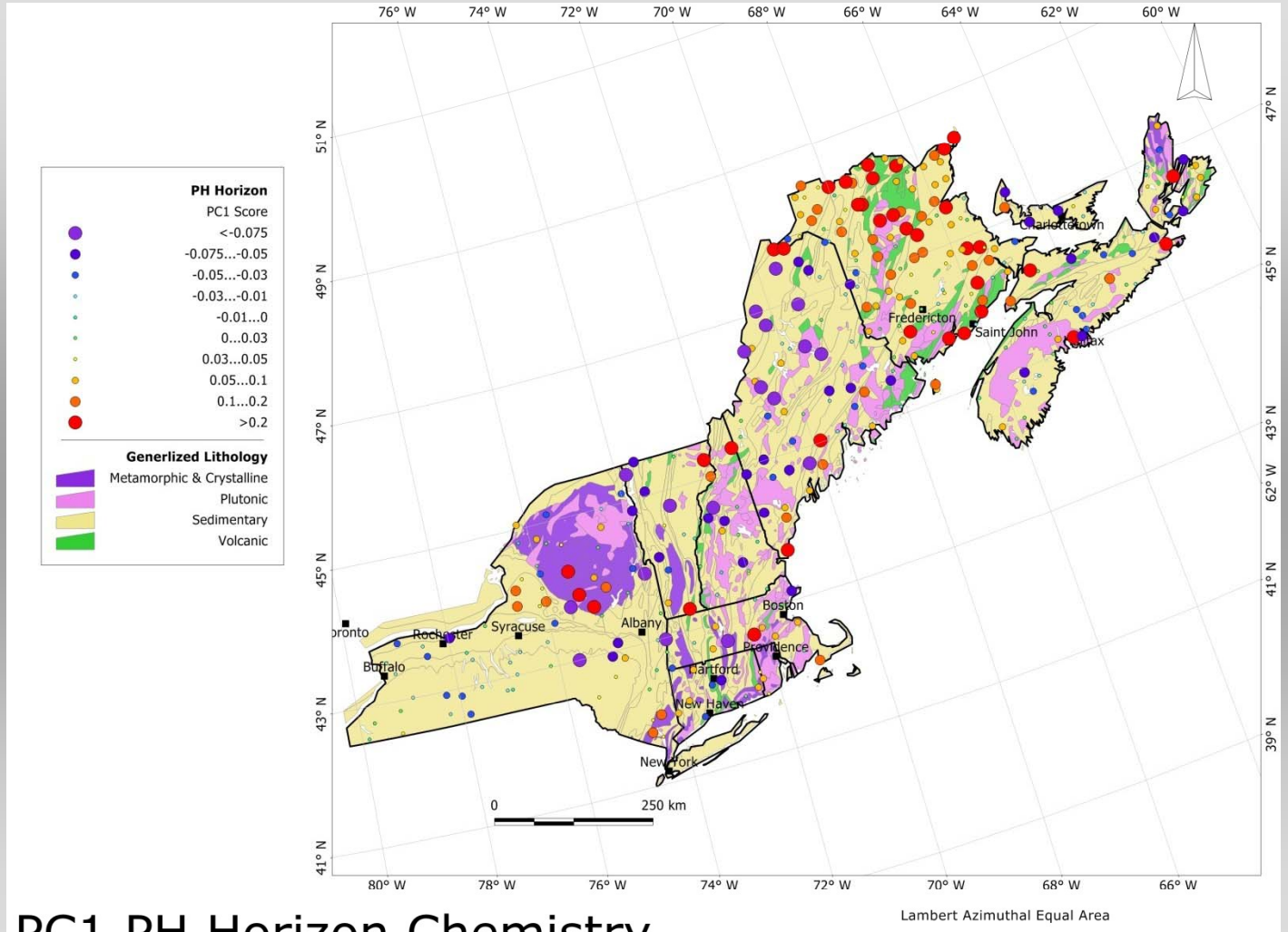
Principal Component Analysis – Soil Geochemistry



Physical Processes



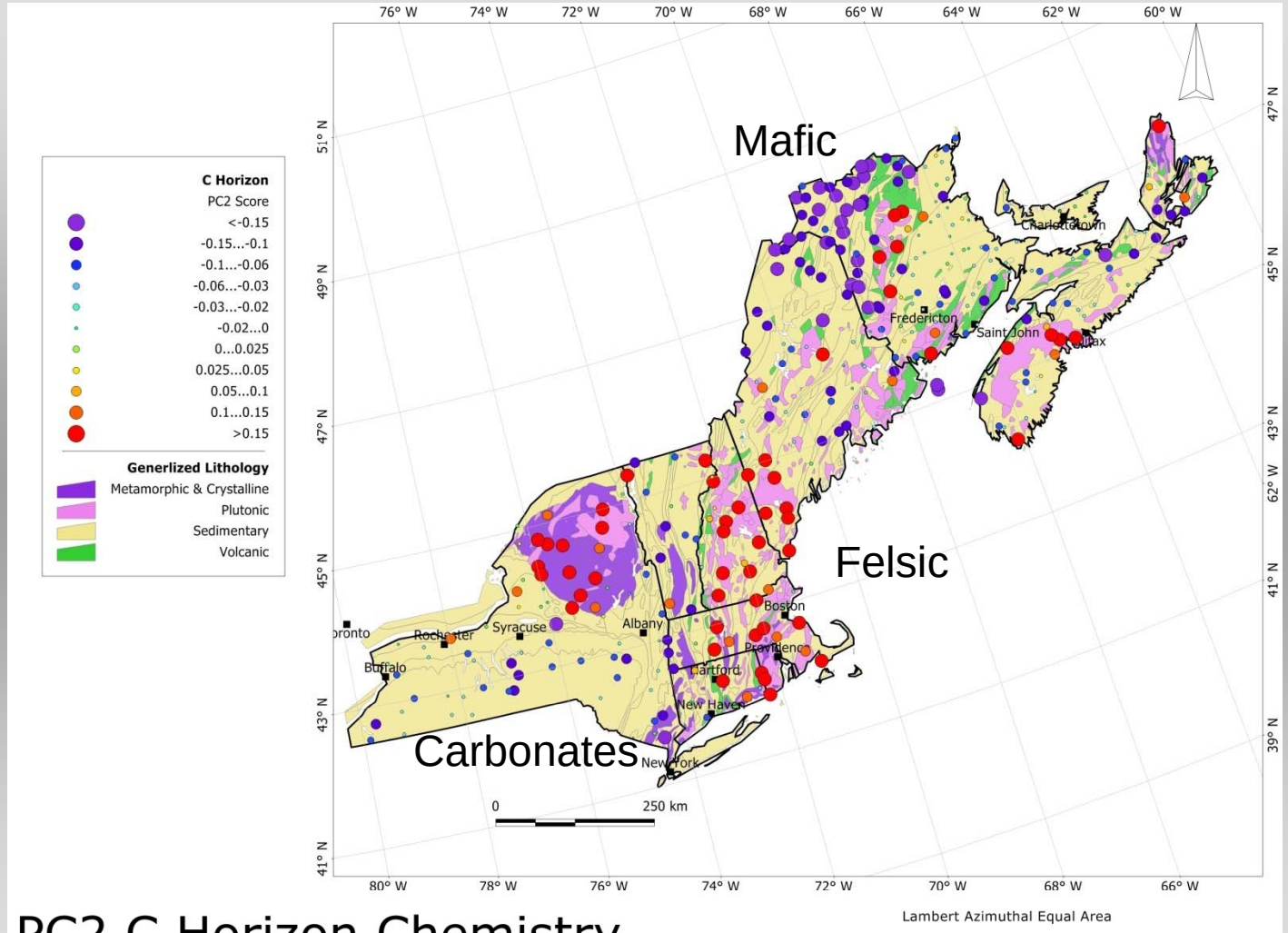
PC1 – PH Horizon



PC1 PH Horizon Chemistry

Increased Cd-S-Pb-Se-Sn-Mo-Bi-Sb in NB and NS

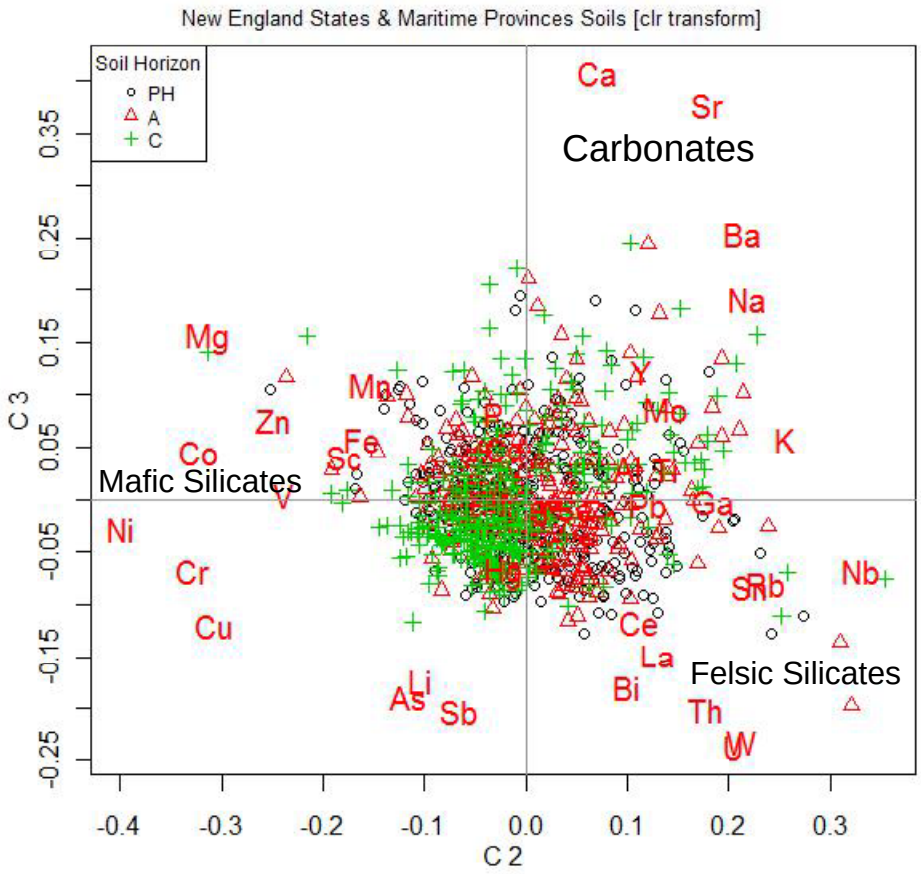
PC2 – C Horizon



PC2 C Horizon Chemistry

Carbonates/Mafic rocks PC2< 0; Felsic rocks PC2 > 0

PC2-PC3 Biplots – Chemistry



Biplot shows bedrock affinities without the influence of the soil profile

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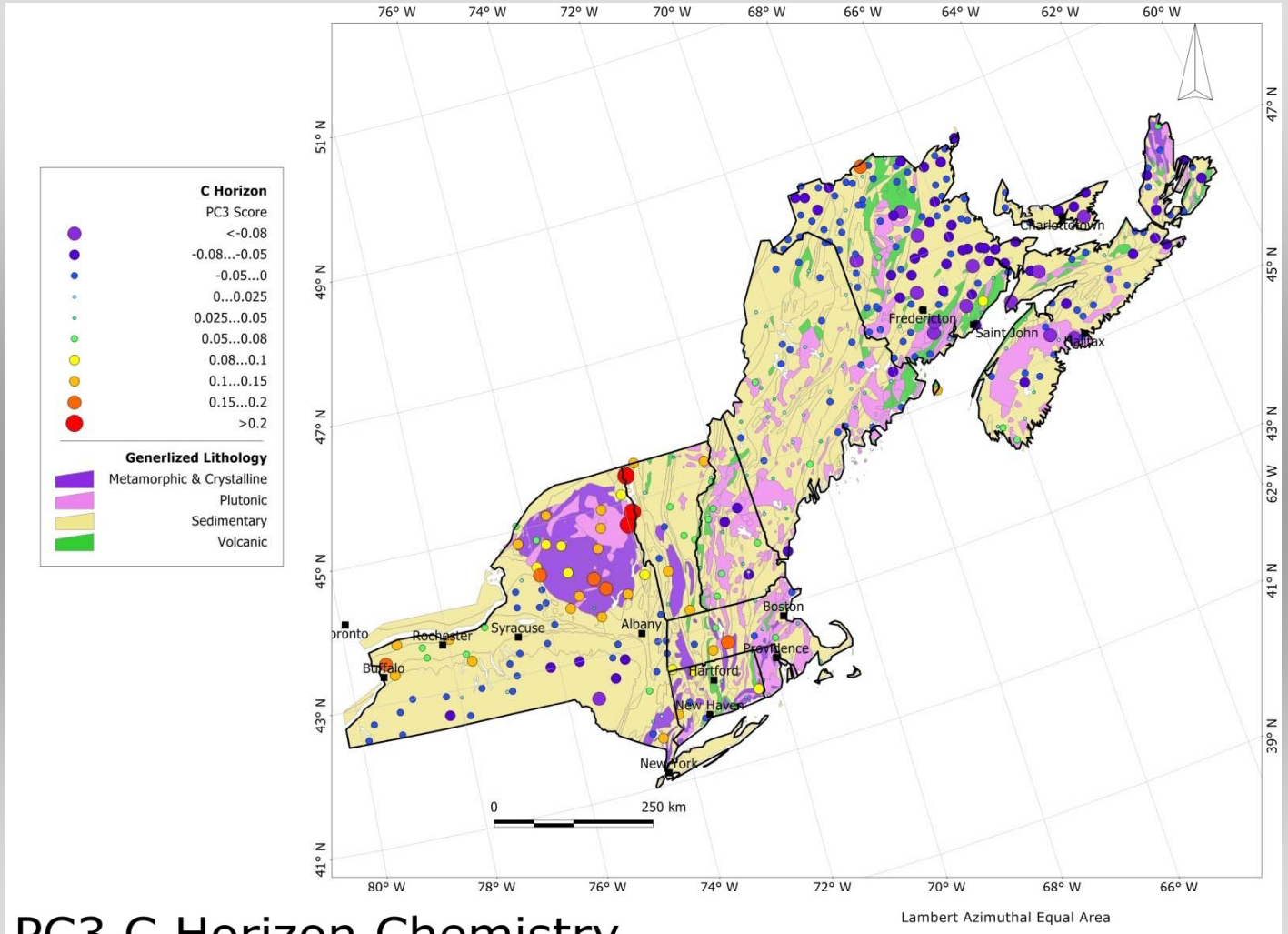
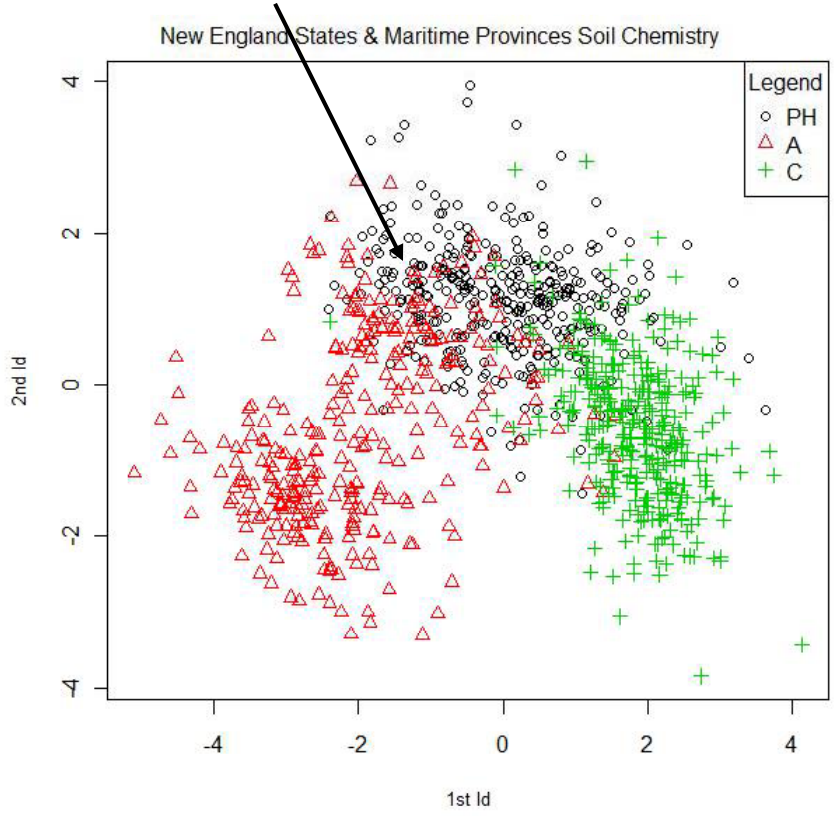
PC3 – C Horizon

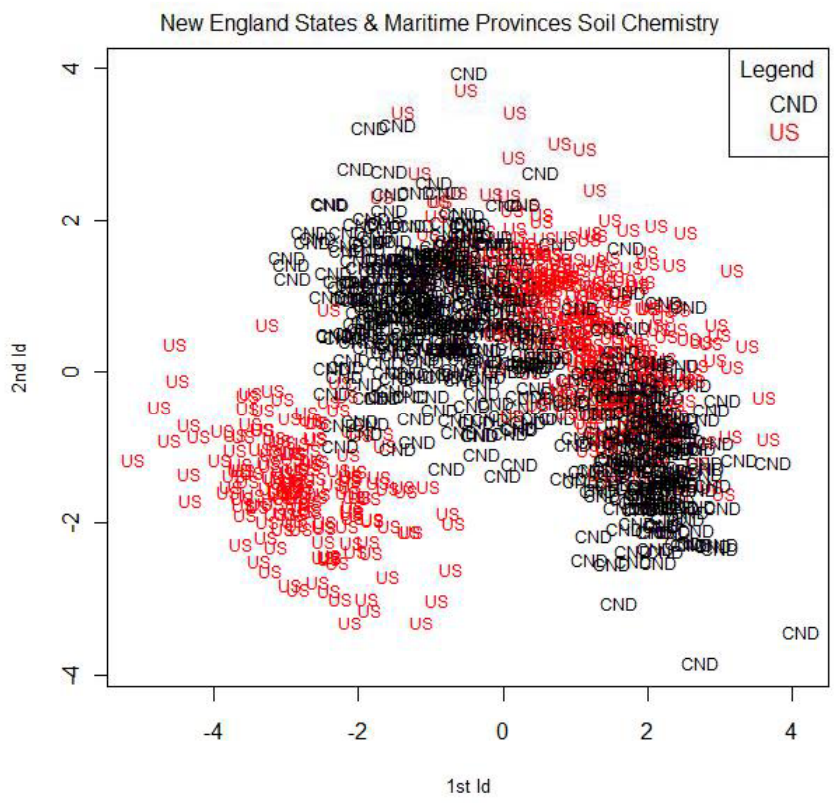


PC3 C Horizon Chemistry

Linear Discriminant Analysis (LDA) – ILR Transform – Soil Geochemistry

A Horizon with high C content





LDA Accuracy Matrix – Soil Geochemistry

		Points	
Horizon	A	C	PH
A	248	9	63
C	1	317	28
PH	12	36	299

	Percentage		
Horizon	A	C	PH
A	77.5	2.81	19.69
C	0.29	91.62	8.09
PH	3.46	10.37	86.17

Overall Accuracy	85.3

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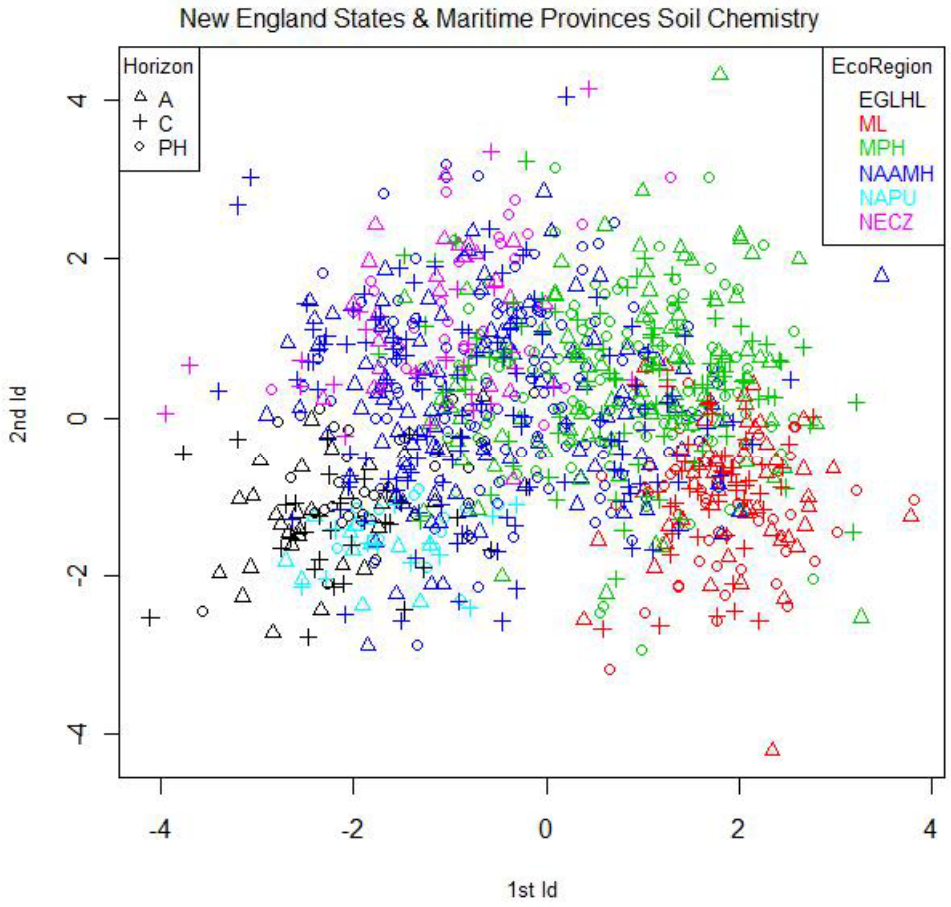
LDA Based on EcoRegions



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LDA – EcoRegions – Accuracy Matrix

	EGLHL	ML	MPH	NAAMH	NAPU	NECZ
EGLHL	66	0	2	15	9	0
ML	0	128	18	1	0	0
MPH	4	27	213	46	0	4
NAAMH	23	15	56	221	9	29
NAPU	1	0	0	4	31	0
NECZ	1	0	2	22	0	54

	EGLHL	ML	MPH	NAAMH	NAPU	NECZ
EGLHL	71.74	0	2.17	16.3	9.78	0
ML	0	87.07	12.24	0.68	0	0
MPH	1.36	9.18	72.45	15.65	0	1.36
NAAMH	6.52	4.25	15.86	62.61	2.55	8.22
NAPU	2.78	0	0	11.11	86.11	0
NECZ	1.27	0	2.53	27.85	0	68.35
Overall Accuracy				71.23%		

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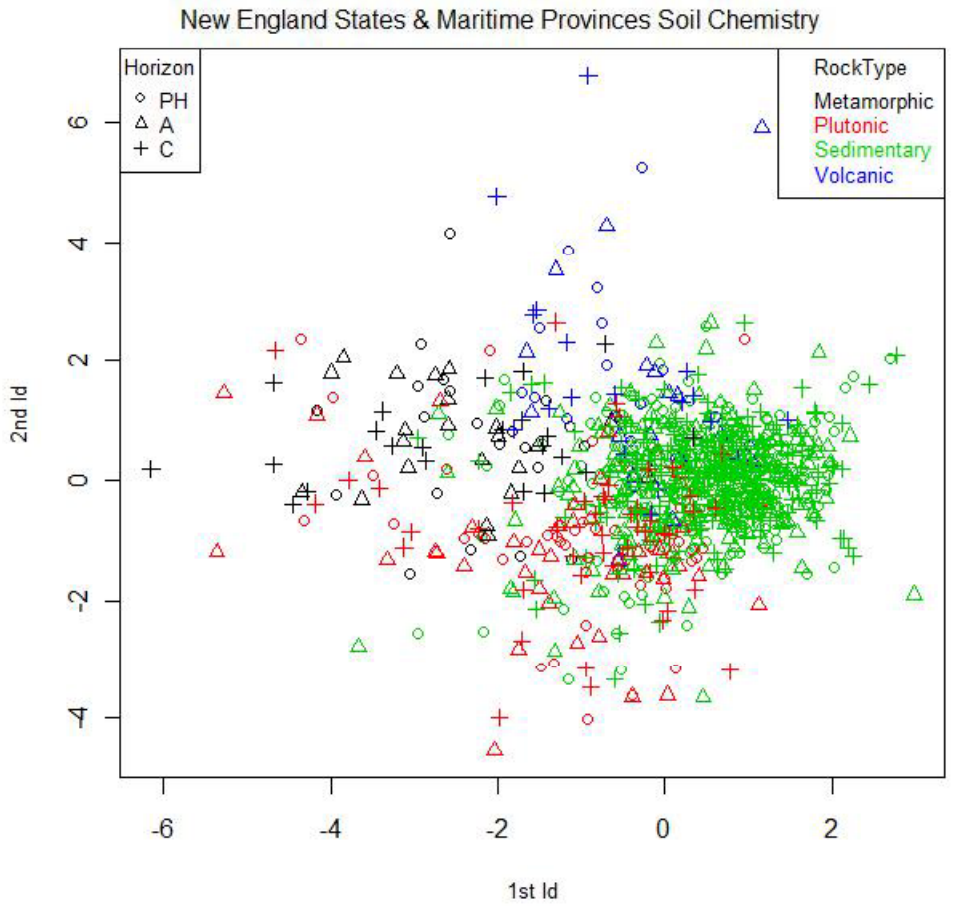
LDA – Rock Type Prediction – Soil Geochemistry



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LDA – Rock Type – Accuracy Matrix

	Metamorphic	Plutonic	Sedimentary	Volcanic
Metamorphic	40	10	15	1
Plutonic	13	56	67	3
Sedimentary	10	27	674	3
Volcanic	1	2	26	24
	Metamorphic	Plutonic	Sedimentary	Volcanic
Metamorphic	60.61	15.15	22.73	1.52
Plutonic	9.35	40.29	48.2	2.16
Sedimentary	1.4	3.78	94.4	0.42
Volcanic	1.89	3.77	49.06	45.28
Total Accuracy		81.69		

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Conclusions

- Logratios and a multivariate approach yields patterns that infer geological processes.
- Results of the survey show transitional distinctions between the upper (A, PH) and lower (C) horizons.
- C horizon correlates well with underlying geology.
- These results provide insight into the process of soil formation and the corresponding geochemical response over a substantial area of eastern Canada and the north-eastern United States.

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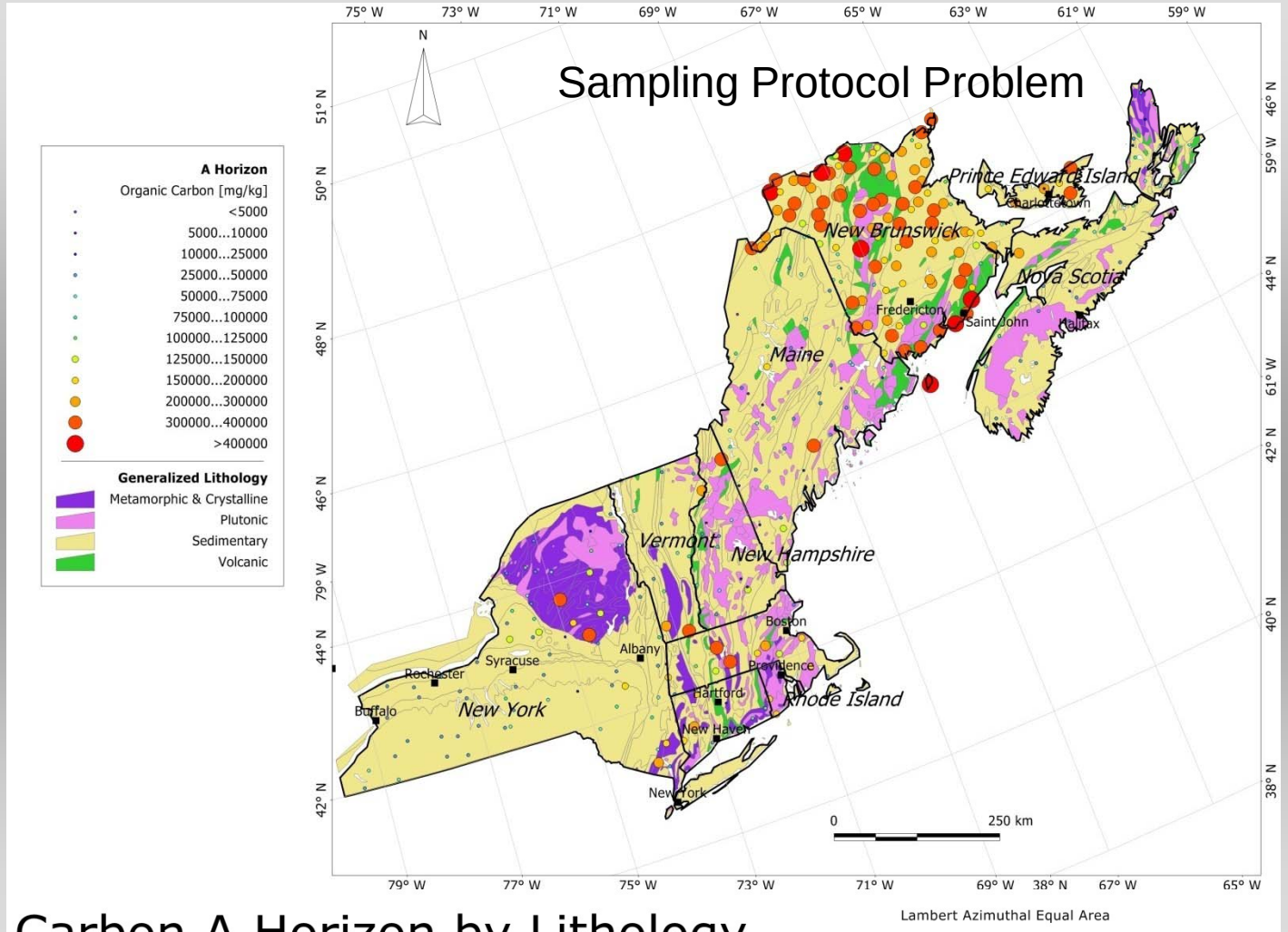
Organic Carbon - A Horizon



Carbon A Horizon by Lithology

High C in A horizon soils in New Brunswick

For more information

- Contact Eric Grunsky
  - Eric.Grunsky@NRCan-RNCan.gc.ca

- Read:
  - Drew, L.J., Grunsky, E.C., Sutphin, D.M., and Woodruff, L.G., 2010, Multivariate analysis of the geochemistry and mineralogy of soils along two continental-scale transects in North America, Science of the Total Environment, v. 409, p. 218-227.

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