Predicting Nutrient and Contaminant Transport via Fractures in Glacially-related Fine-grained Soil Using Field and Laboratory Soil Texture Data

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Introduction

Fractures (i.e., secondary porosity via macropores) in glacially related fine-grained soils and parent materials create preferential flow paths for surface-to-agricultural drainage tile transport and ground water aquifer recharge, allowing nutrients and other pollutants to infiltrate rapidly. However, it can be difficult to detect fractures on site without natural exposures or test pit excavations and soil borings.

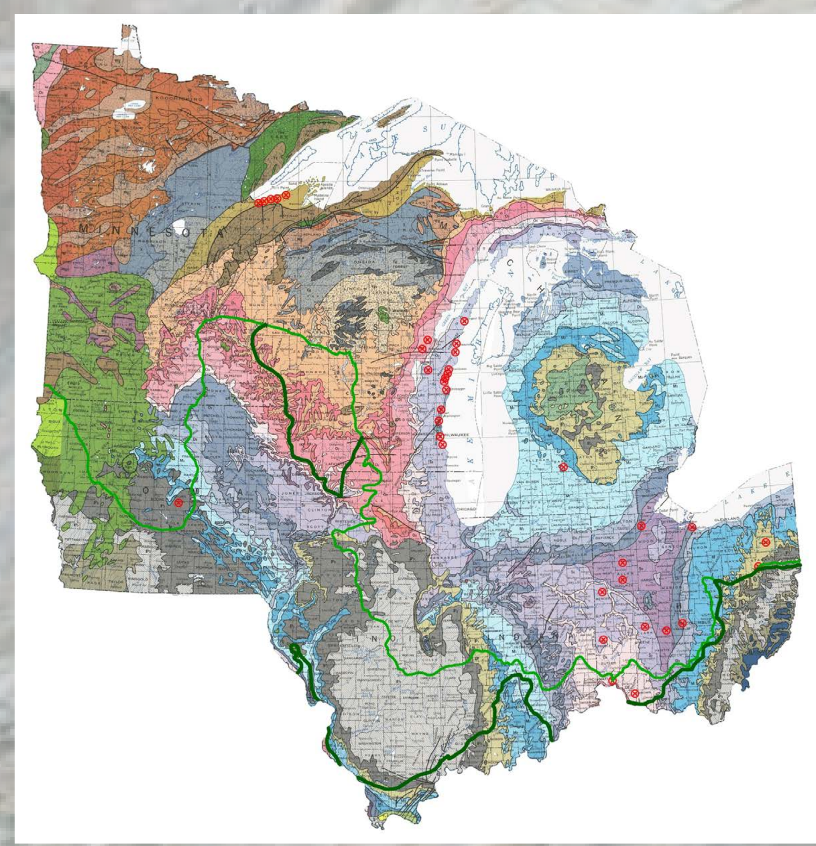
Blue-green algae in Maumee Bay (Western Lake Erie), September 2012. The drought during Spring 2012 caused dissolved reactive phosphorus loading to the lake to be less than 10% of the 2011 levels. The continued growth of blue-green algae, even in times of drought, suggest that the 2012 blooms may be fed by in-lake recycling of nutrients, reflecting base level growth.

Methods

A practical predictive model was developed based on soil texture data from 145 sites in Ohio, 98 sites in Wisconsin, and a few additional sites in Michigan and Iowa, plus results from 30 laboratory scale fracturing experiments. In the laboratory experiments, samples of soils found to be naturally fractured in the field were mixed with increasing proportions of pure silica sand and desiccated to determine at what point the mixtures would no longer support fracturing.

Field Investigation

Historic data collected from university theses, journals and technical reports were used to determine the soil texture classes in those glacial tills known to have fractures. After the data were analyzed graphically, fracture-prone region on ternary diagram, expressed as predictive model was constructed.



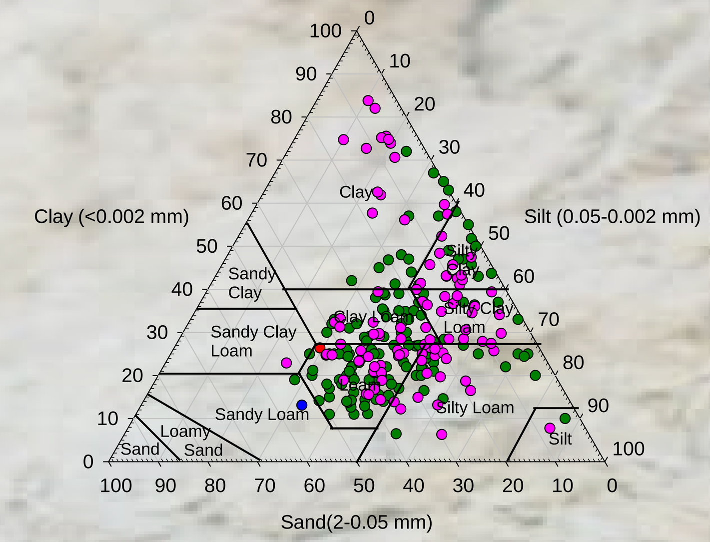
Red dots indicate the sample locations.

Controlled Fracturing Laboratory Experiment ("Mud-pie test")

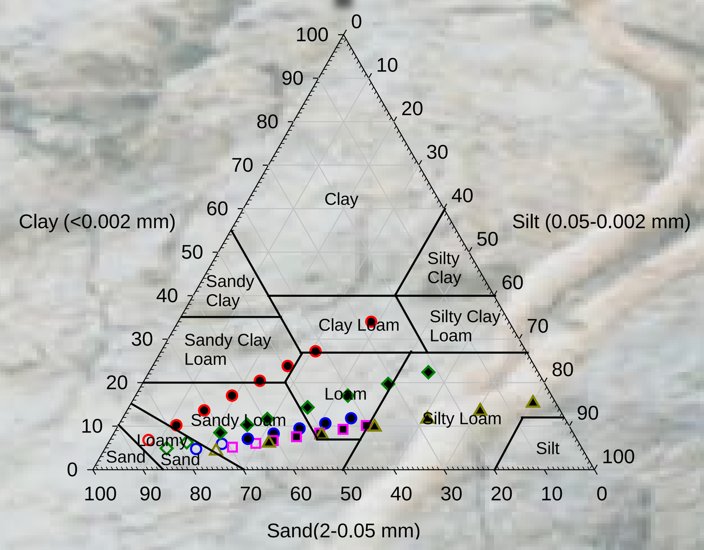
Field soils from Ohio known to have fractures were used. Laboratory methods included grinding five soil samples, adding water and varying amounts of silica sand, pouring the mixtures into pans, drying for over a week and photo-documenting the presence or absence of fractures.

Results

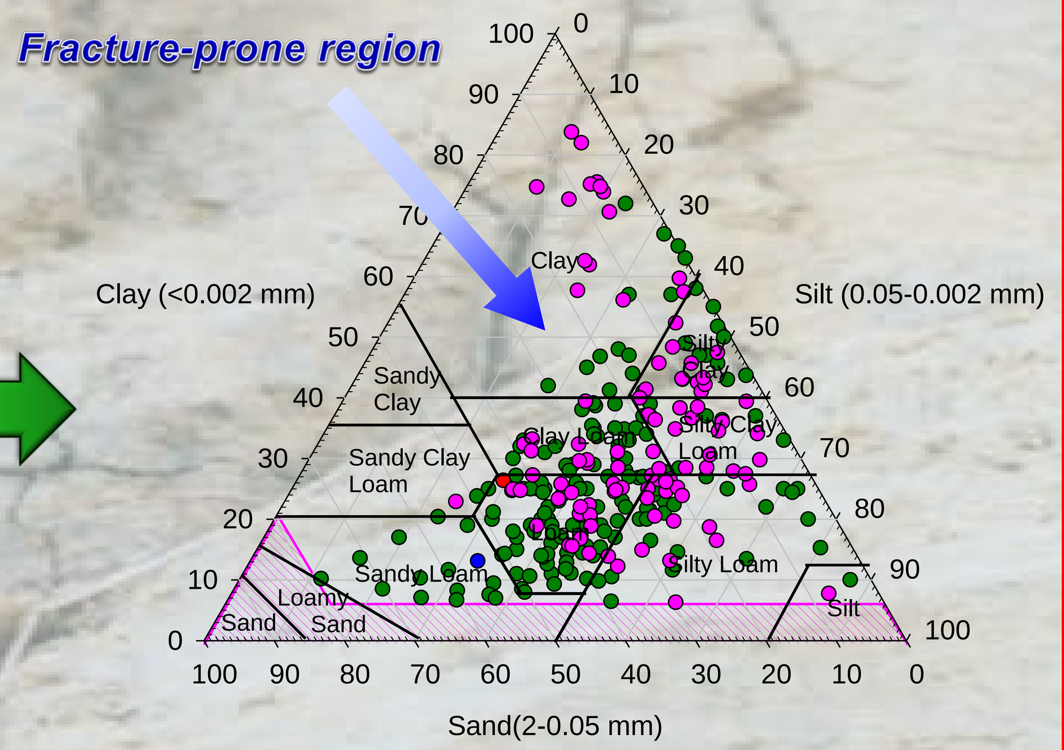
Results were plotted on a USDA ternary diagram to define the boundaries of the fracture-prone region of soil textures. The results showed that glacially related fine-grained soil materials having less than 79% sand or greater than 6.5% clay are more likely to support fracturing.



Soil texture data for glacially-derived soil and till samples in Ohio (143 green points), Iowa (a blue point), Michigan (a red point), and Wisconsin (98 pink points) observed to have fracturing.



Soil texture data observed to have fractures during mud-pie tests with five Ohio field soil/sand mixtures. Filled symbols (30 points) indicate that fractures were observed in mud-pies and blank symbols indicate non-fracturing conditions.



Soil texture data for all 275 fractured, fine-grained till and glacial lacustrine sediment samples from Ohio, Iowa, Michigan, and Wisconsin. The unshaded zone shows those soil textures expected to support fracturing in the Midwest (less than 79% sand and greater than 6.5% clay).

Conclusion

Soil scientists can apply this boundary condition method to their own site-specific data to predict where fracturing is most likely to occur in their location and thus where agricultural drainage tile water and ground water will be most vulnerable to nutrient and pollutant transport. This screening process can also be used to determine which soils, if agriculturally drained, would most benefit from the installations of agricultural tile bioreactors modified to remove both dissolved reactive phosphorus (DRP) and dissolved nitrates which fuel Harmful Algal Blooms (HAB) in Ohio lakes and reservoirs.

NOAA Modis overflight, September, 2012.Green or cloudy areas are colonies of blue-green algae (harmful algal blooms).

Installation of agricultural tile bioreactor at Waterman Farm, The Ohio State University Columbus Main Campus. Designed to remove both dissolved reactive phosphorus and dissolved nitrates.

Another view of the agricultural tile bioreactor showing inlet structures located in front of bioreactor.

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