Soil Analysis

NGEE Barrow Site 0: Sep. 2011 Campaign

Version 4

September 13, 2012

Haruko Wainwright

Version 2: Soil drainage classification is added.

Version 3: More texts on soil drainage classification are added

Version 4: Improved texts on October 9, 2012.

Summary

This report presents soil analysis from the September 2011 campaign, focused on soil profile, texture and carbon/nitrogen (C/N) contents. Since the acquired cores were unconsolidated and compacted during acquisition, the depth might not be quite accurate. However, they provide some useful qualitative insight. It is especially interesting to compare our data with the description of Barrow soil in Gersper et al. [1980] and Bockheim et al. [1999]. The main findings from this analysis are:

- Three different polygonal areas have different soil vertical profiles: high-centered polygons (Zone 1), mid-centered/transitional polygons (Zone 2) and low-centered polygons (Zone 3).
    - Zone 1: Thick dry organic-rich highly oxidized soil without distinct horizon.
    - Zone 2: Clear organic/mineral soil interface at 8-10cm depth.
    - Zone 3: Thick root zone and organic layer above mineral soil
- Soil texture in the mineral soil (or strictly speaking, in the deeper portion 8-25cm, since the organic-rich soil in Zone 1 is included) is quite uniform across the region.
- Soil texture corresponds to alluvial positions near the current/former creek, according to Gersper et al. [1980].
- Carbon content in Zone 1 is distributed fairly uniformly in the vertical direction up to ~25cm. In Zone 2 and 3, the carbon content is concentrated in the shallow organic layer up to ~15cm.
- The soil map at the Barrow area originally developed by Drew [1957] and used in Bockheim et al. [1999] is actually a soil "drainage" map, which is not dependent on mineral soil texture but on soil drainage and soil profile, which might change in the future as the hydrology and landscape change in this region due to the climate change.
- We might expect the two types of zonation in the Barrow area: one depending on the surface soil profile (i.e., soil drainage map) and the other depending on depositional environment (i.e., sandy/silty mineral soil).

1. Site Description

The detailed description of core acquisition is available in Hubbard et al. [2012]. Appendix A includes detail information at each sampling location, such as the core picture, visual description, core locations (both texture cores and C/N cores) and co-located measurements including thaw depth, TDR (proxy for moisture content) and temperature.

In Site 0, three detailed sampling sites were established during the Sep. 2011 campaign; high-centered polygons (Zone 1), mid-centered/transitional polygons (Zone 2) and low-centered polygons (Zone 3). Each site covers different microtopographic features, as is shown in Figure 1.

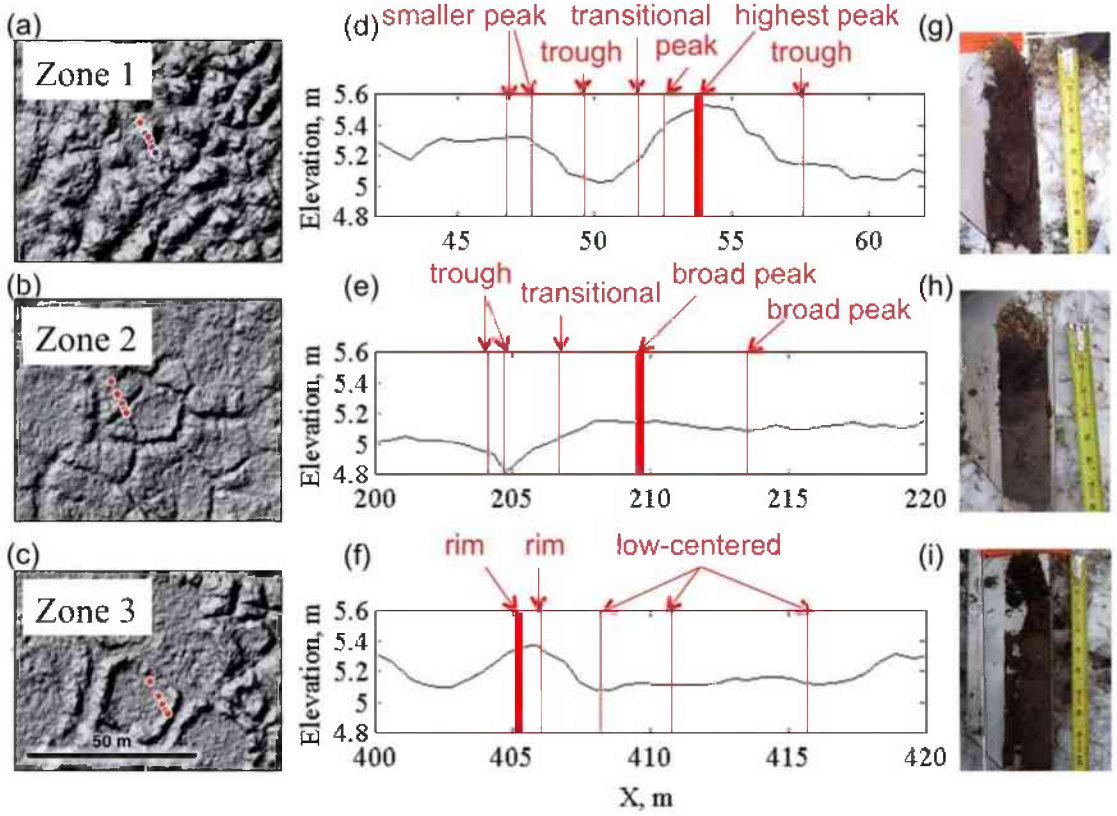

Figure 1. (a-c) Plan view LiDAR detail imagery and (d-f) cross section of three detailed study sites, both showing associated core locations (red lines) as a function of geomorphic position. (g-i) the picture of a core taken from each zone (the locations were shown by thick red lines in d-f). Top: Zone 1, Middle: Zone 2, Bottom, Zone 3. From Hubbard et al. [2012]

2. Vertical Soil Profile

The pictures in Appendix A provide rich information about the soil profile and its heterogeneity in this area. Although there is an individual difference, we can see a distinct characteristic in each zone. Note that this description was created later based on the pictures without seeing the actual samples, and also the author is not a soil specialist. The readers would need to look at the actual pictures (Appendix A) and decide whether this description is correct/wrong.

In Zone 1, none of the vertical profiles have a clear organic/mineral soil interface, although we can see very shallow root zone up to 5cm. In the driest sample from the peak of the high-centered polygon (Location 54), we can see fibric material, which might be common among other locations but could not be seen in the pictures due to wetness. This Zone-1 soil matches this description in Gersper et al. [1980]:

> *"In the better drained, more highly oxidized soils such as are found on the tops of high-centered polygons and the rims of low-centered polygons, highly decomposed sapric organic matter may predominate throughout the entire active layer and continue down into the permafrost."*

Later in Section 4, the carbon content confirms this agreement.

In Zone 2, the pictures show a clear organic/mineral soil interface. The organic layer is black and 8-10cm thick. In Zone 3 (the low-centered polygon area), the soil profiles show a significant difference between the polygon rim and center. At the rim, there are three zones below the shallow root zone (depth > 5 cm). The first zone is a black organic layer similar to the organic layer in Zone 2. The second zone is yellowish-brown fibrous material. The third zone is mineral soil. This profile seems different from a typical profile, where a yellowish-brown organic layer comes on top of a dark-brown organic layer [e.g., Hinzman et al., 1991]. This could be an effect of cryoturbation, which is more active at the rim of low-centered polygons. At the center of the low-centered polygon, although the core recovery is not good, we can see thicker black organic layer (~15cm).

3. Texture Analysis

The texture analysis was conducted for the deeper sections of the soil profile, which corresponds to mineral soil portion except for Zone 1. Each texture location is shown in Appendix A (tx1, tx2….). Figure 2(a) shows the soil texture of all the Sep. 2011 samples on the USDA texture triangle. The soil texture class is predominantly Sandy Clay Loam, although there are some scatters. The Zone-1 samples are more scattered, which could be due to the higher organic content. We can compare this diagram to the one in Gersper et al. [1980], which showed two soil texture groups in the broader Barrow area. This suggests that our site is included in Category A, which corresponds to "alluvial positions and the stream banks". Gersper et al. [1980] also mentioned that Category A is not so common in the Barrow area. In the LiDAR data, we can see that there are old-drainage or creek-like features near the NGEE sites so that it is reasonable to expect the Category A mineral soil at our site.

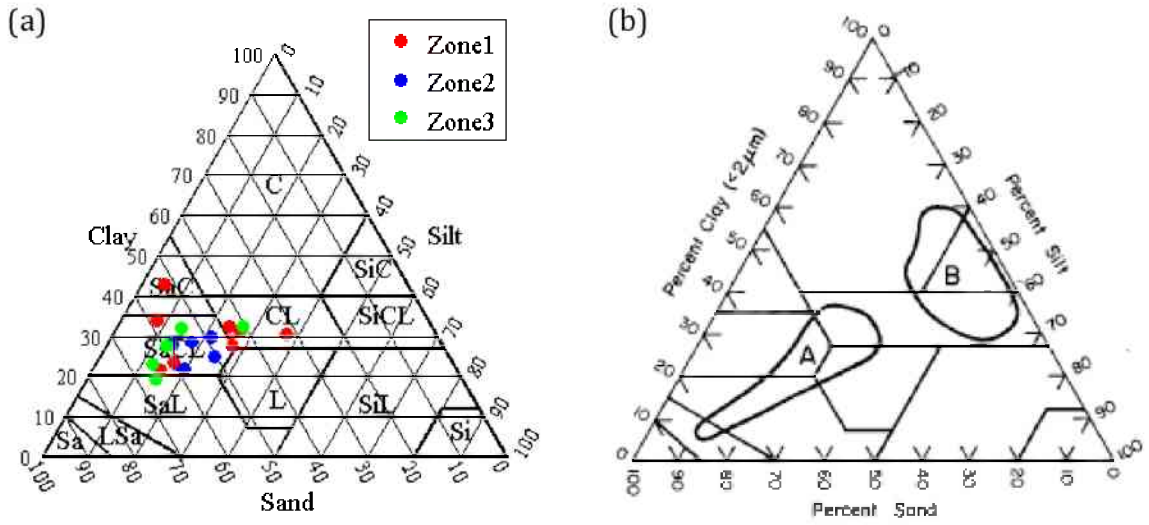

Figure 2. (a) Texture of deeper soil from the NGEE Sep. 2011 campaign on the USDA texture triangle. The symbols for the texture classes are Sa: Sand/Sandy, C: Clay, Si: Silt and L: Loam. (b) From Gersper et al. [1980] *"Particle size distribution and texture of mineral horizons in soils from A) Aeric Pergelic Cryaquepts on sloping areas marginal to Footprint Creek (10 samples), and B) Histic Pergelic Cryaquepls and Pergelic Cryohemists in a moist meadow (86 samples)".*

4. Carbon/Nitrogen Content Analysis

Figure 3 shows the carbon content and carbon/nitrogen (C/N) ratio in each zone. In Figure 3(a), the carbon content in Zone 1 does not decrease with depth significantly, except for Location 50, which is at the bottom of a trough. In Figure 3(b) and (c) (Zone 2 and 3), we can see a large difference in the carbon content between the shallow organic layer and mineral soil. In Zone 1, the carbon content is more distributed vertically; the shallow layer does not have as much carbon as the one in Zone 2 and Zone 3, but the deeper layer has more carbon than the mineral soil in Zone 2 and 3. This figure confirms that our Zone-1 soil fits to the description in Gersper et al. [1980] about the thick organic-rich soil in well-drained high-centered polygon areas (as mentioned in Section 2).

In Figure 3(d-e), the C/N ratio over the area is fairly constant except for the rim of low centered polygons (Zone 3). This C/N ratio ~ 20:1 is a typical value mentioned in Gersper et al. [1980]. It also suggests that the carbon content and nitrogen content vary in a highly correlated manner.

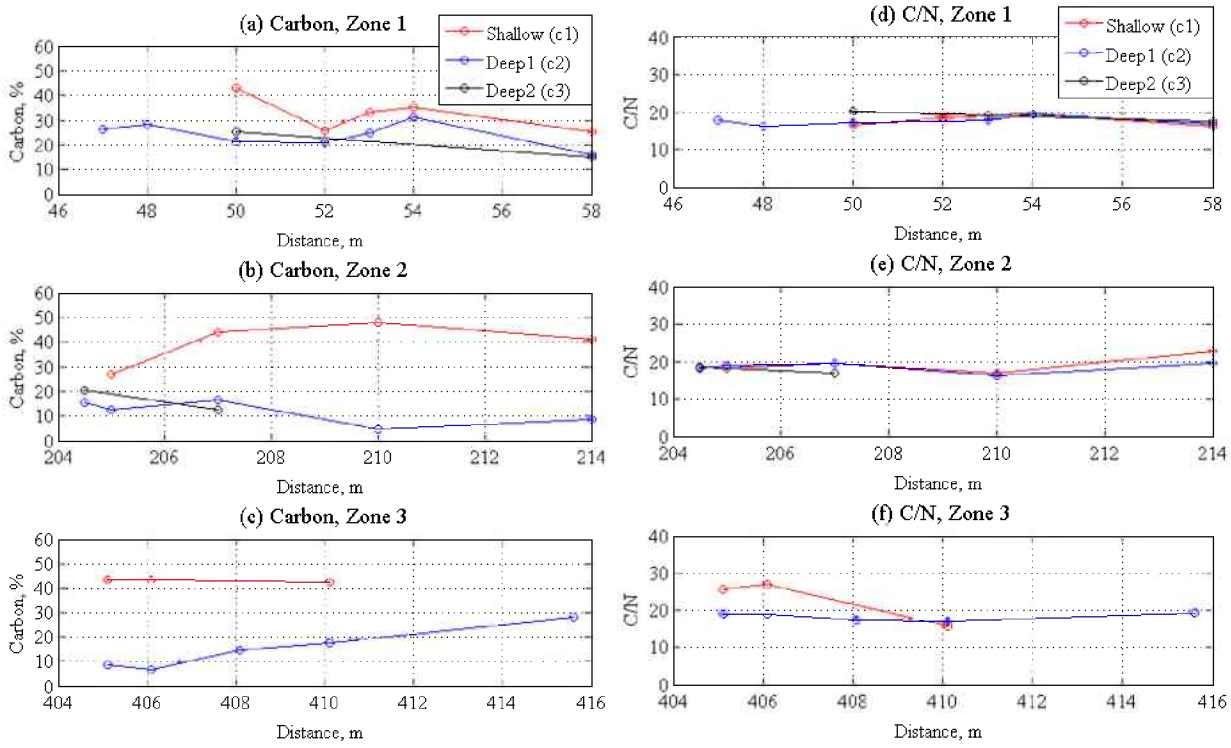

Figure 3. (a-c) Carbon content and (d-f) CN ratio in Zone 1, Zone 2 and Zone 3. The different depth is indicated by three lines Shallow (red), Deep 1(blue) and Deep 2 (black). The core locations (c1, c2 and c3) can be seen in Appendix A.

4. Soil drainage characterization

As a soil classification, there is a Gelisol-order map in the Barrow area [Bockheim et al., 1999]. Table 1 shows the description of each soil type, and Figure 4 shows the soil map around the NGEE sites. According to this classification criteria in Table 1, Zone 1 would be classified as Typic Sapristels based on the polygon feature (well drained; high-centered) and vertical distribution of the carbon content compared to the one listed in Bockheim et al. [1999]. In the map (Figure 4), in fact, there is a small patch of Typic Sapristels near Zone 1. The soil in Zone 1 and Zone 2 would be classified as Typic Aquiturbels, which is poorly drained and has a 10-15cm organic layer below the surface.

It should be noted that this soil classification is based on “drainage”, not on texture/mineralogy. The texture analysis in Section 3 suggests similar texture in the mineral soil across Site 0. Also, Gersper et al.,[1980] suggested that there are two different classes in the broader Barrow area. It would be possible that we have zonation depending on drainage (or microtopography) for surface soil features, as well as zonation depending on the depositional environment (alluvial/marine), which controls mineral soil. This also implies that the drainage or hydrological features have a large impact on soil and geochemical properties, and “soil map” would change if the permafrost degrades and drainage changes in the future.

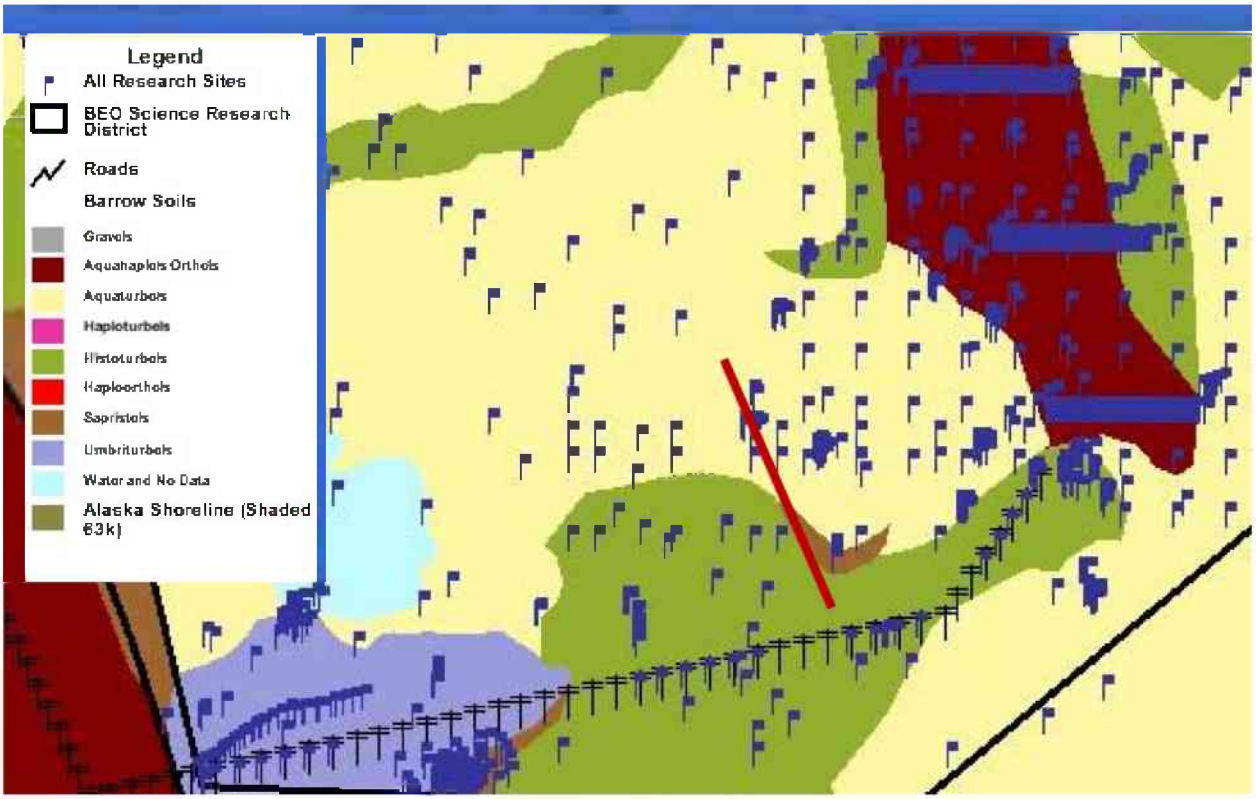

Figure 4. Gelisol-order map around the NGEE sites. The red line represents Site 0, although the location is not exact.

Gelisol order	Former classification	Area	Drainage	Note
Typic Haploturbels	Arctic Brown soil	0.2%	well	
Typic Umbriturbels	Meadow Tundra, Dry Phase	2.0%	moderately well	
Typic Aquiturbels	Meadow Tundra, Normal Phase soils,	53.0%	somewhat poor	contain a 10- to 15-cm-thick O horizon over a highly cryoturbated Bg horizon
Typic Histoturbel	Meadow Tundra, Wet Phase soil	22.0%	poor	20- to 25-cm-thickOhorizon over a highly cryoturbated Bg horizon
Typic Aquorthels	Half Bog, Wet soils	8.6%	very poor	show little evidence of cryoturbation
Typic Sapristels	Half Bog, dry soils	1.0%	well drained	high-centered, ice-wedge polygons. improved drainage and organic matter decomposition
Open water		9.0%		
Beach gravel		4.4%		

Table 1. Description of each soil type in the Gelisol order from Bockheim et al., 1999.

Acknowledgement

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References

Bockheim, J.G., Everett, L.R., Hinkel, K.M., Nelson, F.E. and Brown, J. (1999), Soil organic carbon storage and distribution in Arctic Tundra, Barrow, Alaska. Soil Sci. Soc. Am. J., 63(4), 934–940.

Drew, J.V. (1957), A pedologic study of arctic coastal plain soils near Point Barrow, Alaska. Ph.D. diss., Rutgers Univ. Diss. Abstr. AAC 0022512.

Gersper, P. L.,V. Alexander, S. A. Barkley, R. J. Barsdate, and P. S. Flint (1980), "The Soils and Their Nutrients", Chapter 7 in "An arctic ecosystem, the coastal tundra at Barrow, Alaska", edited by Brown, J., Miller, P. C., Tieszen, L. L., and Bunnell, F. L., US/IBP Synthesis Series 12, Dowden, Hutchinson and Ross, Inc. Stroudsburg, Pennsylvania. 571 pp.

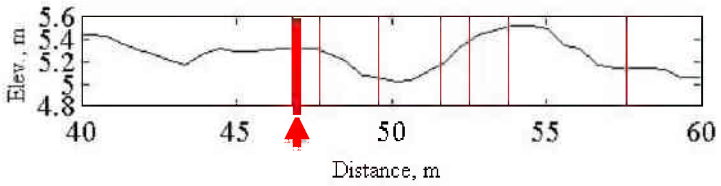
Hinzman, L.D., D.L. Kane, R.E. Gieck and K.R. Everett (1991), "Hydrologic and thermal properties of the active layer in the Alaskan Arctic", Cold Regions Science and Technology, 19, 95- l 10.

Hubbard, S.S., C. Gangodagamage, B. Dafflon, H. Wainwright, J. E. Peterson, A. Gusmeroli, C. Ulrich, Y. Wu, C. Wilson, J. Rowland, C. Tweedie and S.D. Wullschleger, Quantifying and relating land-surface and subsurface variability in permafrost environments using LiDAR and surface geophysical datasets, in press, Hydrogeology

Appendix A

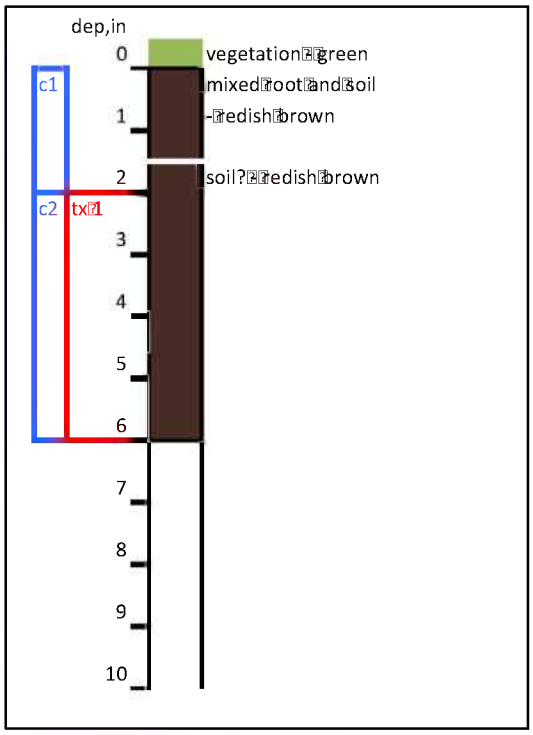
Location Name: 47

Location Description



Basic information

- Collected on 09/27/2011
- Total Length: 6”
- Recovery?: Okay
- # of texture cores: 1
- # of C/N cores: 2
- GPS locations (m):
  Northing: 7909996.585
  Easting: 585560.707
- Elevation (m): 5.2020



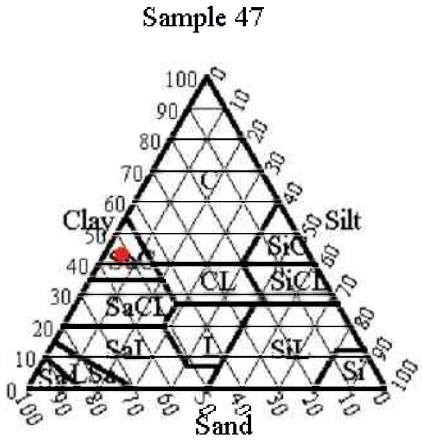
Co-located information

- Thaw depth (cm): 29
- T-8cm (C): 1.2
- T2 (C): 0.9
- TDR: NaN
- Surface water?: No
- Topo: High

Texture Analysis

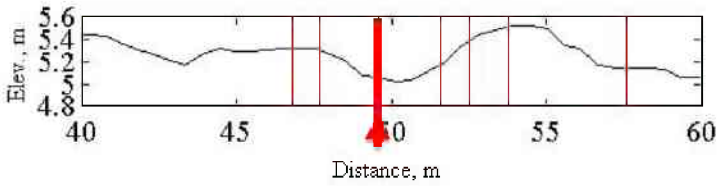
Texture Core 1 (tx1)

- Depth: 2-6”
- Texture {Sand, Clay, Silt}: {52.0, 43.0, 5.0}%
- Soil Class: Sandy Clay
- Notes:



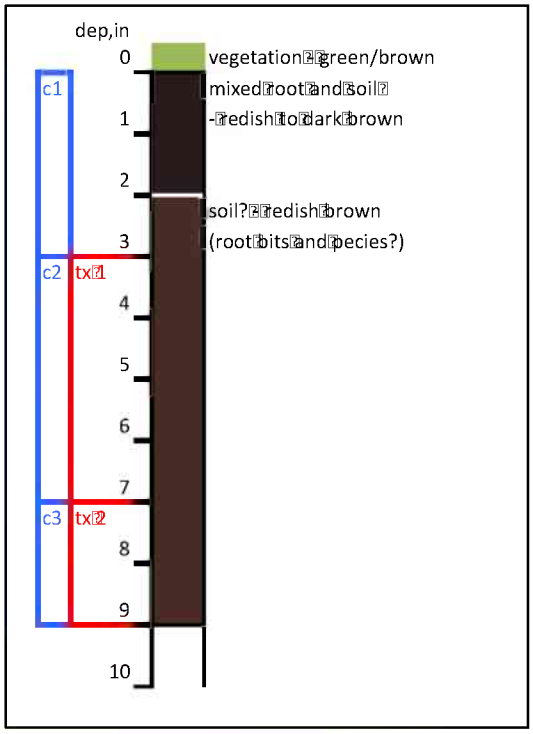
Location Name: 50

Location Description



Basic information

- Collected on 09/27/2011
- Total Length: 9”
- Recovery?: Good
- # of texture cores: 2
- # of C/N cores: 3
- GPS locations (m):
  Northing: 7909998.982
  Easting: 585559.246
- Elevation (m): 4.9240



Co-located information

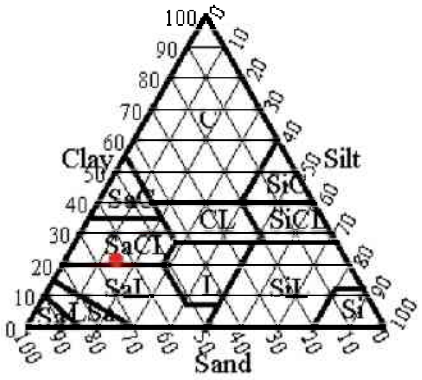
- Thaw depth (cm): 33
- T-8cm (C): 1.2
- T2 (C): 0.9
- TDR: 27.3
- Water?: No
- Topo: Low

Texture Analysis

Texture Core 1 (tx1)

- Depth: 3-7’
- Texture {Sand, Clay, Silt}:
  {64.0, 21.5, 14.5}%
- Soil type: Sandy Clay Loam
- Notes:

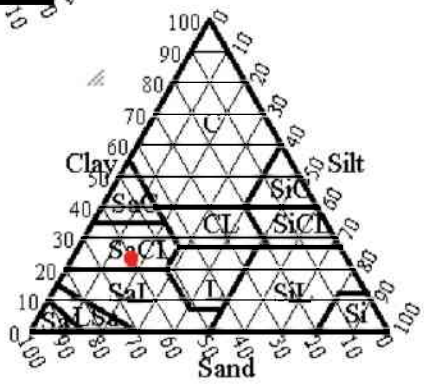
Sample 50-1



Texture Core 2 (tx2)

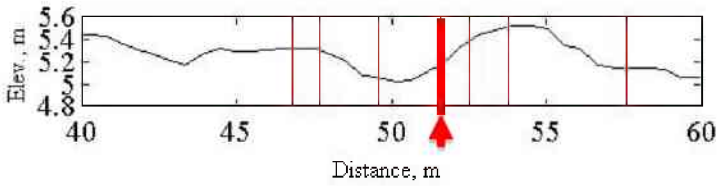
- Depth: 7-9”
- Texture {Sand, Clay, Silt}:
  {60.1, 23.3, 16.6}%
- Soil type: Sandy Clay Loam
- Notes:

Sample 50-2



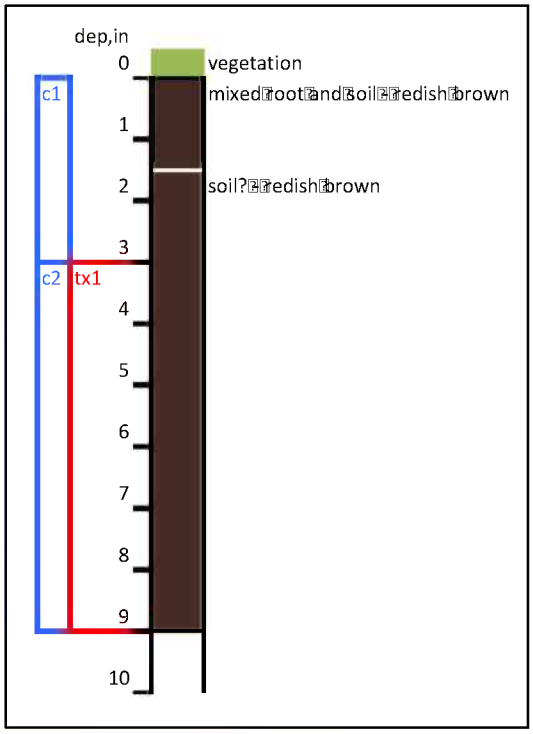
Location Name: 52

Location Description



Basic information

- Collected on 09/27/2011
- Total Length: 9”
- Recovery?: Good
- # of texture cores: 1
- # of C/N cores: 2
- GPS locations (m):
  Northing: 7910000.949
  Easting: 585558.690
- Elevation (m): 5.1100

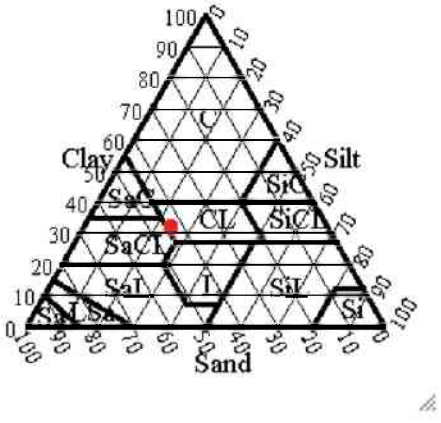


Co-located information

- Thaw depth (cm): 34
- T-8cm (C): 1.3
- T2 (C): 1.1
- TDR: 24.5
- Surface water?: No
- Topo: Transition

Texture Analysis

Sample 52

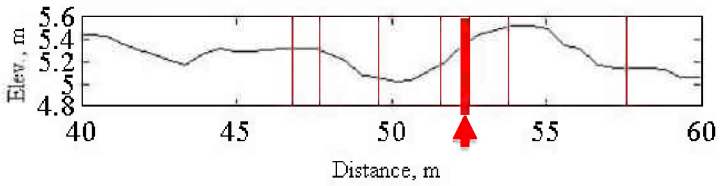


Texture Core 1 (tx1)

- Depth: 3-9”
- Texture {Sand, Clay, Silt}:
  {43.6, 32.3, 24.1}%
- Soil Class: Sandy Clay Loam
- Notes:

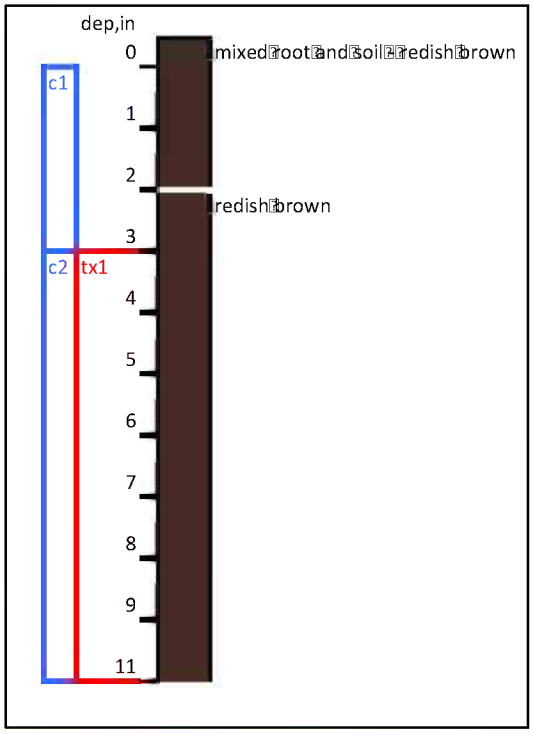
Location Name: 53

Location Description



Basic information

- Collected on 09/27/2011
- Total Length: 11”
- Recovery?: Good
- # of texture cores: 1
- # of C/N cores: 2
- GPS locations (m):
  Northing: 7910001.733
  Easting: 585558.354
- Elevation (m): 5.3740

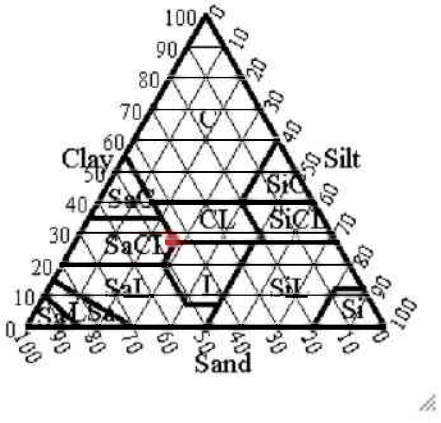


Co-located information

- Thaw depth (cm): 35
- T-8cm (C): 1.3
- T2 (C): 1.0
- TDR: 23.6
- Surface water?: No
- Topo: Peak

Texture Analysis

Sample 53

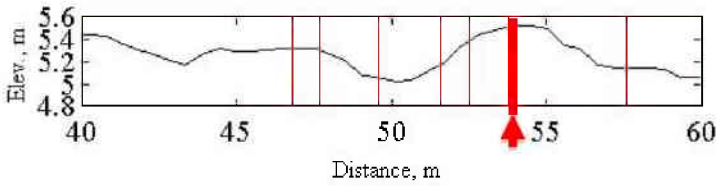


Texture Core 1 (tx1)

- Depth: 3-11”
- Texture {Sand, Clay, Silt}:
  { 45.5, 27.4, 27.1}%
- Soil Class: Sandy Clay Loam
- Notes:

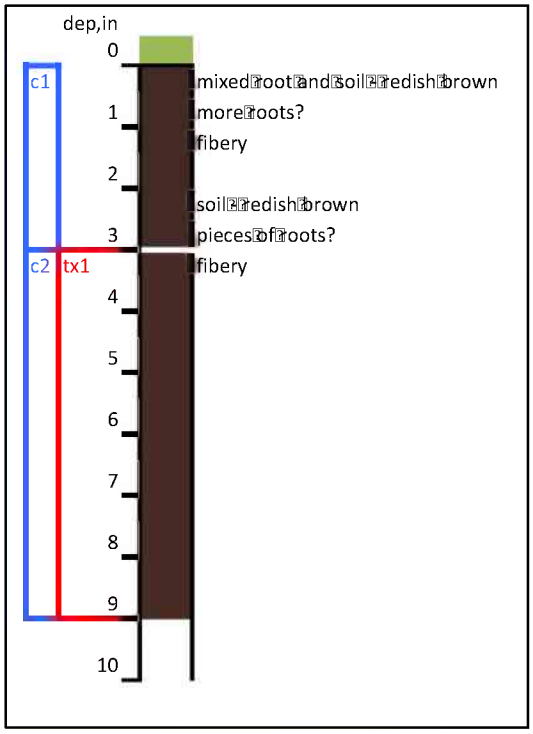
Location Name: 54

Location Description



Basic information

- Collected on 09/27/2011
- Total Length: 9”
- Recovery?: Good
- # of texture cores: 1
- # of C/N cores: 2
- GPS locations (m):
  Northing: 7910002.847
  Easting: 585557.659
- Elevation (m): 5.4500

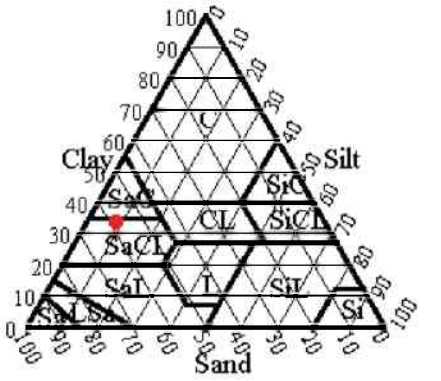


Co-located information

- Thaw depth (cm): 30
- T-8cm (C): 1.4
- T2 (C): 1.0
- TDR: 14.5
- Surface water?: No
- Topo: Peak (highest)

Texture Analysis

Sample 54

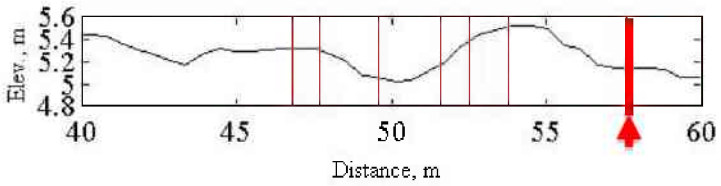


Texture Core 1 (tx1)

- Depth: 3-9”
- Texture {Sand, Clay, Silt}:
  {58.2, 33.9, 7.9}%
- Soil type: Sandy Clay Loam
- Notes:

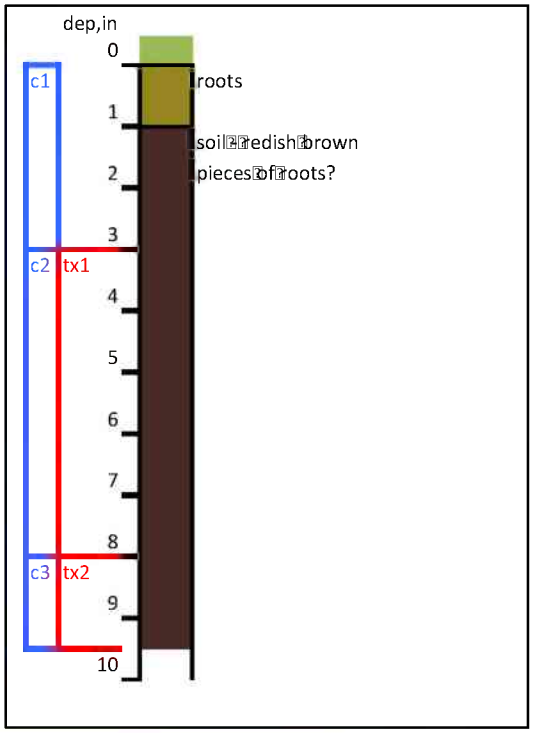
Location Name: 58

Location Description



Basic information

- Collected on 09/27/2011
- Total Length: 10”
- Recovery?: Good
- # of texture cores: 2
- # of C/N cores: 3
- GPS locations (m):
  Northing: 7910006.307
  Easting: 585556.065
- Elevation (m): 5.1290



Co-located information

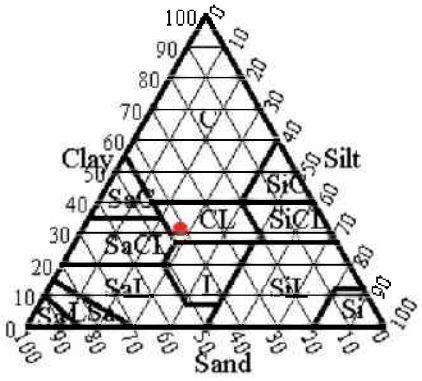
- Thaw depth (cm): 33
- T-8cm (C): 1.3
- T2 (C): 1.0
- TDR: 29.9
- Surface water?: No
- Topo: Transition to low

Texture Analysis

Texture Core 1 (tx1)

- Depth: 3-8”
- Texture {Sand, Clay, Silt}:
  {41.6, 31.4, 27.0}%
- Soil type: Clay Loam
- Notes:

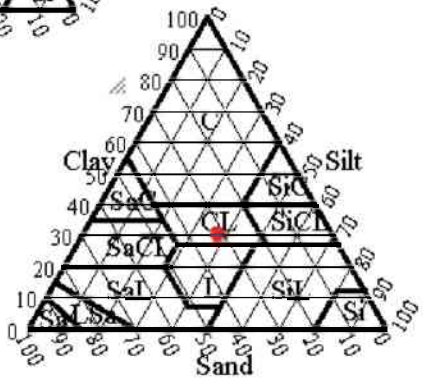
Sample 58-1



Texture Core 2 (tx2)

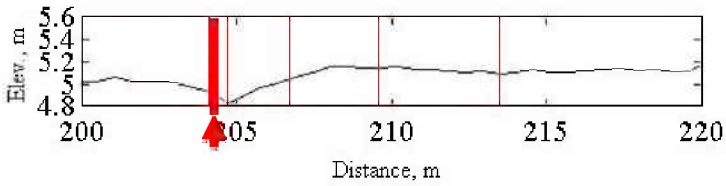
- Depth: 8-9.5”
- Texture {Sand, Clay, Silt}:
  {32.0, 30.7, 37.3}%
- Soil type: Clay Loam
- Notes:

Sample 58-2



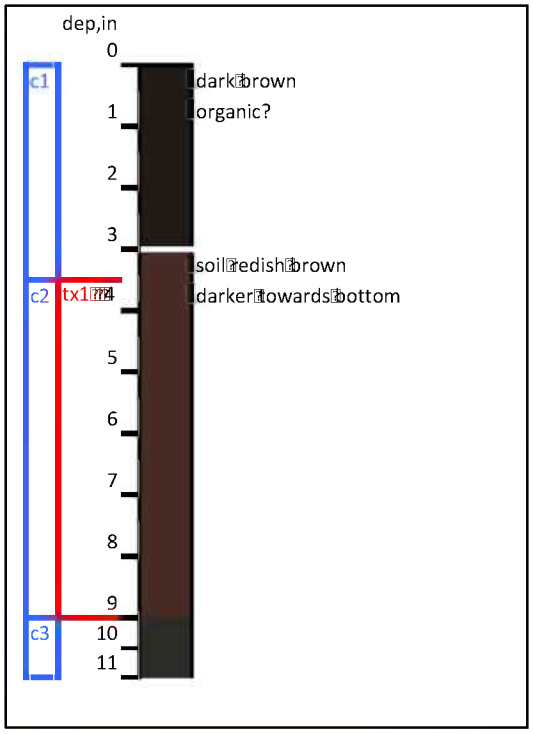
Location Name: 204.5

Location Description



Basic information

- Collected on 09/27/2011
- Total Length: 11”
- Recovery?: Okay
- # of texture cores: 1
- # of C/N cores: 3
- GPS locations (m):
  Northing: 7910137.991
  Easting: 585491.889
- Elevation (m): 4.8620



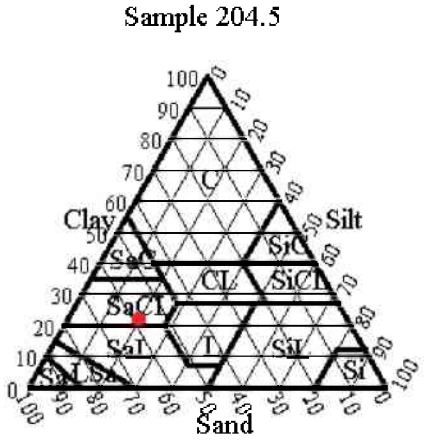
Co-located information

- Thaw depth (cm): 39
- T-8cm (C): 1.1
- T2 (C): NaN
- TDR: 31.5
- Surface water?: ?
- Topo: Trough

Texture Analysis

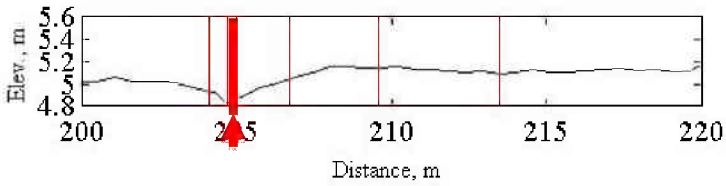
Texture Core 1 (tx1)

- Depth: 3.5-9”
- Texture {Sand, Clay, Silt}:
  {58.3, 22.1, 19.6}%
- Soil type: Sandy Clay Loam
- Notes:



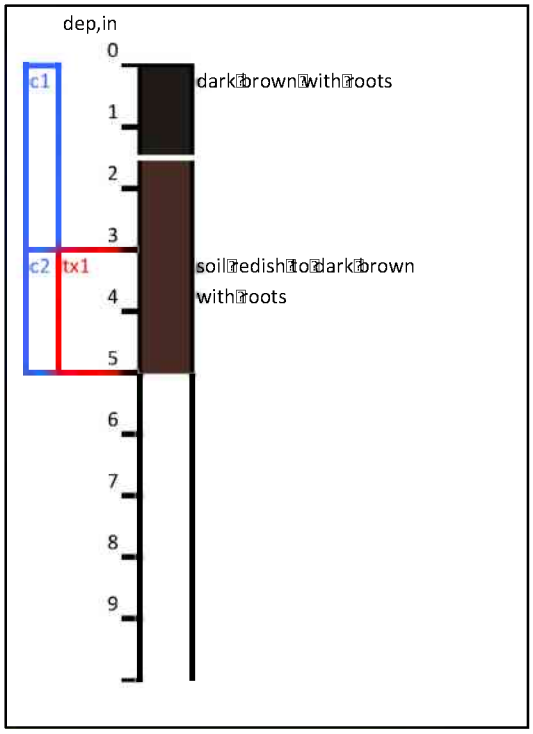
Location Name: 205

Location Description



Basic information

- Collected on 09/27/2011
- Total Length: 5”
- Recovery?: Okay
- # of texture cores: 1
- # of C/N cores: 2
- GPS locations (m):
  Northing: 7910138.472
  Easting: 585491.509
- Elevation (m): 4.8310



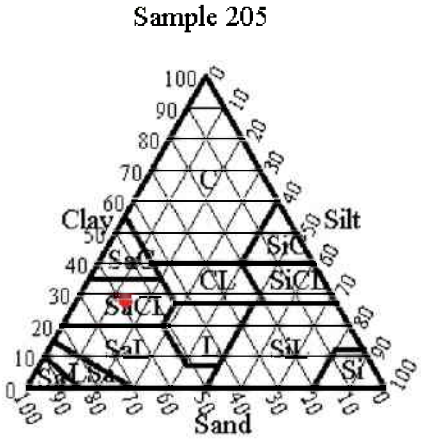
Co-located information

- Thaw depth (cm): 33
- T-8cm (C): 1.2
- T2 (C): NaN
- TDR: 36.2
- Surface water?: Yes
- Topo: Trough

Texture Analysis

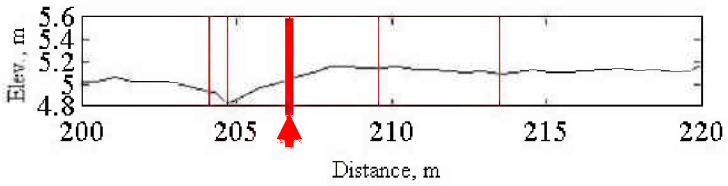
Texture Core 1 (tx1)

- Depth: 3-5”
- Texture {Sand, Clay, Silt}:
  {58.2, 27.9, 13.9}%
- Soil type: Sandy Clay Loam
- Notes:



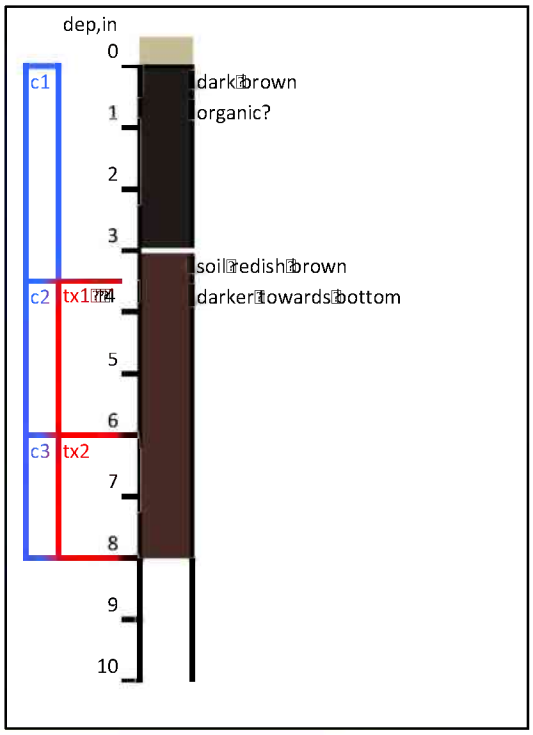
Location Name: 207

Location Description



Basic information

- Collected on 09/27/2011
- Total Length: 8"
- Recovery?: Good
- # of texture cores: 2
- # of C/N cores: 3
- GPS locations (m):
  Northing: 7910140.292
  Easting: 585490.764
- Elevation (m): 4.9210



Co-located information

- Thaw depth (cm): 28
- T-8cm (C): 1.2
- T2 (C): NaN
- TDR: 26.4
- Surface water?: No
- Topo: Transition

Texture Analysis

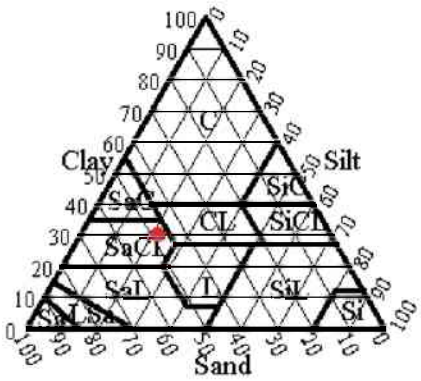
Texture Core 1 (tx1)

- Depth: 3.5-6"
- Texture {Sand, Clay, Silt}:
  {48.5, 30, 21.5}%
- Soil type: Sandy Clay Loam
- Notes:

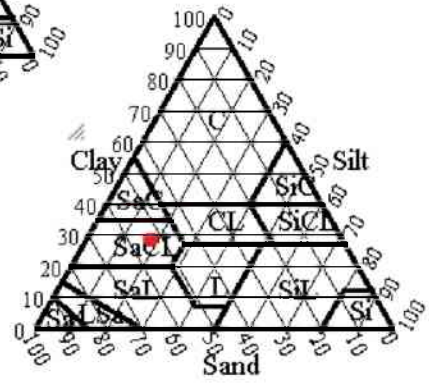
Texture Core 2 (tx2)

- Depth: 6-8"
- Texture {Sand, Clay, Silt}:
  {53.4, 28.8, 17.8}%
- Soil type: Sandy Clay Loam
- Notes:

Sample 207-1

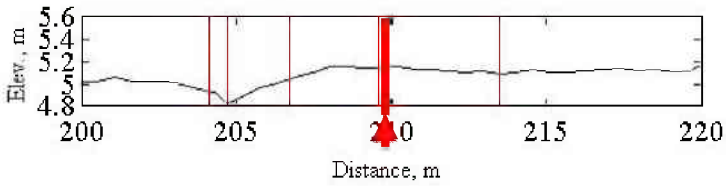


Sample 207-2



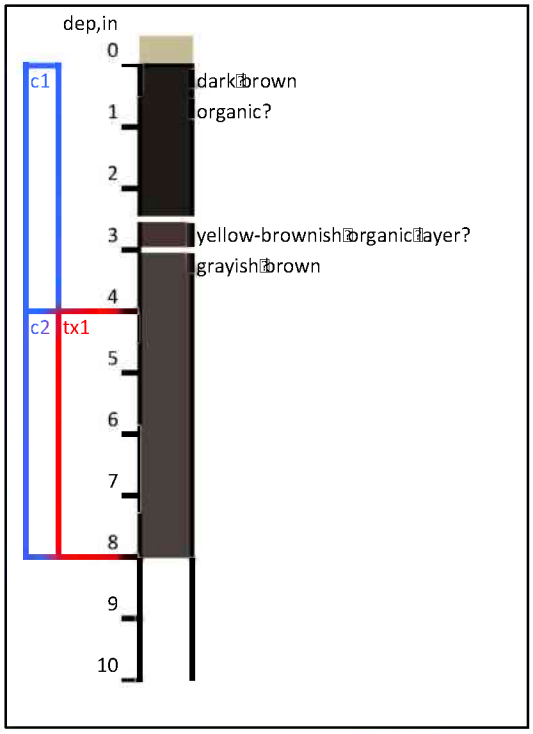
Location Name: 210

Location Description



Basic information

- Collected on 09/27/2011
- Total Length: 8”
- Recovery?: Good
- # of texture cores: 1
- # of C/N cores: 2
- GPS locations (m):
  Northing: 7910142.818
  Easting: 585489.287
- Elevation (m): 5.0100



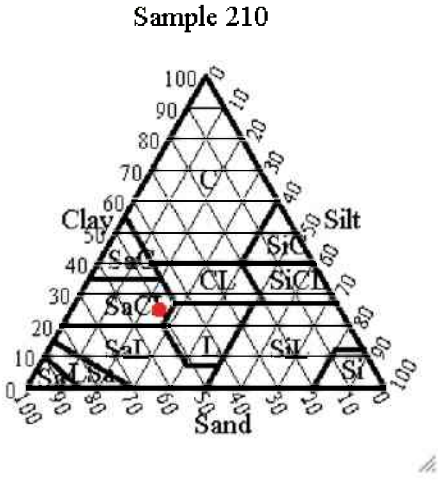
Co-located information

- Thaw depth (cm): 30
- T-8cm (C): 1.2
- T2 (C): NaN
- TDR: 10.8
- Surface water?: No
- Topo: Broad peak

Texture Analysis

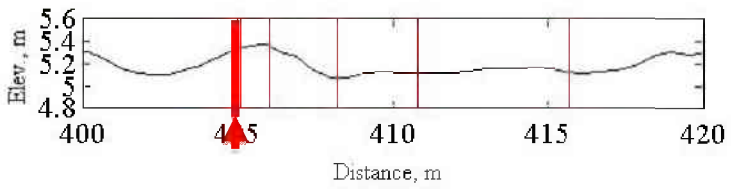
Texture Core 1 (tx1)

- Depth: 4-9”
- Texture {Sand, Clay, Silt}:
  {50.7, 24.8, 24.5 }%
- Soil type: Sandy Clay Loam
- Notes



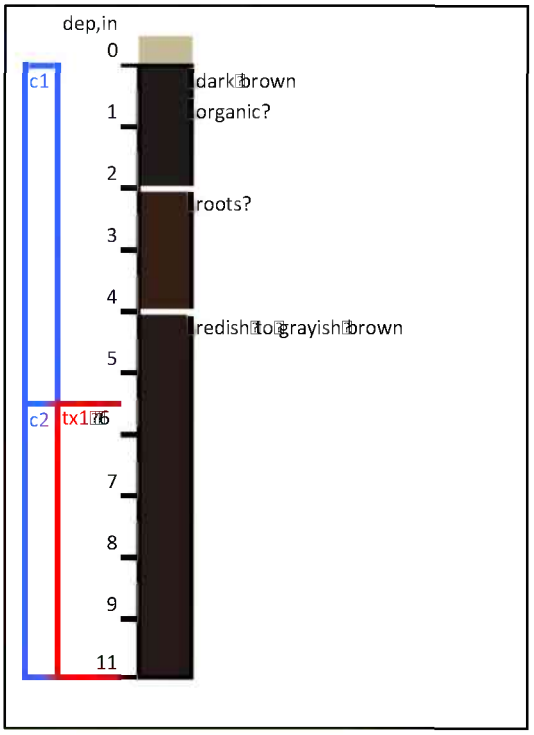
Location Name: A

Location Description



Basic information

- Collected on 09/27/2011
- Total Length: 11”
- Recovery?: Good
- # of texture cores: 1
- # of C/N cores: 2
- GPS locations (m):
  Northing: 7910318.744
  Easting: 585403.903
- Elevation (m): 5.1830



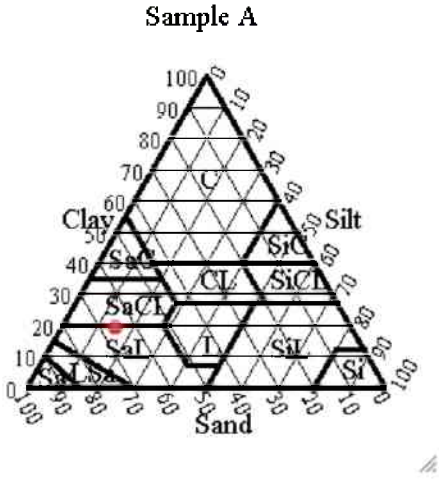
Co-located information

- Thaw depth (cm): 39
- T-8cm (C): 0.9
- T2 (C): NaN
- TDR: 19.1
- Surface water?: No
- Topo: Rim

Texture Analysis

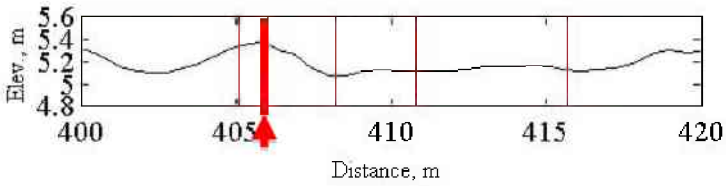
Texture Core 1 (tx1)

- Depth: 5.5-11”
- Texture {Sand, Clay, Silt}:
  {65.9, 19.2, 14.9}%
- Soil type: Sandy Clay Loam
- Notes:



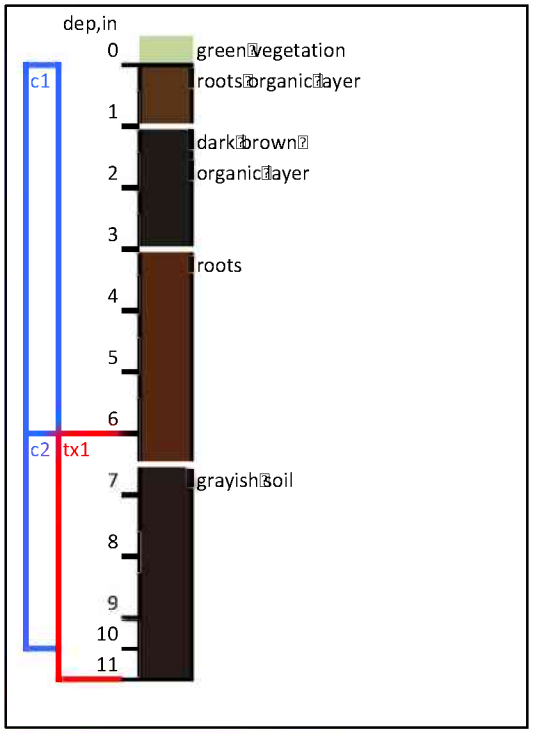
Location Name: B

Location Description



Basic information

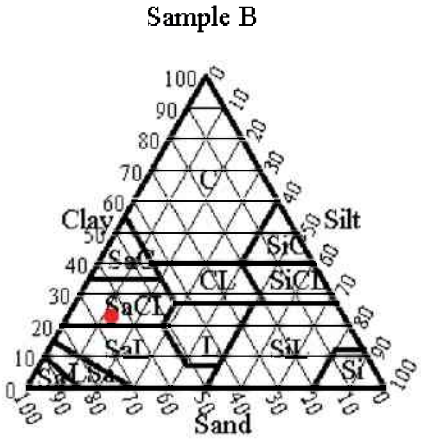
- Collected on 09/27/2011
- Total Length: 11”
- Recovery?: Okay
- # of texture cores: 1
- # of C/N cores: 2
- GPS locations (m):
  Northing: 7910319.503
  Easting: 585403.408
- Elevation (m): 5.1350



Co-located information

- Thaw depth (cm): 38
- T-8cm (C): 0.9
- T2 (C): NaN
- TDR: 61.9
- Surface water?: No
- Topo: Rim to transition

Texture Analysis

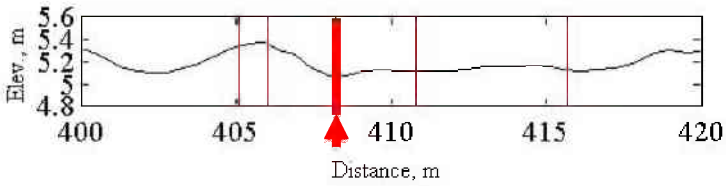


Texture Core 1 (tx1)

- Depth: 6-10”
- Texture {Sand, Clay, Silt}:
  {64.6, 23.2, 12.2}%
- Soil type: Sandy Clay Loam
- Notes:

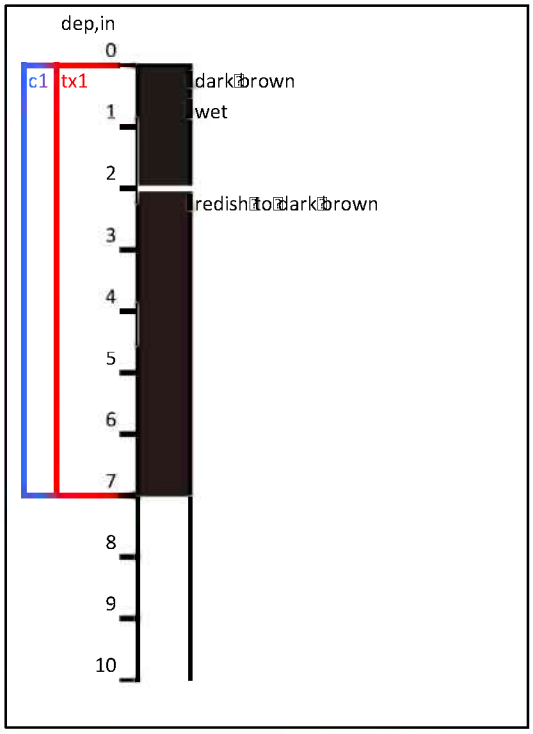
Location Name: C

Location Description



Basic information

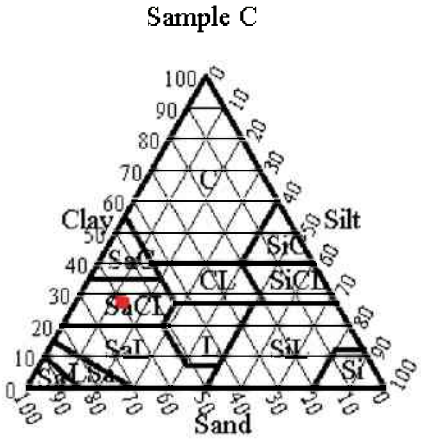
- Collected on 09/27/2011
- Total Length: 7”
- Recovery?: Poor
- # of texture cores: 1
- # of C/N cores: 1
- GPS locations (m):
  Northing: 7910321.375
  Easting: 585402.293
- Elevation (m): 5.0060



Co-located information

- Thaw depth (cm): 52
- T-8cm (C): 1.1
- T2 (C): NaN
- TDR: NaN
- Surface water?: Yes
- Topo: Low center

Texture Analysis

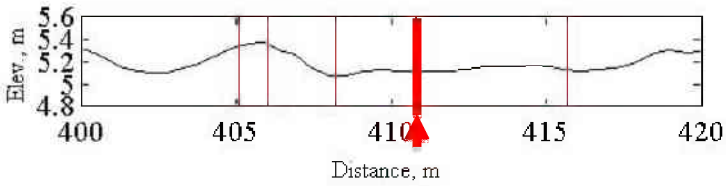


Texture Core 1 (tx1)

- Depth: 0-7”
- Texture {Sand, Clay, Silt}:
  {59.5, 27.7, 12.8}%
- Soil type: Sandy Clay Loam
- Notes:

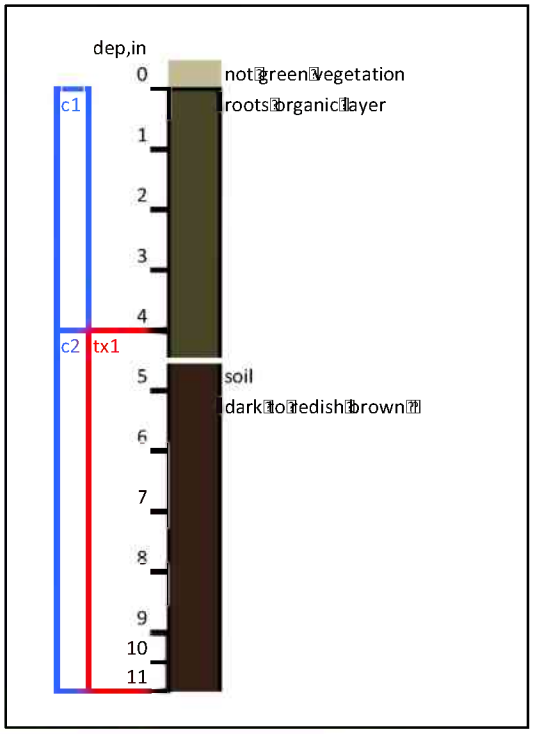
Location Name: D

Location Description



Basic information

- Collected on 09/27/2011
- Total Length: 11”
- Recovery?: Okay
- # of texture cores: 1
- # of C/N cores: 2
- GPS locations (m):
  Northing: 7910323.749
  Easting: 585401.190
- Elevation (m): 5.0450

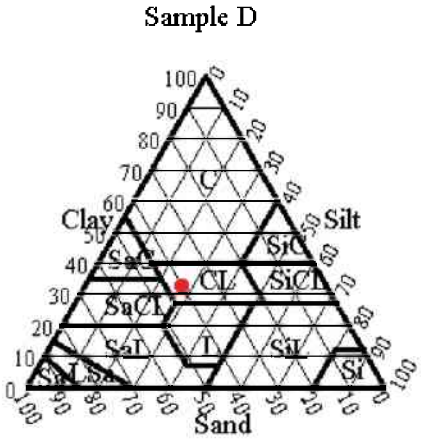


Co-located information

- Thaw depth (cm): 53
- T-8cm (C): 1.1
- T2 (C): NaN
- TDR: NaN
- Surface water?: Yes
- Topo: Low center

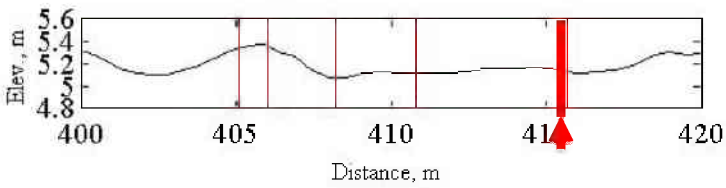
Texture Analysis

- Depth: 4-11”
- Texture {Sand, Clay, Silt}: {40.6, 32.6, 26.8}%
- Soil type: Clay Loam
- Notes:



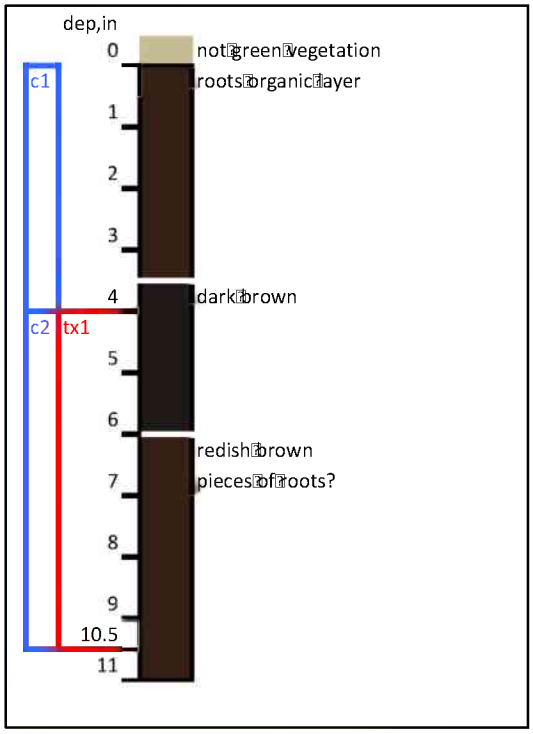
Location Name: E

Location Description



Basic information

- Collected on 09/27/2011
- Total Length: 11”
- Recovery?: Good
- # of texture cores: 1
- # of C/N cores: 2
- GPS locations (m):
  Northing: 7910327.984
  Easting: 585398.770
- Elevation (m): 5.0720



Co-located information

- Thaw depth (cm): 43
- T-8cm (C): 1.1
- T2 (C): NaN
- TDR: NaN
- Surface water?: Yes
- Topo: Low center

Texture Analysis

- Depth: 4-10.5”
- Texture {Sand, Clay, Silt}: {54.0, 31.9, 14.1}%
- Soil type: Sandy Clay Loam
- Notes: