Rocks and Soil

Can we discern a relationship between parent material (rock and mineral type) and specific soil properties using the tools available at Earthworks?

Earthworks, Cal-Wood
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Purpose/ Question:

Can we discern a relationship between parent material (rock and mineral type) and specific soil properties using the tools available at Earthworks? How can relationships between rocks and minerals and soil have practical applications?

Prediction:

There is a discernable relationship between parent material (source rock and minerals) and the specific soil properties that will be measurable. However, other factors determine soil properties as well. Analysis of the connection between source material (rocks and minerals) will lead to further questions and investigations.

Reason we chose this question:

- to utilize rocks and minerals into an interdisciplinary study
- to develop a project theme that could apply to each of our diverse school locations
- to develop skills of descriptive and quantitative methodology in rock identification, soil sampling and analysis of soil chemistry
- to make connections between conceptual or descriptive geology and quantitative factors of rocks, minerals and soils.

Team Members:

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Scientists: Hartmut Spetzler (hartmutspetzler@colorado.edu), Ray Beiersdorfer (ray@cc.ysu.edu), Pete Modreski (pmodreski@usgs.gov), Nicole Feldl

Introduction:

Our research was conducted at several different locations around the area of Solitude Point. The two rock types studied at this location were a 1.4 billion year old igneous pegmatitic granodiorite and a 1.7 billion year old metamorphic migmatite gneiss. A granodiorite is an intrusive igneous rock. A migmatite gneiss is a rock formation that has been invaded by igneous materials which produces a complex mixture. At this location, the granodiorite has intruded the local metamorphic gneiss. The dominant mineral composition of the granite at this site includes quartz, microcline (potassium feldspar) and albite (sodium feldspar), muscovite and biotite mica and hornblende amphibole. The dominant mineral composition of the gneiss at this site included quartz, plagioclase feldspar (sodium/calcium feldspar), biotite mica and some hornblende amphibole. Even though both rock types contain similar minerals, it is the percent composition of the minerals and the rock's petrology (occurrence, origin and history) that are different.

Because there are differences in mineralogy and properties within the parent rocks, weathering (physical and chemical) of the rocks occurs at various rates. Once the larger rocks are weathered to smaller particles, the different properties of the individual minerals allow for continued weathering to produce different types of soils with varying soil horizons.

In our analysis of the soils, we separated the different organic soil horizons from the mineral soil horizons and looked for variations within the sand, silt and clay content. Quartz is composed of silica (SiO_2) which is one of the most abundant compounds in the earth's crust. Quartz is fairly stable and can be found in both rock types but is represented more in the igneous rock. . As the rock types are weathered, quartz is deposited and assists in the building of sand. The silicates - amphiboles, micas, feldspars- are also composed of the silica tetrahedron held together by a metal ion such as Al^{+3}, Mg^{+2}, K^{+1}, Na^{+1}, and Ca^{+2}. Many of the minerals found within both rock types contain silica in the form of silicates, but not enough to contribute significantly to the composition of sand.

Micas and amphibles are also considered silicates, and when weathered contribute to the deposition of silica . Muscovite mica is a light colored, tabular potash mica and is most commonly found in igneous rocks. This type of mica absorbs moisture and chemically changes into clay. It may also contribute potassium to the soil. Biotite mica is a dark colored, tabular mica commonly associated with some granites and metamorphic rocks.

Amphiboles are dark colored minerals containing calcium, magnesium and iron. They can be identified in both rock types as dark, long, needle-like crystals.

Feldspar has been found to be an abundant mineral within the earth's crust and is also present in both rock types. The igneous rocks contain potassium feldspar which is abundant in granites and silica rich igneous rocks. It can be identified in the granodiorite outcrops and surrounding ground mass by its pink color. The metamorphic rocks contain plagioclase feldspar which varies in color and appearance. Feldspars are important to our study because they provide the materials for the production of clay.

The minerals that weather and are deposited to soil are the products of a pre-existing parent rock.

Methodology

Materials

soil auger
rock hammer
collection bags
LaMotte Test Kits
pH meter
conductivity meter
graduated tubes with pointed bottom and cap
digital camera
GPS
Filter paper
Flasks
Graduated cylinders
Tube holder
Bottles with caps for soil samples (100 ml- 250 ml)

Taking Soil Samples

1. Previewed sites to find outcrops of igneous and metamorphic rocks.
2. Considered orientation and slope to be similar for each site.
3. Chose site with metamorphic outcrop at ~8000 ft.
4. Chipped off a small sample of rock.
5. Made WAVE point on GPS with latitude, longitude, and elevation.
6. Determined slope and orientation of site.
7. Took pictures of the site, close up and specific traits.
8. Described vegetation and other aspects of area
9. Took several core samples with soil auger.
   - Separated organic/A horizon from B/C horizon in soil sample and placed samples in separate labeled plastic bags.
   - Repeated core samples within 2 meters of the first sample until ~100 grams of sample are collected.
   - Observed smell and physical appearance of the soil.
10. Chose 3 other sites with similar features for another metamorphic sample and 2 igneous samples.

Tests on soil samples

1. **Preparation of soil**: Sieved samples with ¼ inch sieve and collected sieved sample and materials that did not sieve in separate containers. Sieved samples were used for testing.

2. **Moisture**

- Weighed 60 gram soil sample and placed on flat glass dish
- Heated in microwave on high power for three minutes.
- Weighed sample and repeated heating until no more weight loss.

3. **Phosphorus test**: LaMotte Kit

- Added 1.5 gram soil sample to extracting solution to line 6.
- Shake for one minute and allow to settle
- Transfer 3 ml of clear liquid to clean tube.
- Add 6 drops of Indicator solution to the second tube and shake to mix.
- Add one Phosphorus test tablet and shake to dissolve.
- Match sample color to color chart.

4. **Potassium test**: LaMotte Kit

- Fill clean tube to line 7 with Extracting solution
- Add 2 grams of soil sample and shake vigourously for one minute.
- Remove cap and allow to settle.
- Transfer clear liquid to line 5 of new tube.
- Add 1 indicator tablet to soil extrat and shake to dissolve.
- Add Potassium test solution two drops at a time, swirl tube to mix, and compare to chart.
- Repeat adding drops until extract turns blue.

5. **Conductivity test**: Dissolved ionic salts

- Test ionic water with TDS meter for base reading.

- Place TDS meter in solution of soil and ionic water in the texture samples.
- Record readings, repeat, and average.
- Repeat for all samples.

Texture: LaMotte Kit

Materials:
11 graduated tubes, 45 ml
tube holder

1. Label each of the 11 cylinders with name of soil sample.
2. Add the soil sample to the 15 ml mark. Tap to remove air spaces.
3. Add 1 ml of Texture Dispersing Reagent to the sample.
4. Add water to the 45 ml mark.
5. Cap and gently shake for two minutes.
6. Allow to sit over night to settle into layers.
7. After about 12 hours, measure the layers. The bottom layer is sand. The next layer is silt.
8. Add 1 ml of Soil Flocculation Reagent to soil samples to cause clay to settle.
9. After 24 hours, measure levels again.
10. The clay fraction is calculated by adding the sand and silt fractions and subtracting this total from the initial volume of soil used for the separation. (15 ml)

Nitrogen testing: Hach Kit

Part 1: Calcium sulfate extraction:

1. Add 1 g soil sample, .1 gram Calcium sulfate, and 25 ml of ionized water in round mixing container.
2. Cap & shake each bottle vigorously for 1 min.
3. Using a plastic funnel and filter paper, filter the contents of the bottle into another round sample bottle

4. Analyze this extract for nitrate-nitrogen within 2 hours (or refrigerate samples)

Part 2: Test extract for nitrogen

1. Label 1 Color Viewing Tube “S” for sample & another Color Viewing Tube “B” for blank. Rinse both with ionizing water.
2. Add a small amount of the extract to “S”, shake, and empty.
3. Add the extract to the 5 ml line.
4. Add the contents of one Nitra Ver 5 Powder Pillow to “S” tube. Cap and shake for exactly one minute.
5. Immediately place tubes “S” and “B” in the outside hole and tube “S” in the inside hole.
6. After 5 minutes, hold the Color Comparator up to a light source. Rotate the disc until the color in the window for tube “B” matches the color in the window for tube “S”.
7. Record the value in the window.
8. Take two more readings for the sample, rotating the color disc between each reading.
9. Complete all 3 readings within 10 minutes of placing in the holder.
10. Rinse all tubes with deionized water and repeat test for all samples.

<u>Protocol for pH determination:</u>

Equipment and materials: prepared soil samples, stirring spoon or spatula, Hach kit, 25 mL graduated cylinder, 50 mL beakers, digital pH meter, pH 7.00 buffer solution.

1. Set out dry soil samples
2. Use a 5 g volumetric scoop (Hach kit) to measure 4 scoops total of prepared soil sample into a 50 mL beaker.

3. Use a 25 mL graduated cylinder to measure and add 20 mL of deionized water to the 50 mL beaker of soil.
4. Stir contents of beaker with spatula or spoon for 60 seconds at 10 minute intervals over 30 minutes total time. Therefore, stir at 0 min, 10 min, 20 min, 30 min.
5. Repeat above procedures # 2-4 for each soil sample, resulting in aqueous extracts.
6. Calibrate the pH meter by immersing it one inch below the surface of 7.00 buffer solution. Adjust to read pH = 7.0.
7. Rinse pH meter with de-ionized water and wipe with tissue.
8. Immerse tip of pH meter into aqueous extracts of soil samples, stir until meter reads a constant value. Read and record data to nearest 0.1 pH unit.
9. Rinse pH meter with de-ionized water in preparation for next sample.
10. Repeat procedural steps # 7-9 for each sample.

Quality Control:

Care in several areas were important for good science.

a. Selection of sample sites We chose sample sites that were similar with one another in elevation, slope and directional orientation. The sample sites chosen for taking soil samples within the category of metamorphic rock had no other categories (igneous or sedimentary) of rock outcroppings above them. The sample sites chosen for taking soil samples within the category of igneous rock had no other categories (metamorphic or sedimentary) of rock outcroppings above them. This was done to mitigate (reduce) the factor of soil forming from rocks or minerals other than those chosen for our study.

b. Collecting of soil samples Care was taken to ensure that the soil samples collected were from locations similar in vegetation. For example, we never sampled directly under any trees and were careful to not sample closely or directly downhill from rotting logs or wood piles. All soil samples were collected with attention to similar shrubbery and density of grasses and other ground plants.

The auger used for soil sampling was cleaned in the field between each sample selection. Samples were collected directly into sample bags properly labeled.

c. Lab protocol : Lab protocols were followed carefully per instructions on the soil testing kits. Soil samples were dried to enable testing with approximately equal dry soil horizons. Soil samples were carefully dried to in a manner that ensured that the organic material did not char or break down thermally. Final quantitative and qualitative readings were done by one member of the team to eliminate bias due to different people reading the equipment or color charts. Care was taken to start with clean containers and not contaminate the samples when moving equipment from one sample to another

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Descriptions of sites:

Site 1:
Metamorphic 100 O & A
Met 101 B & C

Site 2:
Met O & A
Met B & C

Site 3:
Granite 100 O & A
Granite B & C

Site 4:
Granite O & A
Granite B& C

Site	Sample #	latitude	longitude	elevation	orientation	slope
1	Met 100 O/A	40.15495	-105.38793	7980	224	18
1	Met 100 B/C	40.15495	-105.38793	7980	224	18
2	Met 101 O/A	40.15496	-105.38766	7960	229	29
2	Met 101 B/C	40.15496	-105.38766	7960	229	29
3	granite 100 O/A	40.15625	-105.39047	8000	210	10
3	granite 101 B/C	40.15625	-105.39047	8000	210	10
4	granite 102 O/A	40.15617	-105.39056	8000	210	20
4	granite 103 B/C	40.15617	-105.39056	8000	210	20

Observations:

Site 1: Metamorphic site:
Trees: Douglas Fir, Ponderosa Pine

Shrubs: Ribes

Forbs: several varieties, including galliardia, sticky geranium, buckwheat, goldenrod, cinquefoil, single flower sunflower, puccoon

Grasses: blue bunch, wheat grass, needlegrass, calamagrostas, poa, cheatgrass

Soil: Musty smell

Site 2: Metamorphic site

Trees: Pine, Juniper

Shrubs: Fringe sagewort, Pur Tri, Ribes

Forbs: hairy goldmaster, penstomen, buckwheat, puccoon, hairy goldenmaster, single flower sunflower

Grasses: AgriSpi, Poa, sedges, calamagrostis

Site 3: Igneous site

Trees: pine

Shrub: currant, antelope bitterbrush

Forbs: pentsamon, blanket flower, astragolis, loco weed, fleabain, buckwheat, pussy toes

Grasses: sedge, june grass, sage wort, fringe

Site 4: Igneous

Trees: Pine

Bush: currant, antelope bitterbrush

Grasses: June grass, blue buch, sedges,

Forbs: goldenrod, buckwheat, puccon, phalcia, sticky geranium, yarrow, fringed sage, cinquefoil,

General Observations: Igneous site had sparser vegetation, including fewer forbs, than the metamorphic site. There was also more bare ground in the igneous site.

Data Tables and Graphs

Soil Particle Size

	Sand	Silt	Clay	Soil Total
Met 101 O/A	7	3	2	12
Met 100 O/A	6	4	2	12
Met 100 B/C	7	5	4	16
Met 101 B/C	7	5	3	14
				0
Granite 102 O/A	5	4	3	12
Granite 100 O/A	8	3	3	13
Granite 102 B/C	8	3	4	14
Granite 100 B/C	8	1	2	11

Electrical Conductivity vs Soil Particle Size

	Total Soil EC Normalized	Sand EC Normalized	Silt EC Normalized	Clay EC Normalized
Met 100 O/A	0.91	0.95	0.63	1.25
Met 101 O/A	0.95	0.82	0.85	1.67
Met 100 B/C	0.62	0.71	0.44	0.71
Met 101 B/C	0.98	1.10	0.70	0.83
Granite 100 O/A	1.16	1.05	1.39	0.83
Granite 102 O/A	1.26	1.57	0.87	0.83
Granite 100 B/C	0.74	0.66	1.58	0.62
Granite 102 B/C	1.37	1.14	1.52	1.25

pH vs Soil Particle Size

	pH Total Soil Normalized	pH Sand Normalized	pH Silt Normalized	pH Clay Normalized
Met 100 O/A	0.93	0.99	0.64	1.12
Met 101 O/A	0.89	0.98	0.98	1.72
Met 100 B/C	1.20	1.03	0.62	0.77
Met 101 B/C	1.09	1.07	0.67	0.87
Granite 100 O/A	1.01	0.88	1.14	0.83
Granite 102 O/A	0.93	1.26	0.68	0.79
Granite 100 B/C	1.01	0.92	2.14	0.65
Granite 102 B/C	0.93	0.88	1.14	1.25

Potassium (K) vs Soil Particle Size

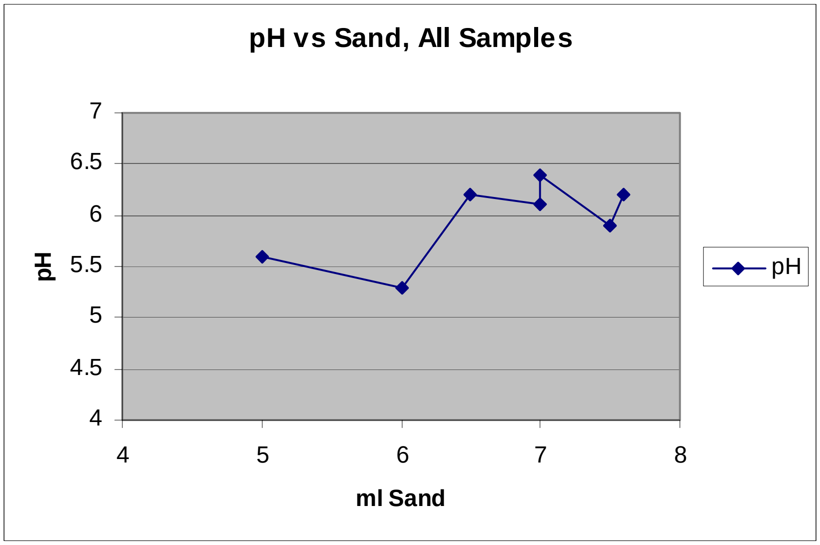
	K Total Soil Normalized	K Sand Normalized	K Silt Normalized	K Clay Normalized
Met 100 O/A	1.20	1.23	1.43	1.43
Met 101 O/A	1.00	0.84	0.71	1.53
Met 100 B/C	0.93	1.05	0.53	0.82
Met 101 B/C	1.03	1.13	0.59	0.96
Granite 100 O/A	0.74	0.65	0.71	0.64
Granite 102 O/A	1.20	1.47	0.67	0.96
Granite 100 B/C	1.11	0.97	1.91	0.72
Granite 102 B/C	0.80	0.65	0.71	0.96

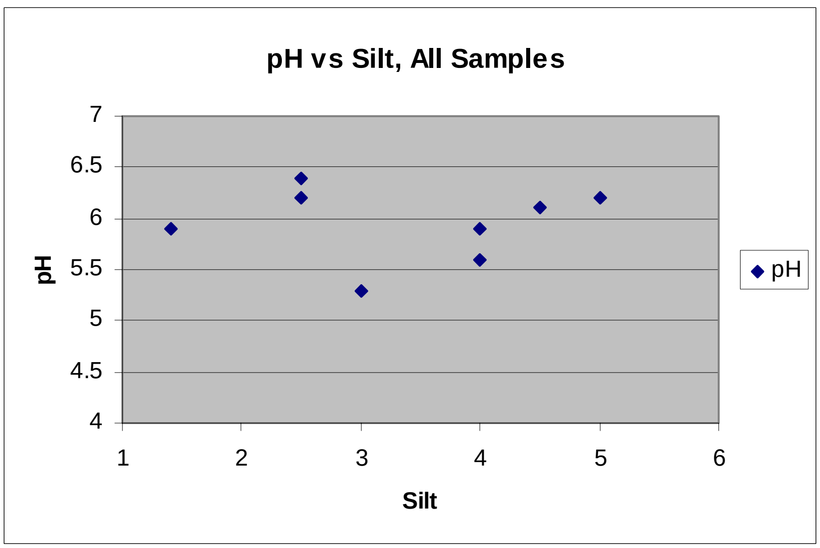
Nitrogen (N) vs Soil Particle Size

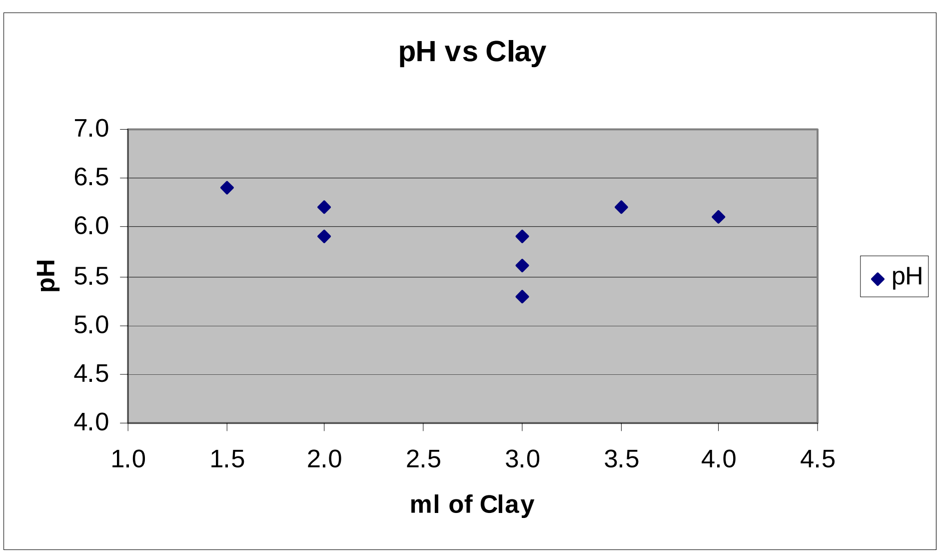
	N Soil Total Normalized	N Sand Normalized	N Silt Normalized	N Clay Normalized
Met 100 O/A	0.98	0.98	0.73	1.18
Met 101 O/A	0.85	0.70	0.81	1.31
Met 100 B/C	0.82	0.91	0.63	0.73
Met 101 B/C	1.40	1.51	1.08	1.31
Granite 100 O/A	0.90	0.78	1.17	0.79
Granite 102 O/A	1.63	1.96	1.22	1.31
Granite 100 B/C	0.60	0.52	1.39	0.39
Granite 102 B/C	0.82	0.65	0.97	0.98

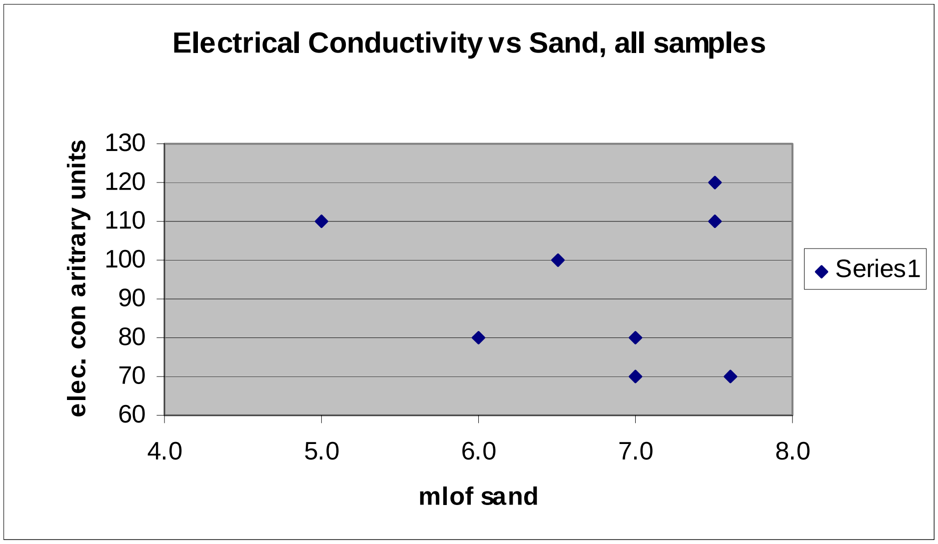
Phosphorus (P) vs Soil Particle Size

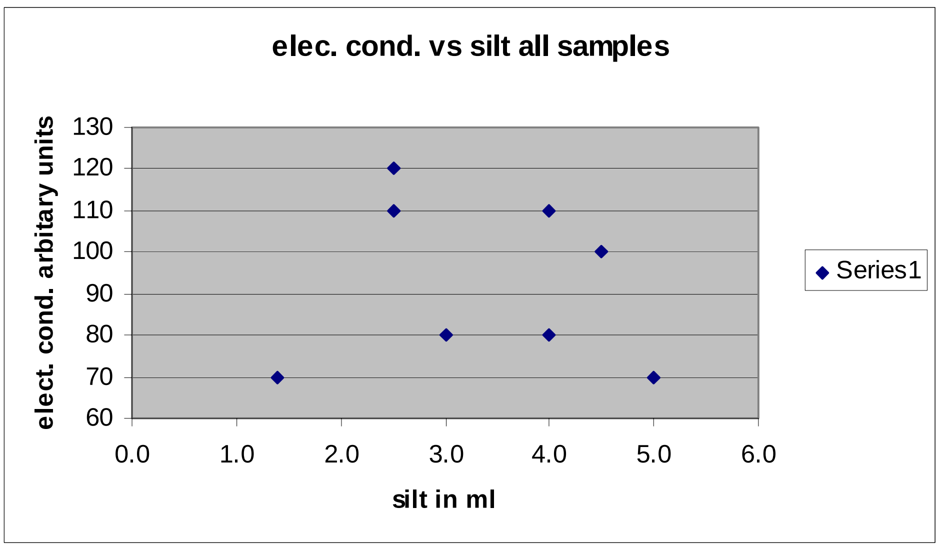
	P Total Soil Normalized	P Sand Normalized	P Sand Normalized	P Clay Normalized
Met 100 O/A	0.84	1.10	0.76	1.19
Met 101 O/A	0.87	0.95	1.01	1.59
Met 100 B/C	0.26	0.38	0.24	0.27
Met 101 B/C	1.00	1.43	0.95	1.12
Granite 100 O/A	1.08	1.24	1.70	1.12
Granite 102 O/A	0.84	1.32	0.76	0.80
Granite 100 B/C	0.31	0.35	0.87	0.24
Granite 102 B/C	1.17	1.24	1.70	1.67

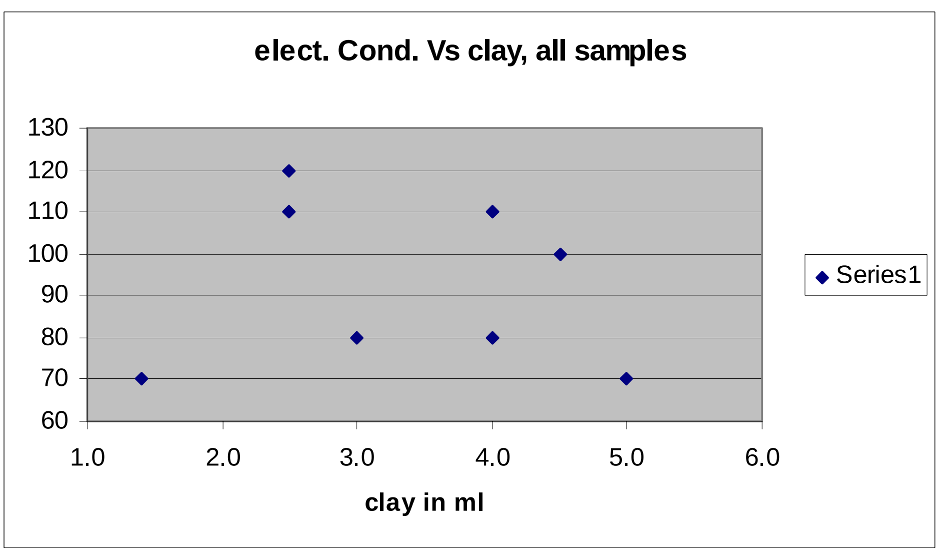

pH vs Sand, All Samples
7
6.5
6
5.5
5
4.5
4
pH
4
5
6
7
8
ml Sand
pH

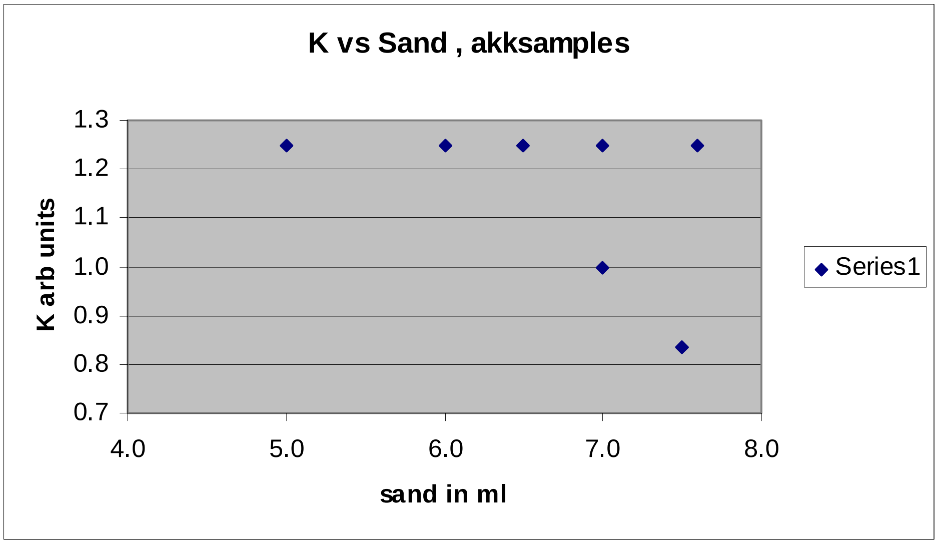

pH vs Silt, All Samples
7
6.5
6
5.5
5
4.5
4
pH
1
2
3
4
5
6
Silt
pH

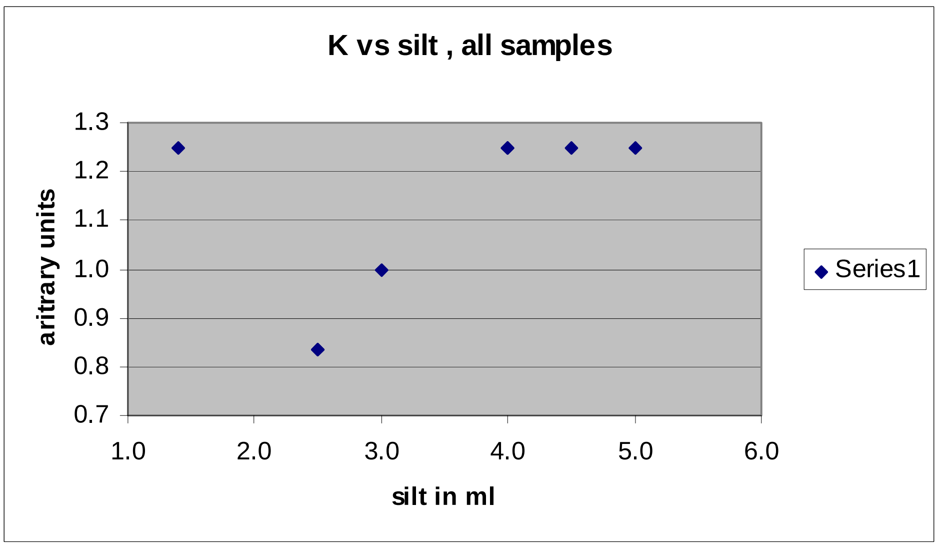

pH vs Clay
7.0
6.5
6.0
5.5
5.0
4.5
4.0
pH
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
ml of Clay
pH


Electrical Conductivity vs Sand, all samples
elec. con aritrary units
130
120
110
100
90
80
70
60
4.0
5.0
6.0
7.0
8.0
mlof sand
Series1


elec. cond. vs silt all samples
elect. cond. arbitary units
130
120
110
100
90
80
70
60
0.0
1.0
2.0
3.0
4.0
5.0
6.0
silt in ml
Series1


elect. Cond. Vs clay, all samples
130
120
110
100
90
80
70
60
1.0
2.0
3.0
4.0
5.0
6.0
clay in ml
Series1


K vs Sand , akksamples
K arb units
1.3
1.2
1.1
1.0
0.9
0.8
0.7
4.0
5.0
6.0
7.0
8.0
sand in ml
Series1


K vs silt , all samples
aritrary units
1.3
1.2
1.1
1.0
0.9
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0.7
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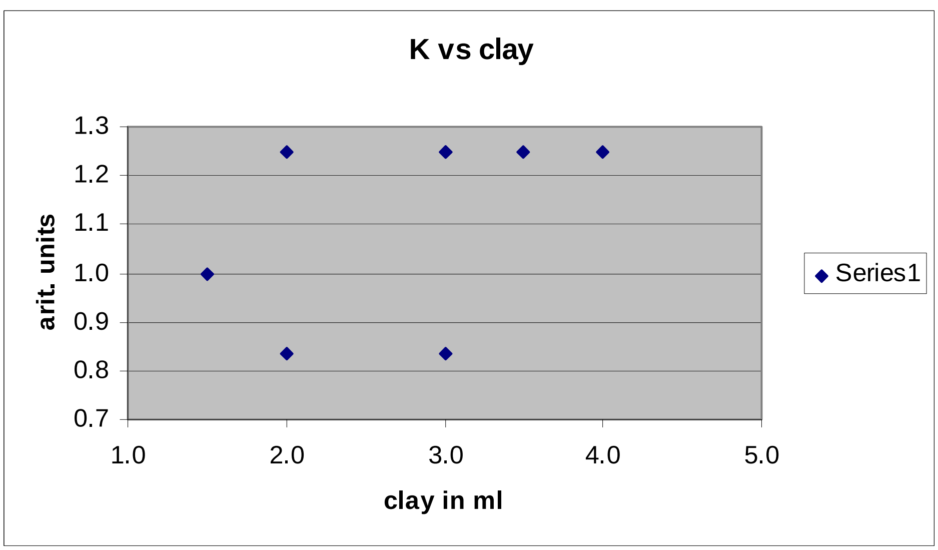
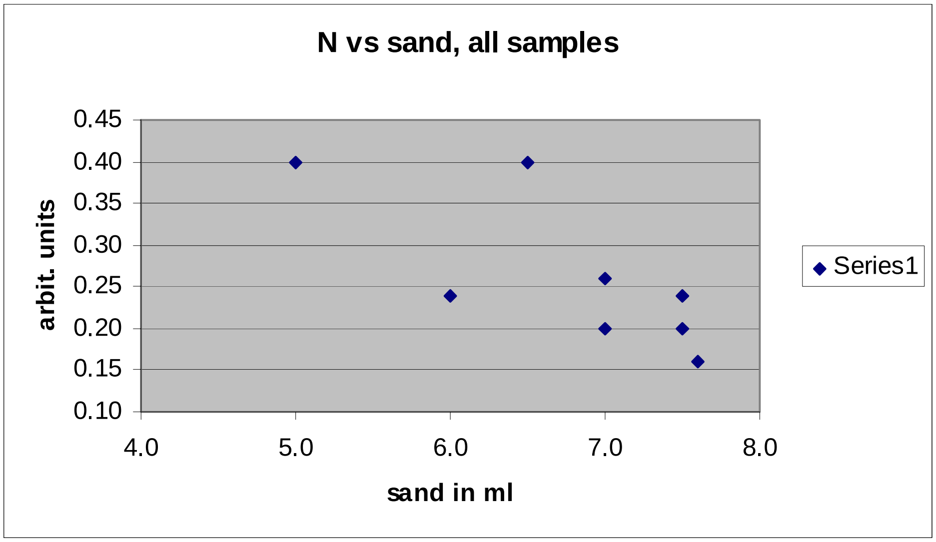
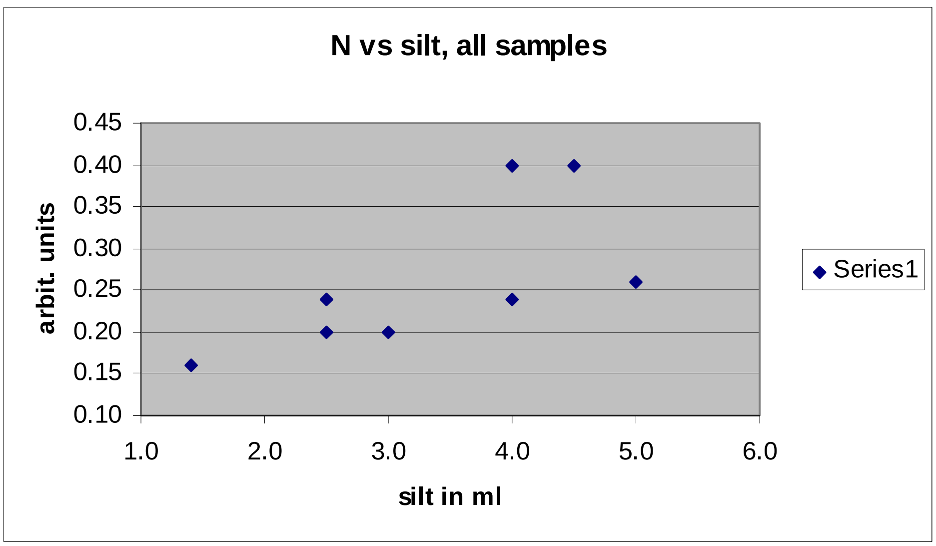
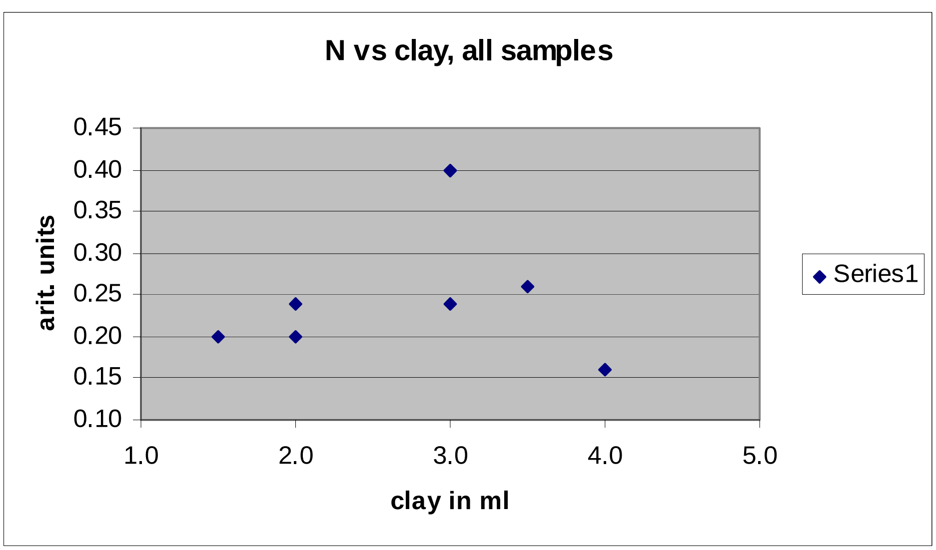
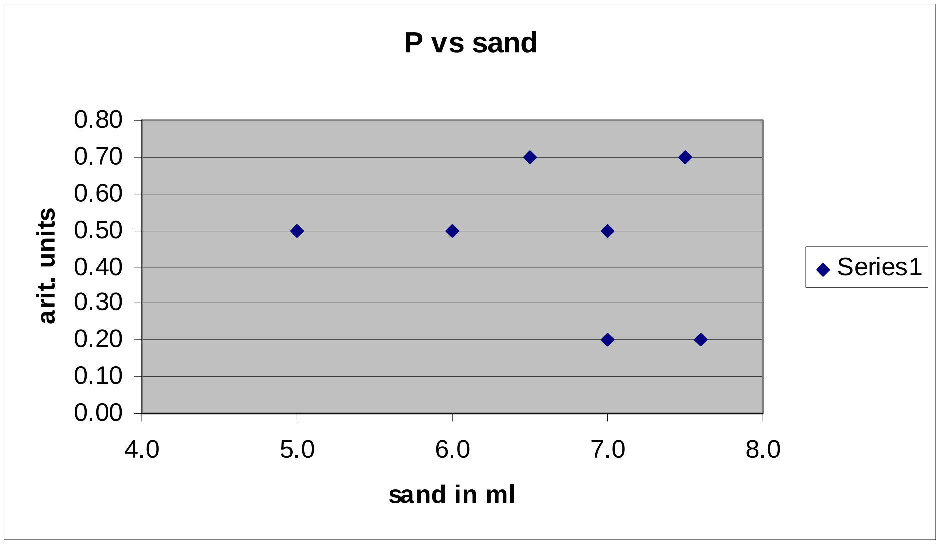
2.0
3.0
4.0
5.0
6.0
silt in ml
Series1

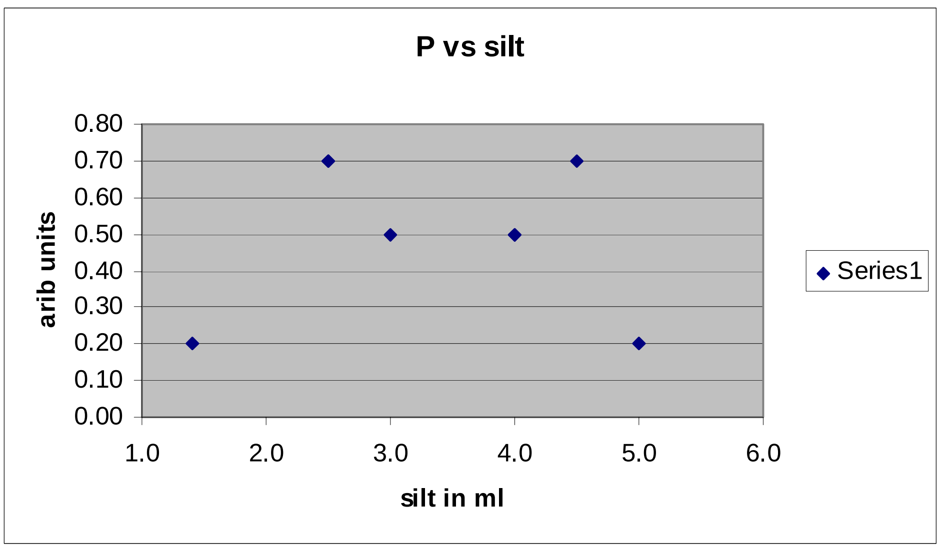

K vs clay
arit. units
1.3
1.2
1.1
1.0
0.9
0.8
0.7
1.0
2.0
3.0
4.0
5.0
clay in ml
Series1

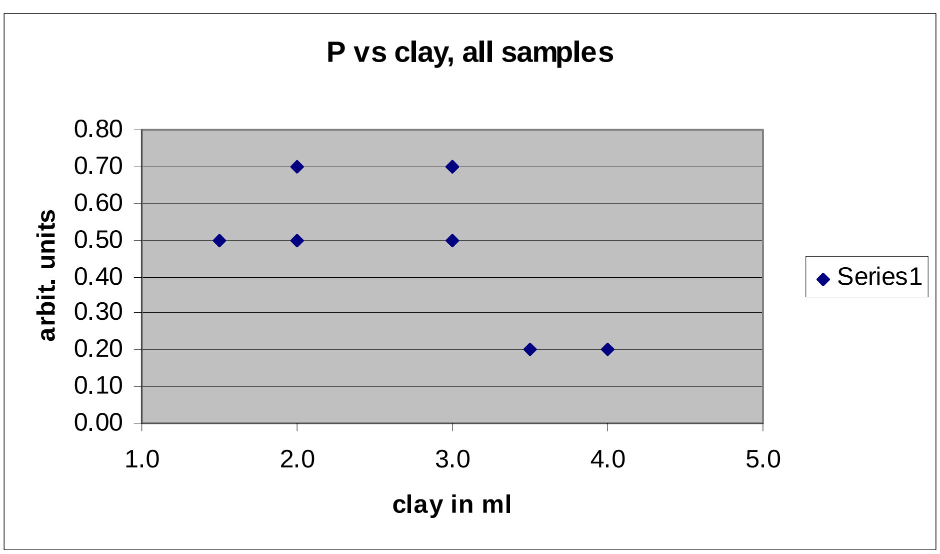

N vs sand, all samples
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
arbit. units
4.0
5.0
6.0
7.0
8.0
sand in ml
Series1

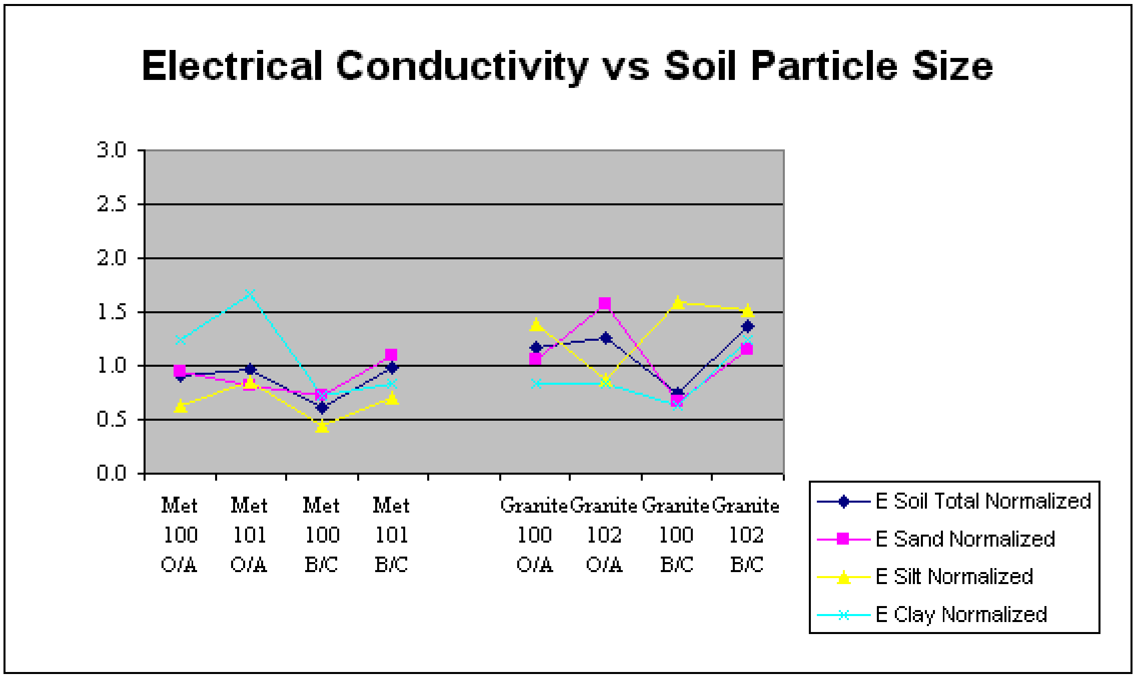

N vs silt, all samples
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
arbit. units
1.0
2.0
3.0
4.0
5.0
6.0
silt in ml
Series1

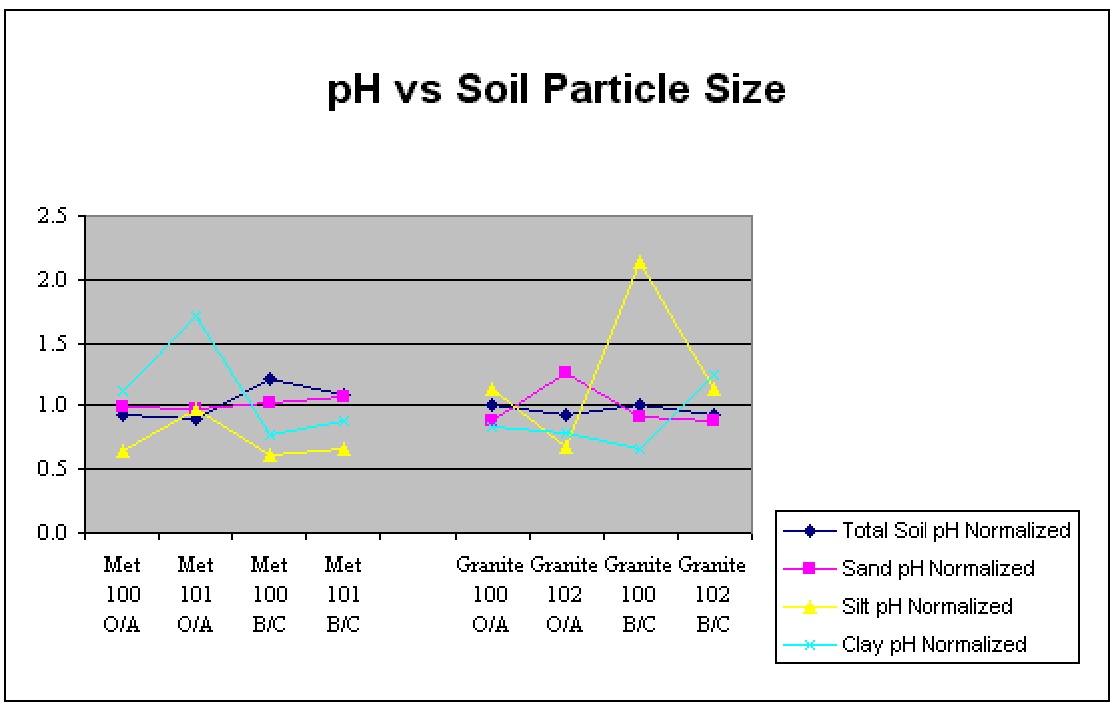

N vs clay, all samples
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
arit. units
1.0
2.0
3.0
4.0
5.0
clay in ml
Series1

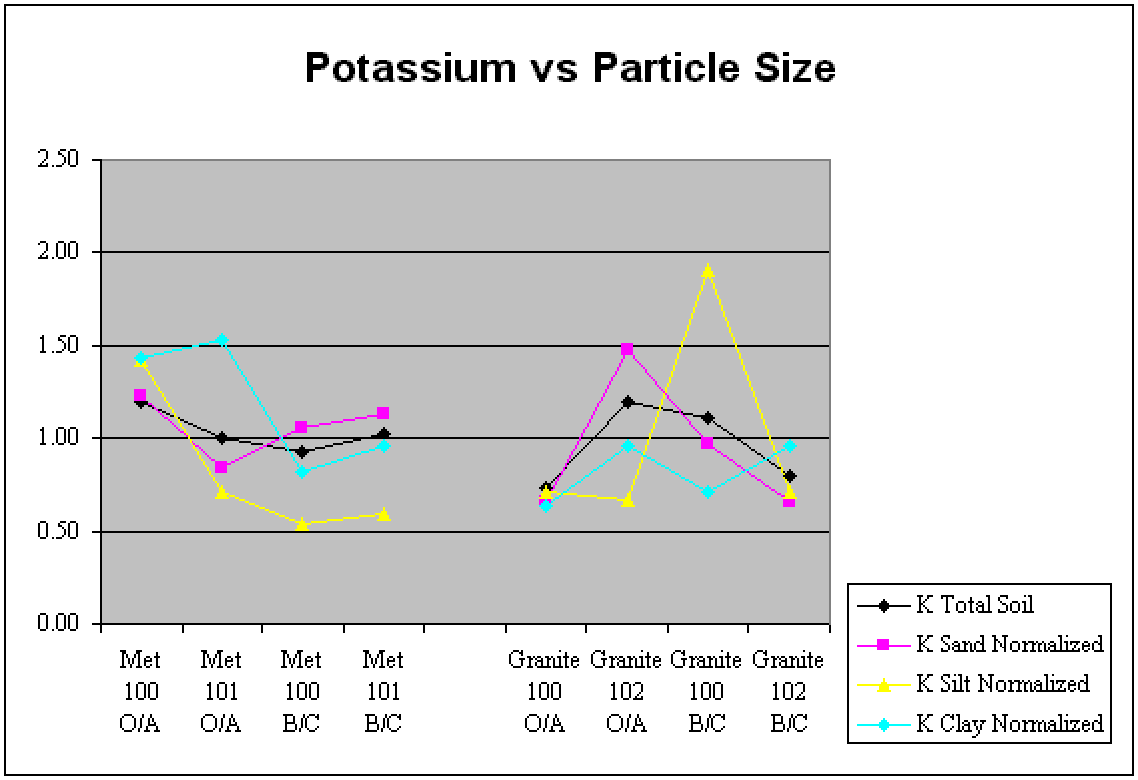

P vs sand
arit. units
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
4.0
5.0
6.0
7.0
8.0
sand in ml
Series1

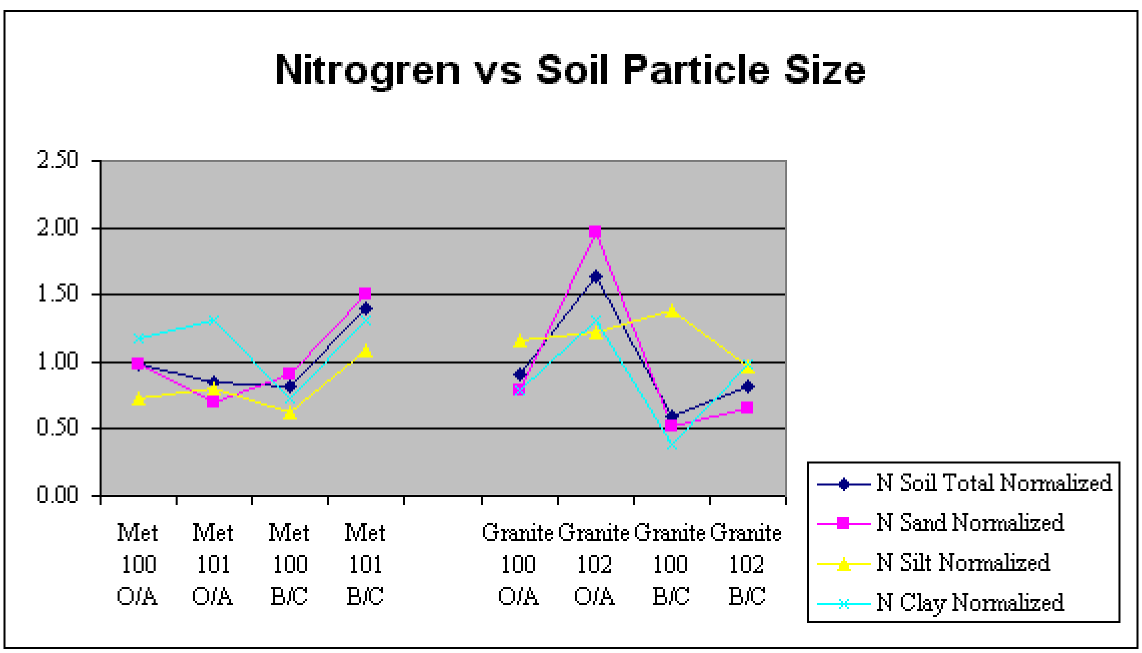

P vs silt
arib units
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
1.0
2.0
3.0
4.0
5.0
6.0
silt in ml
Series1

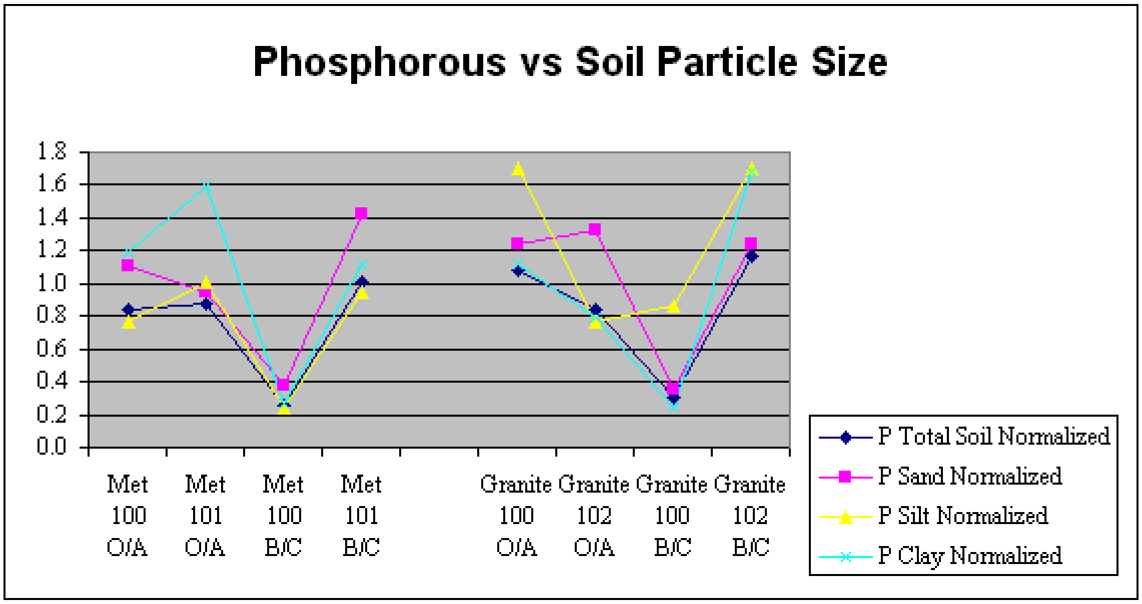

P vs clay, all samples
arbit. units
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
1.0
2.0
3.0
4.0
5.0
clay in ml
Series1

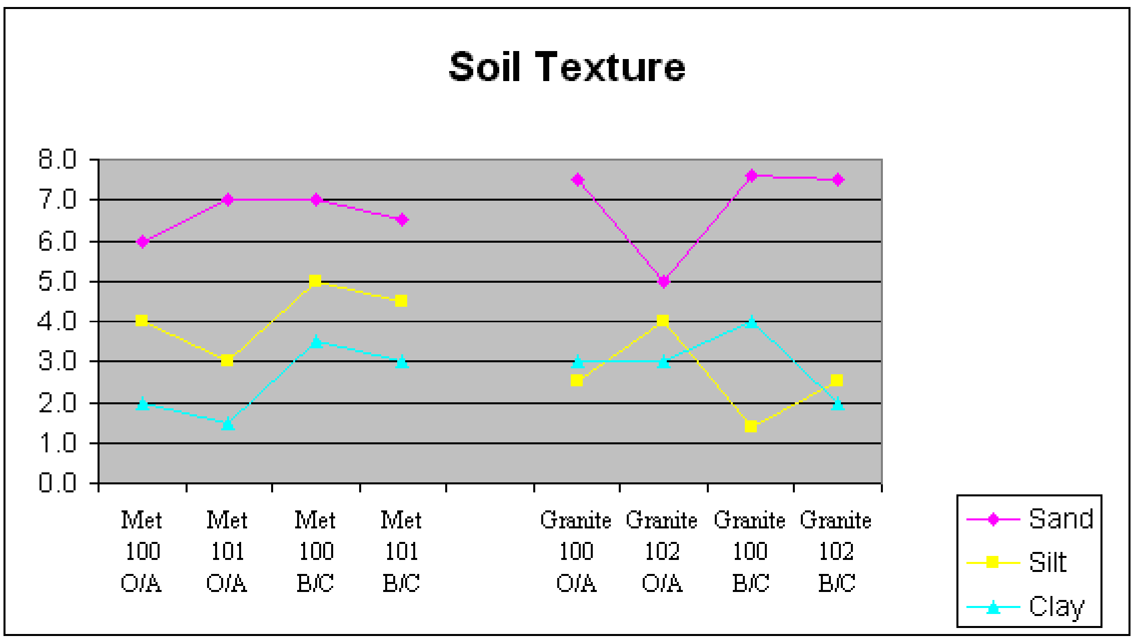

Electrical Conductivity vs Soil Particle Size
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Met 100 O/A
Met 101 O/A
Met 100 B/C
Met 101 B/C
Granite 100 O/A
Granite 102 O/A
Granite 100 B/C
Granite 102 B/C
E Soil Total Normalized
E Sand Normalized
E Silt Normalized
E Clay Normalized


pH vs Soil Particle Size
2.5
2.0
1.5
1.0
0.5
0.0
Met 100 O/A
Met 101 O/A
Met 100 B/C
Met 101 B/C
Granite 100 O/A
Granite 102 O/A
Granite 100 B/C
Granite 102 B/C
Total Soil pH Normalized
Sand pH Normalized
Silt pH Normalized
Clay pH Normalized


Potassium vs Particle Size
2.50
2.00
1.50
1.00
0.50
0.00
Met 100 O/A
Met 101 O/A
Met 100 B/C
Met 101 B/C
Granite 100 O/A
Granite 102 O/A
Granite 100 B/C
Granite 102 B/C
K Total Soil
K Sand Normalized
K Silt Normalized
K Clay Normalized


Nitrogren vs Soil Particle Size
2.50
2.00
1.50
1.00
0.50
0.00
Met 100 O/A
Met 101 O/A
Met 100 B/C
Met 101 B/C
Granite 100 O/A
Granite 102 O/A
Granite 100 B/C
Granite 102 B/C
N Soil Total Normalized
N Sand Normalized
N Silt Normalized
N Clay Normalized


Phosphorous vs Soil Particle Size
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Met 100 O/A
Met 101 O/A
Met 100 B/C
Met 101 B/C
Granite 100 O/A
Granite 102 O/A
Granite 100 B/C
Granite 102 B/C
P Total Soil Normalized
P Sand Normalized
P Silt Normalized
P Clay Normalized


Soil Texture
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Met 100 O/A
Met 101 O/A
Met 100 B/C
Met 101 B/C
Granite 100 O/A
Granite 102 O/A
Granite 100 B/C
Granite 102 B/C
Sand
Silt
Clay

Conclusions of our study

We found that the igneous soil had higher sand and lower silt content than the metamorphic soil. The metamorphic soil had considerably higher silt content in the BC layer than in the organic rich OA layer. For the igneous soil this trend was reversed and the difference was smaller.

The major story of the chemical differences in the soils could be found in the silt layers i.e. when trends in chemical concentrations were found; they were most accentuated in the silt layers.

We conclude that some minerals (e.g. quartz) in the igneous source rock are more resistant to weathering and thus resist silt formation more effectively than the minerals in the metamorphic rock. Why the silt is concentrated in the BC horizon in the metamorphic rock and more evenly distributed, but slightly more concentrated in the OA horizon in the igneous soil remains a question.

Recommendations for further study are to focus on the silt to substantiate the chemical differences indicated by the present study. This could be accomplished by separating the silt portions out of the A, B, and C horizons.