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**LAB MANUAL for Introduction to Soil Science course**



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# PREFACE AND MARKING CRITERIA

Welcome to the APBI 200 lab section!

Most labs take place in room 102 in the MacMillam building. Please arrive on time. Read the appropriate section of the lab manual beforehand and bring the manual to the lab.

Most of the labs will require you to perform calculations using the data you collected. Some of these calculations can be challenging. We strongly encourage you to perform most of the calculations during the lab session. This way the instructor/TA can answer your questions immediately. He/she will also be able to correct you should you be making mistakes.

*Note – This lab manual is available on-line at the UBC Wiki site for APBI 200*

## General instructions regarding all lab assignments:

All assignments are due exactly one week after the lab. Make sure you:

- Read carefully all the questions and instructions
- Attach all the required documents to your assignment

Assignments should be written concisely, neatly, and legibly. Procedures and equipment should not be reported. Do not submit the entire lab manual sections with your assignment – just detach data collection sheets and other relevant pages.

Clearly indicate all calculations and attempt all questions. It will often be necessary to **consult the textbook, lecture notes** or other sources to provide good answers to these questions. Grades can be roughly interpreted as follows:

100%	Reserved for a few excellent reports, cannot be significantly improved
90%	Very well presented and interpreted
80%	Sound report, no major weaknesses
70%	Adequate presentation and explanation of results
60%	Intermediate
50%	Poor, just acceptable
40-10%	Unsatisfactory
0	No report submitted, or submitted too late

All assignments should be handed in on time, hence pay attention to the due date. Late assignments will not be graded. In cases where a student fails to hand in a report due to sickness, the assignment should be handed in to the instructor (not the TA). If the instructor considers it appropriate, she will arrange for grading.

# LAB # 1 – UBC CAMPUS FIELD TRIP

The purpose of this field trip is to observe soils *in situ*. During this lab you will get an opportunity to:

1. See local examples of soil parent materials
2. Consider the factors of soil formation and relate their influence to the occurrence of different soils
3. Examine soil profiles in detail

This field trip takes place before much lecture material has been presented, so you need to read the following discussion of definitions and concepts pertaining to soil, soil horizons, soil profiles, factors of soil formation and soil surveys prior to the lab.

On the day of the field trip, wear clothing suitable for the outdoors, including sturdy footwear. Rubber boots work well in wet weather.

Assemble in the laboratory (room 102A in MacMillan Building). We will walk to the study sites as a group. The tour usually lasts about 2 hours. Several stops will be made to observe parent materials, soils, and soil use.

## 1. DEFINITIONS AND CONCEPTS

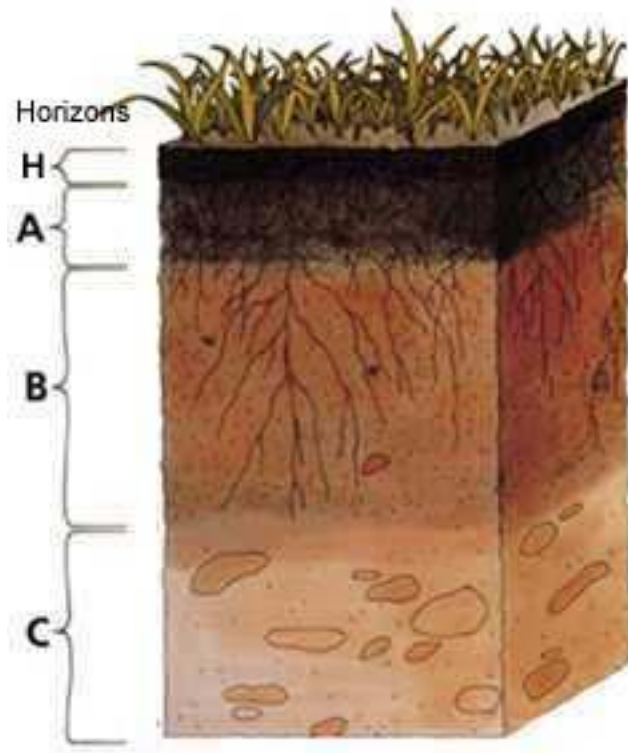
### *What is soil?*

Soil is an important natural resource used by many industries and for many purposes. As the human population increases so does the need for proper soil utilization and competition for soil resources intensifies. It is important, therefore, to understand the nature and properties of soil so that soils may be managed most effectively.

In general, soil refers to the loose surface of the earth as distinguished from solid rock. Different disciplines use different definitions for soil. For most people soil is the material that nourishes and supports growing plants. However, rocks, water, snow, and even air are capable of supporting plant life. Foresters and farmers often have a more practical concept of soil, considering it to be the medium in which forests and other crops grow. The engineer, on the other hand, looks upon soil as the unconsolidated material, extending down to bedrock, which supports roads, foundations and runways.

In defining soil, one of the most difficult boundaries to draw is the lower limit between what is soil and what is not soil. This lower boundary of soil is sometimes taken at the vague limit of the common rooting depth or the lower limit of the soil horizons resulting from soil-forming processes, whichever is deepest.

## *Soil horizons and soil profile*



*Figure 1. A soil profile showing the major soil horizons.  
Credit: Wikimedia Commons*

A **soil horizon** is defined as a layer of mineral and/or organic soil material, approximately parallel to the land surface, with characteristics affected by processes of soil formation. It differs from adjacent layers in properties such as color, texture, structure, and chemical, biological, and mineralogical composition.

Many different processes are involved in the development of soil horizons. Essentially these processes involve the addition, transformations, translocations, and removal of materials. The horizons are identified and named on the basis of the major processes involved in their formation. The important types of soil horizons and their designations will be discussed in lab 5.

The two dimensional vertical section down through all the horizons in a soil is called the **soil profile** (Fig. 1).

### *The five factors of soil formation*

Soil on the earth's surface is undergoing continual changes, which are usually not noted by casual observation. The number, kind, and characteristics of horizons present in the profile are the result of these changes, which may have been going on for only a short period of time, or for hundreds of thousands of years. The nature of the changes and of the horizons they produce is determined by five principal factors, referred to as the **factors of soil formation**:

- 1) Climate
- 2) Biota (plants, microbes, animals, and humans)
- 3) Parent material
- 4) Topography (slope, elevation, and aspect)
- 5) Time

Different combinations of the five factors of soil formations lead to the formation of a different profile and different soils. Since all five factors vary greatly over the Earth's surface, many different kinds of soil occur. Each different kind of soil will occupy an area (or areas) of the land surface.

The landscape as a whole can be viewed as being made up of many different individual soils, much as a jigsaw puzzle is built up from individual irregular-shaped pieces. However, the boundaries between soils are usually not abrupt, but gradual, and coincide with changes in one or more of the factors of soil formation.

A **definition** of a soil recognizing these concepts is that a soil is “a natural body at the earth’s surface having properties due to the integrated effects of climate, and biota, acting upon parent material as conditioned by topography, over time”.

### ***Soil surveys***

**Soil surveys** are conducted to determine the nature and distribution of soils in different areas. The soil boundaries are usually being plotted on aerial photographs and the results of soil surveys are made available in soil maps and reports.

During the soil survey operations the individual soils are named using names taken from the geographical location where they occur, e.g., Ladner. The soils are also classified so that soils with similar characteristics are grouped together. Such **classification** shows relationships between soils and provides a basis for soil management.

## **2. FACTORS OF SOIL FORMATION ON UBC CAMPUS**

### **A. PARENT MATERIAL**

As is true for most of Canada, the parent materials of the soils of the UBC area are materials left by the Pleistocene glaciation, which lasted from about 2 million years ago until 10,000 years ago. On campus, the uppermost part of the parent material often consists of glacial till. Till is composed of stones in a matrix of sand, silt and clay and was transported and deposited directly from glacier ice.

Till deposits are the main source of inorganic particles in the surface mineral horizons of the campus soils. Since most of the particles in these deposits were relatively large (gravel and sand), most of the inorganic particles in the soils are also large, and the soils are coarse in texture. The pores between these relatively large particles are also large, and consequently soil horizons formed from these materials, unless cemented, are very permeable to air, water, and roots. The low percentage of fine mineral particles (silt and clay), and high proportion of large pores, cause the soil to have very limited ability to store water unless appreciable organic material is present. In addition, soils developed on coarse-textured till deposits have limited ability to supply nutrients in forms available to plants.

### **B. CLIMATE**

Some climatic characteristics for the UBC area that are important for soil formation can be found at:

[http://climate.weather.gc.ca/climate\\_normals/index\\_e.html](http://climate.weather.gc.ca/climate_normals/index_e.html)

During the relatively mild, wet Vancouver winters there is a marked moisture surplus. Most of this water moves quickly into the unfrozen coarse-textured soil, but the type of parent material will determine the fate of the percolating water. For example, the downward movement of water is slowed in the parent materials of low permeability and water accumulates on the top of such parent materials.

Passage of water charged with carbon dioxide through the soil dissolves soluble materials and basic elements, leaving the soil horizons acidic and low in soluble salts.

During the winter, most of the soil pores are filled with water creating anaerobic and reducing conditions. On the other hand, there is a marked water deficiency in summer, and the soils become dry. Air then replaces water in the pores and oxidizing conditions prevail. This causes elements such as iron to become oxidized and form red precipitates.

### **C. BIOTA**

The UBC campus is within the Coastal Douglas-fir biogeoclimatic zone, where mature forest cover is mostly Douglas-fir (*Pseudotsuga menziesii* (Mirbel) Franco), western hemlock (*Tsuga heterophylla*), and western red cedar (*Thuja plicata*). When logging began in the area (around 1886), a heavy stand of these species covered the area, and large stumps of this forest may still be seen. Logging was first done with oxen, and skid roads are still visible in some places. The second growth forest now present was established by natural regrowth following local fires.

The forest has affected soil formation in the area in many ways. One of the most obvious is that tree litter (needles, leaves, twigs, bark, etc.) is the source of organic matter in the surface organic L, F, and H horizons. The roots are also a source of some organic matter below the LFH horizons. However, trees roots are not as effective at translocating organics belowground as are fibrous roots of grasses. In the forested areas of the campus, therefore, much of the organic matter is present at the soil surface. Because of the acidic conditions and the coarseness of the soil, there are relatively few earthworms and insects present and there is only limited mixing of organic litter with the mineral soil. Where the soils have been cleared and seeded to hay and other crops the upper part of the mineral soil may be darker in colour, indicating an increase in organic matter.

The forest also affected soil formation by the cycling of elements from the soil to the vegetation and back to the soil. Nutrients are taken up by tree roots and returned to the soil as organic litter. In this way, elements are consistently being returned to the soil surface. Another way in which soil and parent material is brought up to the surface is by uprooting of trees. This effect may be noted from the large volume of material adhering to the roots of upturned trees and in the irregular micro-relief of the soil surface. Tree uprooting contributed to the lack of distinct horizons in many of the soil profiles.

The role played by humans in the formation of the soils of the UBC campus area has increased significantly since the beginning of logging in the late 1800s. The effects of various human activities are now evident everywhere, and in many areas the soils are quite different from the pristine or natural soils. Some of the most obvious ways in which people have produced these changes are by mechanically moving and burying soils, adding lime, fertilizers, manure and other materials, changing the kind of vegetative cover and living organisms present in the soil, and altering drainage, runoff and erosion patterns.

### **D. TOPOGRAPHY**

Boundaries between soils often coincide with changes in topography. The main impacts of topography on soil formation and distribution in the UBC area are related to its effect on soil water and erosion.

When the forest canopy or other vegetation cover protects the soil, practically all the

precipitation enters the soil and there is little runoff. However, when the mineral soil is exposed by cultivation, fire, or logging, infiltration of water into the soil is slowed down and runoff may occur. Water moving over the soil surface then tends to pick up and move finer particles (especially silt and clay) down the slope. The coarser particles of sand, gravel, and boulders are left behind. The finer material may be deposited on the lower slopes, in depressions, or removed completely with the runoff water.

Some of the water that infiltrates the soil moves down through the soil profile to join the groundwater. Many of the parent materials found on campus have very low permeability and water tends to accumulate and move laterally above them. This water may also accumulate in depressions, saturating the soil above. When this occurs, anaerobic, reducing conditions lead to soil gleying.

## **E. TIME**

All soils on campus have formed since the retreat of the last ice sheet and the elevation of the land surface above sea level. This is estimated to have been approximately 8,000 to 10,000 years ago. Therefore, compared to some soils of non-glaciated areas of the world such as those from Australia, soil formation has been going on for a relatively short time. As a result, the weathering of soil minerals has not proceeded to the same extent as in older landscapes.

Other factors that have contributed to relative youthfulness of the soils on the campus have been soil movement on the slopes, and the turning and churning effects of tree uprooting referred to earlier. These factors contributed to the lack of distinct soil horizons, which is a characteristic of many of the soils on campus.

Very young soils with little or no horizon development occur on beach and fan materials at the foot of sea cliffs, and on playing fields and other areas where soils have been moved and reconstructed by people.



To learn more about typical soils of the UBC campus, you might want to view a video clip entitled “Soil Description” posted at <http://luitool.soilweb.ca/second-growth-forest/>

## **References**

- Armstrong, J.E. 1956. Surficial geology of Vancouver area. BC geology survey of Canadian department of mines and technical surveys. Ottawa.
- Clague, J. and B. Turner. 2003. Vancouver, city on the edge. Tricouni Press, Vancouver, BC. pp. 191.
- Lavkulich, L.M., and C.A. Rowles. 1970. Effect of different land use practices on a British Columbia Spodosol. Soil Science 111 (5): 323-329.
- Luttmerding, H.A. 1980-81. Soils of the Langley-Vancouver map area. RAB Bull 18. Report No. 15, BC Soil Survey. 6<sup>th</sup> vol., BC Ministry of Environment.



⇒ What you need to do during the lab:

- At both stops record soil description by filling out the forms given on the next pages
- Keep these forms for your future reference

There is no assignment to hand out for this module, but information gathered during this field trip will come in handy during lab 8, when you will be asked to describe two soil profiles and discuss differences between them.

## DATA COLLECTION

Stop number: <b>1</b>					
Location:					
Parent material:					
Elevation:					
Aspect:					
Relief:					
Vegetation:					
<b>Soil profile description</b>					
Horizon	Depth (cm)	Colour	Texture	Structure	Soil pH
Soil Classification					
Other comments:					

## DATA COLLECTION

Stop number: <b>2</b>					
Location:					
Parent material:					
Elevation:					
Aspect:					
Relief:					
Vegetation:					
Soil profile description					
Horizon	Depth (cm)	Colour	Texture	Structure	Soil pH
Soil Classification					
Other comments:					

# LAB 2 – SOIL TEXTURE AND BULK DENSITY

The purpose of this lab is to learn about two fundamental soil properties, texture and bulk density. You will get a chance to:

- Determine soil textural class using particle size analysis data (the hydrometer method) and the hand-texturing (feel) method
- See how soil bulk density is determined using the core method and perform calculations involving density and porosity

## SECTION 1 – SOIL TEXTURE

Soil scientists often refer to soils as coarse, fine, loamy, light, or heavy. These terms all describe the texture of the soil. Soil texture is an important soil property that refers to relative proportions of sand, silt, and clay particles in the fine earth fraction (i.e., mineral or inorganic fraction of soil with particles smaller than 2 mm).

Knowledge of soil texture is critical for understanding soil behaviour and management. When describing soils in the field, the texture is often the first and most common soil property determined by agronomists, engineers, and foresters. Land managers can draw many conclusions from soil texture. For example, texture affects the porosity of soils, which in turn determines how much water the soil can hold, how fast water moves through the soil, and ultimately, its long-term fertility.

### SOIL SEPARATES (PARTICLES)

The mineral (inorganic) fraction of soil is made up of grains of different sizes called soil separates (or particles). Depending on its size each particle will fall into the **coarse fragments** (gravels, cobbles, boulders or stones) or **fine earth fraction** (sand, silt, and clay) categories. Coarse fragments diameter is greater than 2 mm whereas fine earth fraction particles have a diameter smaller than 2 mm. From largest to smallest the soil separates are:

<b>Coarse fragments</b>	Stones (boulders)	diameter >25 cm
	Cobbles	diameter 7.5 - 25 cm
	Gravel	diameter 2 mm - 7.5 cm
<b>Fine earth fraction</b>	Sand	diameter 0.05 - 2 mm
	Silt	diameter 0.002 - 0.05 mm (2 – 50 $\mu$ m)
	Clay	diameter <0.002 mm (< 2 $\mu$ m)

#### (1) Sand particles

Sand particles are those with a diameter between 2 and 0.05 mm. Sand particles are the only particles of the fine earth fraction that may be large enough to be seen with the naked eye. Sand feels grainy when rubbed between the fingers. Because of their large size particles of sand have relatively low specific surface area (the surface area for a given volume or mass

of particles). Most sand particles consist of a single mineral, usually quartz ( $\text{SiO}_2$ ). Predominantly sandy soils have low total porosity ( $f$ ), but large individual pores. Consequently, sand can hold little water and is prone to drought. In addition, sandy soils have low capacity to adsorb nutrients.

## (2) Silt particles

Silt particles are smaller than 0.05 mm, but larger than 0.002 mm. Individual silt particles are not visible with the naked eye. Silt feels soapy or powdery (like flour) when rubbed between the fingers. Silt particles are essentially micro-sand particles with quartz as the predominant mineral. Soils having predominantly silt particles do not hold together well when wet, though they are more cohesive than sandy soils.

## (3) Clay particles

Clay particles are smaller than 0.002 mm and they behave as **colloids** (if suspended in water they do not readily settle out). Clay feels smooth when dry and sticky when wet. Because of their small size particles of clay have very high specific surface area. Clay has high total porosity ( $f$ ), but small individual pores. Consequently, soils with a high number of clay particles have a very high water and nutrient holding capacity.

Silt and sand comprise essentially primary minerals that originate from the physical breakdown of rocks and their minerals. Clay is usually made of secondary minerals, which are formed in the soil by the chemical recombination of silicon, aluminum, and oxygen atoms to form new types of minerals.

**Soil texture is an expression of the relative amounts of sand, silt, and clay particles (or separates) in the fine earth fraction.** The amounts are conventionally given as percent (mass basis), so that sand, silt, and clay add up to 100%.

## SOIL TEXTURAL CLASSES

Textural names are given to soils based on the relative proportions of each of the three fine-earth soil separates - sand, silt, and clay. Soils that contain predominantly clay-size particles are called **clay** or heavy clay (textural class), those with high silt-size particles content are called **silt** (textural class), and those with a high sand content are called **sand** (textural class). A **loam** is a textural class that represents a mixture of sand, silt, and clay particles and it exhibits the properties of those particles in about equal proportions.

After the percentages of sand, silt, and clay are determined in the laboratory by particle-size analysis the **textural triangle** (Fig. 2) is used to determine the soil textural name.

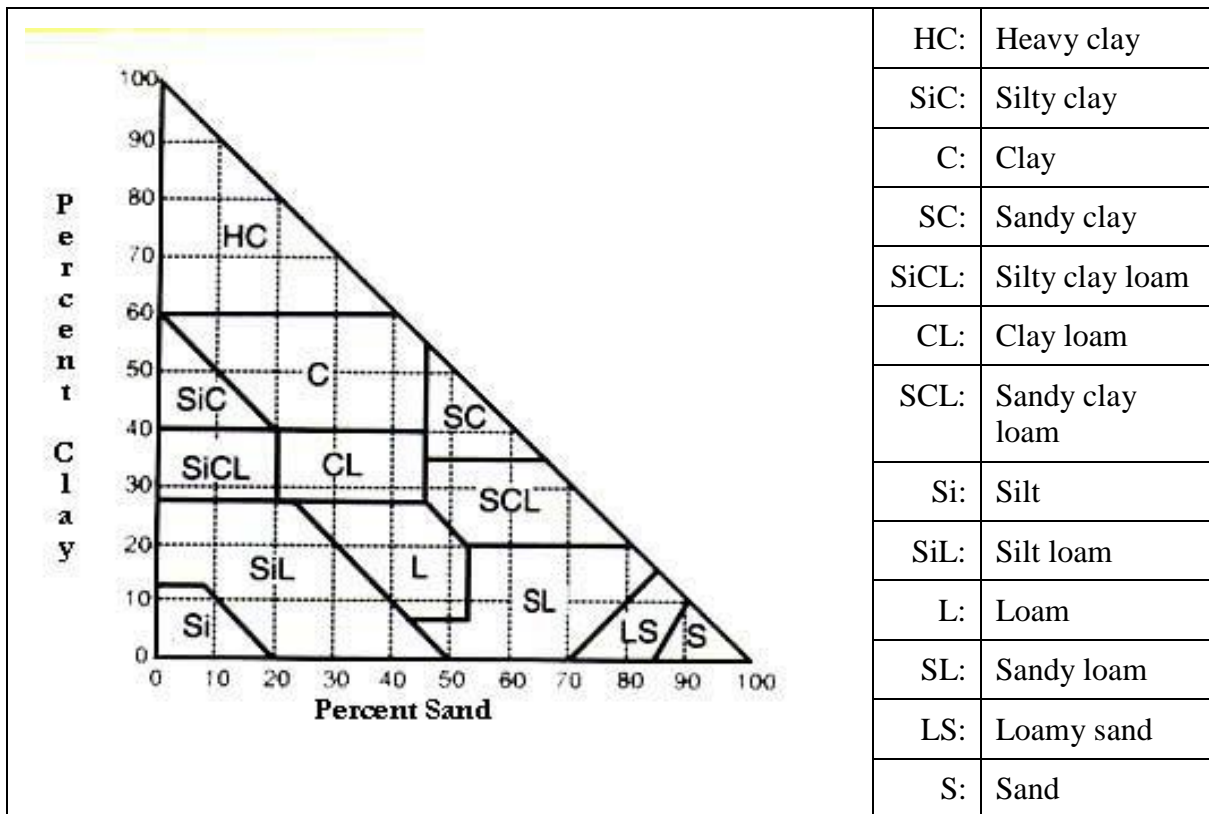


Figure 2: Textural triangle

## **METHODS FOR EVALUATING PARTICLE SIZE DISTRIBUTION AND TEXTURAL CLASS**

There are several methods available for determining particle size distribution and textural class. These methods differ in accuracy, efficiency, equipment requirement, etc. Some methods are not suited for all particle sizes (e.g., visual estimates are only possible for coarse fragments).

### **Visual estimates**

Coarse fragment content of soils is often estimated visually. To be done reliably, this requires practice with known samples. Usually, one estimates the fraction of the soil profile surface area occupied by coarse fragments. This can be converted to percent on a volume basis.

### **Hand-texturing**

Along with visual estimation of coarse fragment content, this is the most common method of assessing soil particle size distribution. Every practicing soil scientist, agronomist, and forester should be familiar with hand texturing. This method requires frequent “calibration” with samples of known texture, preferably from the region where hand texturing is to be done.

## Sieving

'Engineering sieves' may be used for separating various size classes of sand and coarse fragments. Dry sieving down to about 0.25 mm (250  $\mu\text{m}$ ) can be efficient, but sieving with fine mesh requires a long time and usually coarse and medium sand have to be removed prior to sieving. Sieving becomes difficult and unreliable for mesh openings finer than 80  $\mu\text{m}$ , and wet sieving under controlled, very low water pressure is commonly used when these very fine sieves are used. Sieving moist samples is totally ineffective, because moist soil particles clog all but the coarsest sieves (even the 2-mm sieve is subject to this problem).

## Sedimentation

For soils finer than 2 mm, sedimentation is often used for precise quantitative estimates. Because the coarse and very coarse sand settles out too quickly for accurate determination by sedimentation, a combination of sieving (down to 0.5 mm) and sedimentation is sometimes used. The two most common applications of sedimentation are the pipette method and the hydrometer method.

In this lab you will get a chance to practice two methods of soil texturing:

- 1) a sedimentation method: the hydrometer method
- 2) a field method: hand texturing

# THE HYDROMETER METHOD

The determination of soil texture in the laboratory is called **particle size analysis** or **mechanical analysis**. The amounts of silt and clay (+/- sand) are usually determined by a sedimentation procedure, which uses a basic principle of sedimentation called "**Stoke's Law**": because soil particles are denser than water, they tend to sink, settling at a velocity that is proportional to their size. In other words, the bigger the particle, the faster it will fall.

## SEDIMENTATION THEORY – STOKE'S LAW

Stoke's Law states that the speed or velocity ( $V$ ) of a particle falling through a fluid is directly proportional to the gravitational force  $g$ , the difference between the density of the particle ( $\rho_s$ ) and the density of the fluid ( $\rho_L$ ), and the square of the effective particle diameter ( $D^2$ ). The settling velocity is inversely proportional to the viscosity or "thickness" of the fluid ( $\eta$ ). Since velocity equals distance  $Z$  divided by time  $t$

Stoke's Law can be written as:

$$V = \frac{Z}{t} = \frac{D^2 g (\rho_s - \rho_L)}{18\eta}$$

$D$  = effective particle diameter (mm)

$g$  = gravitational acceleration = 9.81 m/s<sup>2</sup>

$\rho_s$  = particle density = 2.65 x 10<sup>3</sup> kg/m<sup>3</sup>

$\rho_L$  = fluid density (i.e. density of water) = 1.0 x 10<sup>3</sup> kg/m<sup>3</sup>

$\eta$  = fluid viscosity, i.e. viscosity of water at 20°C = 10<sup>-3</sup> Ns/m<sup>2</sup>

Note: Stoke's Law is based on certain simplifying assumptions:

1. All soil particles have the same density
2. Particles are spherical, smooth, and rigid
3. The suspension is sufficiently dilute that particles do not interact with each other or the container
4. There is no Brownian motion of fluid molecules
5. There is no turbulence, i.e. fluid flow around particles is laminar

The distance Z represents depth of fall by the particle in the time t. The depth Z is called effective depth of measurement. The diameter of the particle (D) corresponding to a known depth Z is calculated by rearranging the previous equation:

$$D = \sqrt{\frac{18\eta Z}{g(\rho_s - \rho_L)t}}$$

For convenience in calculation, one may define a parameter Y:

$$Y = \frac{18\eta}{g(\rho_s - \rho_L)}$$

So that the diameter of the particle (D) may be calculated by the simpler equation:

$$D = \sqrt{\frac{18\eta Z}{g(\rho_s - \rho_L)t}} = \sqrt{\frac{YZ}{t}}$$

**SAMPLE PREPARATION FOR THE HYDROMETER METHOD**

In order for the procedure to work, all the soil particles have to be separated from each other (i.e. dispersed). Dispersant solution (e.g. sodium hexametaphosphate) is added to 40 g of soil and the soil is mechanically stirred on a shaker. Dispersant solution separates all the clay particles and breaks apart the soil aggregates. Organic matter that serves as a cementing agent also has to be destroyed. For this we usually use hydrogen peroxide.

Next the suspension (a mixture of soil particles and liquid) is transferred into a 1000-mL sedimentation cylinder and distilled water is added until the volume reaches 1000 mL. A blank sample is also prepared by pouring 50 mL of the dispersant solution and 950 mL of distilled water into a sedimentation cylinder.

Cylinders and their contents should be brought to a known, constant temperature before proceeding with sedimentation analysis.



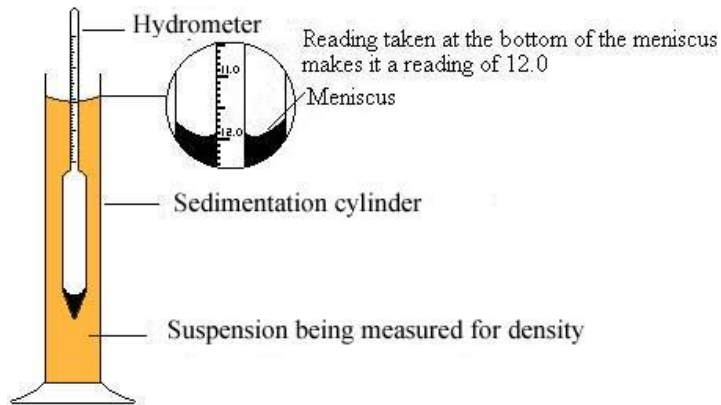
Sample preparation is time consuming and will be done for you in advance.





## DATA COLLECTION

Data are collected with a hydrometer often called a Bouyoucos hydrometer after the scientist who invented it (Fig. 3).



*Figure 3: The Bouyoucos hydrometer*

The hydrometer indicates the density of the suspension at its center of buoyancy. If the suspension is very dense, the hydrometer does not sink very much. On the contrary if the suspension density is low the hydrometer will sink deeper. The density of the suspension depends on the amount of soil particles still in suspension so the hydrometer provides a measure of how much soil is still suspended at any given time.

### ⇒ What you need to do during the lab:

#### • **Take sample readings**

- 1) Mix the suspension thoroughly using a rod with a disk on the end. Lift it gently up and down the cylinder.
- 2) Lift the rod out and note the time
- 3) After approximately 10 seconds slowly insert the hydrometer into the cylinder. Use your finger to steady the hydrometer.
- 4) Record readings at the base of the meniscus at 30, 50, 70, and 90 seconds after lifting the rod out of the suspension
- 5) Repeat all previous steps 3 times and calculate an average reading for each time
- 6) Record the average reading on the DATA COLLECTION SHEET FOR HYDROMETER METHOD

**Data for 7, 11, and 14 hours will be given to you during the lab.**

#### • **Take a blank reading**

- 1) Insert your hydrometer into the blank cylinder and steady it. The blank cylinder contains distilled water.
- 2) Once the hydrometer is steady record the blank reading. It should not vary with time since there are no particles settling.

## CALCULATIONS

- 1) For each reading ( $R$ ) calculate **the effective depth of measurement ( $Z$ )** by using the equation:

$$Z = (-0.00164 R) + 0.163 \quad [\text{m}]$$

This equation is based on dimensions of a standard ASTM 152H soil hydrometer and a standard sedimentation cylinder. The effective depth of measurement is the depth of the hydrometer bulb below the initial level, and not the depth below the surface during measurement, because fluid is displaced by the hydrometer.

Then calculate particle diameter ( $D$ ) using Stokes' Law:

$$D = 1000 \sqrt{\frac{YZ}{t}} \quad [\text{mm}]$$

The factor of 1000 converts to mm from the units of m.

- 2) For each measurement calculate **the concentration  $C$**  of particles remaining in suspension:

$$C = R - R_L \quad [\text{g L}^{-1}]$$

Subtraction of the hydrometer reading for the blank solution ( $R_L$ ) corrects the  $R$  reading for temperature effects on hydrometer buoyancy and for any error in hydrometer zero calibration.

Then calculate the mass percentage of the soil sample smaller than  $D$  ( $P_D$ ), corresponding to each measurement:

$$P_D = 100 C/B \quad [\%]$$

$B$  is the mass of soil sample per suspension volume (set to 40 g L<sup>-1</sup>).

- 3) On semi-logarithmic paper (to be provided during the lab) **plot** the dependent variable  $P_D$  (on the linear y axis) versus the independent variable  $D$  (on the logarithmic x axis).

Draw a smooth 'best fit' curve using the 7 data points. This curve is known as the particle size distribution curve.

- 4) For  $D = 0.05$  mm (the sand-silt boundary) and  $D = 0.002$  mm (the silt-clay boundary) **find  $P_D$**  by interpolation on your graph.

- 5) Determine **percent clay, silt and sand** as follows:

$P_{0.002}$  = percent clay (you get this directly from the graph)

$P_{0.05} - P_{0.002}$  = percent silt (both  $P_{0.05}$  and  $P_{0.002}$  values are obtained from the graph)

$100 - P_{0.05}$  = percent sand ( $P_{0.05}$  value is obtained from the graph)

## Reference

Gee, G.W. and Bauder, J.W. 1986. Particle-size analysis. p. 383-411. In A. Klute (ed.) Methods of soil analysis. Part 1. 2nd ed., Agron. Monogr. 9. ASA-SSSA, Madison, WI.

**DATA COLLECTION SHEET FOR HYDROMETER METHOD**

Symbol	Property	Value
$T$	Temperature	20.5°C
$\eta$	Liquid viscosity	0.000990 Pa s (= kg m <sup>-1</sup> s <sup>-1</sup> )
$\rho_L$	Liquid density	998.08 kg m <sup>-3</sup>
$G$	Gravitational acceleration	9.81 ms <sup>-2</sup>
$\rho_s$	Particle density	2650 kg m <sup>-3</sup>
$R_L$	Hydrometer reading for the blank solution	
$Y$	$= \frac{18\eta}{g(\rho_s - \rho_L)} =$	1.0995 x 10 <sup>-6</sup> m s
$B$	Mass of soil sample per suspension volume	40.0 g L <sup>-1</sup>

$T$	$R$	$Z$	D	$C$	$P_D$
time (s)	hydrometer reading (g L <sup>-1</sup> )	depth of fall by the particle (m)	particle diameter (mm)	conc. of particles < $D$ (g L <sup>-1</sup> )	percent particles < $D$ (%)
30 Average					
50 Average					
70 Average					
90 Average					
25,200 (7h)					
39,600 (11h)					
50,400 (14 h)					

**Don't forget to attach these tables to the lab assignment**

## HAND-TEXTURING

Often we find ourselves in a situation where we do not have access to a laboratory to use the hydrometer method. Therefore, another, simpler method of determining soil texture is used – the **hand-texturing** or **feel method**.

### ⇒ What you need to do during the lab:

You will be given samples of known texture as well as 2 “mystery” samples. Hand-texturing takes practice, so spend some time practicing in the laboratory on the known samples before moving on to the mystery samples. Record your observations and conclusions (regarding soil textural class) in the table below.

Place the equivalent of about a teaspoon of soil in the palm of your hand. Pick out and discard coarse fragments and large pieces of organic matter. The soil must be just moist, hence add water drop wise and work the soil with the fingers of your other hand to obtain a moist workable putty.

### *DATA COLLECTION SHEET FOR HAND TEXTURING*

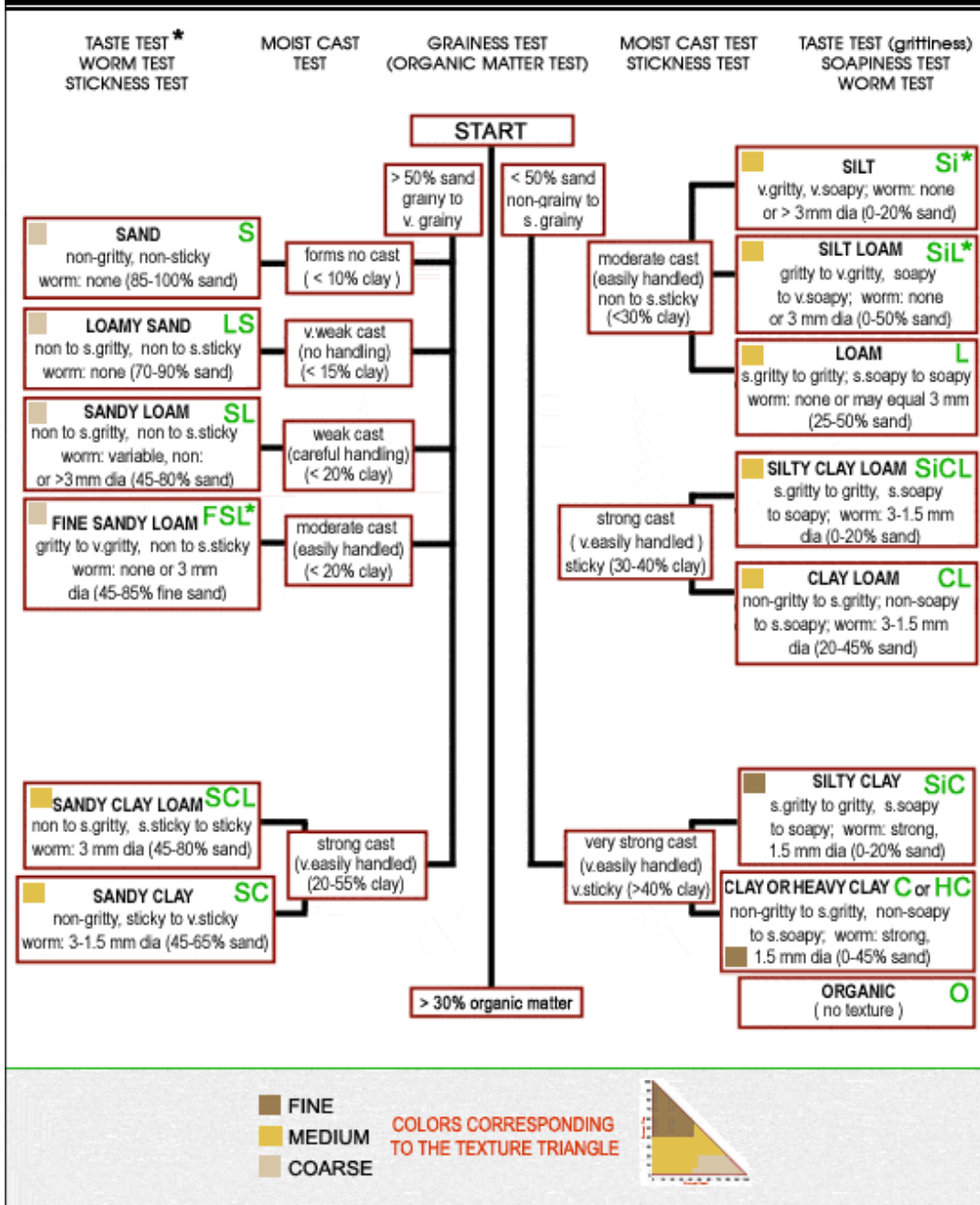
	<b>Mystery sample A</b>	<b>Mystery sample B</b>
Graininess test		
Moist cast test		
Stickiness test		
Worm test		
Soapiness test		
Soil texture		
Justification (why you chose that texture)		

**Don't forget to attach this table to the lab assignment**

In this course we will use texture field tests as described in the “Field methods for describing terrestrial ecosystems” handbook:

<http://www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh25.htm>. A flow chart and some definitions are attached on the next 2 pages.

# KEY FOR SOIL TEXTURE DETERMINATION



\* Silt feels slippery or soapy when wet; fine sand feels stiffer, like grinding compound or fine sandpaper.

## Key to Abbreviations Measurement Conversions

s = slightly  
v = very  
dia = diameter

3.0 mm = 1/8"  
1.5 mm = 1/16"

**Fine Fraction (particle diameter)**

SAND ----- (S) 2 - .05 mm  
SILT ----- (Si) .05 - .002 mm  
CLAY ----- (C) <.002 mm

## **Key to Soil Texture (from “Field Methods for Describing Terrestrial Ecosystems”, 1998)**

### **Graininess Test**

Rub the soil between your fingers. If sand is present, it will feel “grainy”: you will be able to feel the individual grains. Determining whether sand constitutes more or less than 50% of the sample is the first decision in the key.

### **Moist Cast Test**

Compress some moist soil by clenching it in your hand. If the soil holds together (i.e., forms a “cast”), then test the durability of the cast by tossing it from hand to hand. The more durable it is, the more clay is present.

### **Stickiness Test**

Moisten the soil thoroughly and compress it between thumb and forefinger. Determine degree of stickiness by noting how strongly the soil adheres to the thumb and forefinger when pressure is released, and how much it stretches. Stickiness increases with clay content.

### **Worm Test**

Roll some moist soil between the palms of your hands to form the longest, thinnest worm possible. The more clay present, the longer, thinner and more durable the worm will be.

### **Taste Test (Not recommended due to health concerns)**

Work a small amount of moist soil between your front teeth. Silt particles are distinguished as fine “*grittiness*”, unlike sand, which is distinguished as individual grains (i.e., graininess). Clay has no grittiness.

Well-decomposed organic matter (humus) imparts silt-like properties to the soil. However, when subjected to the taste test, it feels non-gritty. It is generally very dark in color when moist or wet, and stains the hands brown or black. This organic matter is not used as a determinant of soil texture; estimates of the silt content of humus-rich mineral soils should be reduced accordingly. If the soil contains more than a few % of organic matter, hand texturing may become unpractical.

**Soapiness Test.** Work a small amount of wet soil between your thumb and fingers. Silt feels slick and not too sticky (i.e., clay) or grainy (i.e., sand); the greater the dominance of a slick feel, the greater the silt content.

## **Reference**

BC Ministry of Environments, Lands, and Parks and the BC Ministry of Forests. 1998. Field methods for describing terrestrial ecosystems. Land management handbook no. 25. Victoria, BC.

## SECTION 2 - BULK DENSITY

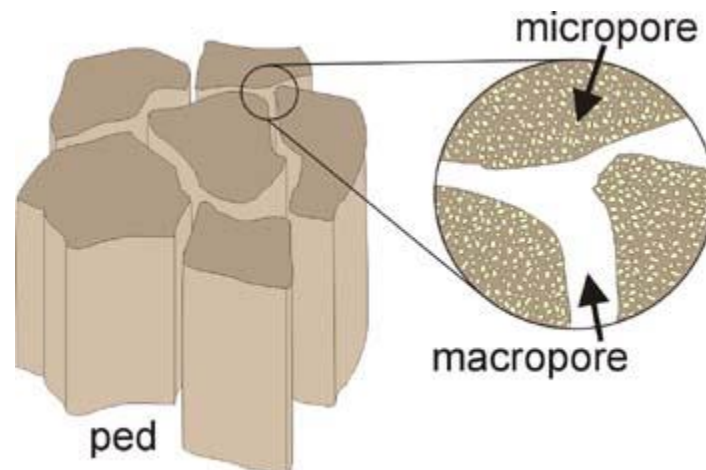
### 1. INTRODUCTION

The relationship between soil solids and pores is very important in soil science. This lab section is intended to introduce you to the concepts of soil density and soil porosity.

**Bulk density** values provide a very useful conversion factor between soil mass and soil volume. For example, bulk density values allow engineers to calculate the weight of soil to be removed during an excavation of given volume. High bulk density values may indicate to land managers the presence of compact layers in soil that could restrict root and water penetration.

In addition, bulk density measurements are used to calculate the total pore volume (the **porosity**) of soil. Low bulk density is generally associated with high porosity. Soil pores contain air for plant root metabolism and provide a reservoir for water storage. Good irrigation planning requires that one takes into account the porosity as well as the initial moisture content of the soil.

Bulk density values are affected by soil **texture** and modified by **structure** (aggregation of soil particles). In general, fine-textured soils exhibit lower bulk densities than coarse-textured soils (e.g. sands). In fine-textured soils, particles tend to be organized in aggregates (or peds), especially if adequate amounts of cementing agents such as organic matter are present. As can be seen on Fig. 4, there are pore spaces both within and between aggregates. As a result, these fine-textured soils have higher pore space and lower bulk density than sandy soils.



*Figure 4: Macropores between individual aggregates (peds) and micropores within aggregates. Credit: UBC Centre for Teaching, Learning and Technology.*

Soil bulk density can vary significantly between soils and within a soil profile and is influenced by management practices (e.g. tillage, livestock grazing, timber harvesting). Incorporation of large amounts of organic matter will lower the bulk density while processes that compact the soil will increase bulk density.

# BULK DENSITY, PARTICLE DENSITY, AND POROSITY CALCULATIONS

The density of any object is its mass divided by its volume. Soil density is the **oven-dried** mass per unit volume, often expressed in  $\text{g}/\text{cm}^3$  or  $\text{Mg}/\text{m}^3$  (Note: M = megagrams = 1,000,000 g = 1 metric tonne).

In soil science we are interested in measuring two different density values: bulk density ( $\rho_b$ ) and particle density ( $\rho_s$ ) and then  $\rho_b$  and  $\rho_s$  are used to calculate soil porosity ( $f$ ).

## Soil bulk density

**Bulk density ( $\rho_b$ )** is the oven-dried soil mass divided by total soil volume.

- Soil mass = Mass solids + Mass air + Mass water  
Mass air  $\sim 0$  and in the oven-dried soil Mass water  $\sim 0$  so:  
Oven-dried soil mass = Mass solids ( $M_s$ )
- Total soil volume ( $V_t$ ) = pore volume ( $V_f$ ) + solid volume ( $V_s$ )

Then:

$$\rho_b = \frac{M_s}{V_t} = \frac{M_s}{V_f + V_s}$$

Bulk density is very variable. In mineral soils it may range from 1.0 to 1.8  $\text{g}/\text{cm}^3$ .

## Soil particle density

Particle density only represents the density of soil particles.

**Particle density ( $\rho_s$ ) is the mass of soil solids ( $M_s$ ) divided by solid volume ( $V_s$ ):**

$$\rho_s = \frac{M_s}{V_s}$$

Particle density is higher than bulk density, and fairly constant in different soils. In most mineral soils particle density can be assumed to equal about 2.65  $\text{g}/\text{cm}^3$  (the particle density of quartz). In organic soils particle density is lower and can be presumed to be around 1.3  $\text{g}/\text{cm}^3$ . In extremely compacted soils, where pore space ( $V_f$ ) is near zero, the bulk density value may begin to approach the particle density value.

## Soil porosity

**Porosity ( $f$ )** refers to the ratio of pore volume ( $V_f$ ) to total soil volume ( $V_t$ ):

$$f = V_f / V_t$$

- We know that  $V_t = V_f + V_s \Leftrightarrow V_f = V_t - V_s$

So:

$$f = \frac{V_t - V_s}{V_t} = 1 - \frac{V_s}{V_t}$$



- And that: 
$$\frac{\rho_b}{\rho_s} = \frac{M_s/V_t}{M_s/V_s} = \frac{V_s}{V_t}$$

Then:

$$f = 1 - \frac{\rho_b}{\rho_s}$$

## 2. BULK DENSITY MEASUREMENT METHODS

To determine soil bulk density the volume and the oven-dried mass of the soil must be measured. Two methods are commonly used:

- 1) the core method
- 2) the excavation method

**Core method:** a special coring instrument or bulk density sampler (double-cylinder, drop-hammer sampler with a core) is designed to remove a cylindrical core of soil without crushing soil aggregates. The sampler head contains an inner cylinder and is driven into the soil with blows from a drop hammer. The inner cylinder containing an undisturbed soil core is then removed and trimmed to the end with a knife to yield a core whose volume can easily be calculated from its length and diameter. The weight of this soil core is then determined after drying in an oven at 105°C.



Figure 5: Sampling for soil bulk density using a core sampler. Credit: Novak Rogic (UBC)

**Excavation method:** this method was developed by soil engineers who needed a method suitable for use in stony and gravelly soils. This is a simple method that involves digging out a small hole, oven drying and weighing the excavated soil. Volume of the excavation is determined by lining the hole with plastic film and filling it completely with a measured volume of water (or sand, or silicon beads). Bulk density is then calculated from the oven-dry mass of the excavated soil and the excavation volume.

## Reference

Blake, G.R. and Hartge K.H. 1986. Bulk density. p. 363-375. *In* A. Klute (ed.) Methods of soil analysis. Part 1. 2nd ed., Agron. Monogr. 9. ASA-SSSA, Madison, WI.

Krzic M., T. Naugler, S. Dyanatkar, and C. Crowley. 2010. Soil Bulk density. Virtual Soil Lab Modules. The University of British Columbia, Vancouver.

[<http://soilweb.landfood.ubc.ca/labmodules/compaction/soil-bulk-density>]

### ⇒ What you need to do during the lab:

We will use the core method to determine the bulk density of our soil sample. Core sampling will be demonstrated during the lab.

- 1) Record the height and inside diameter of the inner cylinder as well as the oven-dried weight of the soil (these numbers will be given to you during the lab)
- 2) Calculate the core volume then soil bulk density

### DATA COLLECTION

Depth of sampling	Core height	Core diameter	Volume of core	Oven-dried wt. of soil	Bulk density
0 – 7.5 cm					

Don't forget to attach this table to the lab assignment.

# LAB 3 - WATER RETENTION

The purpose of this lab is to allow you to learn how to interpret water retention curves. You will be asked to build a water retention curve for two soils with contrasting textures. You will then be able to interpret these curves in terms of pore space and pore size distribution.

## 1. INTRODUCTION

A water retention curve indicates the manner in which a particular soil retains and loses water, and also the proportion of stored water that is available for plant growth.

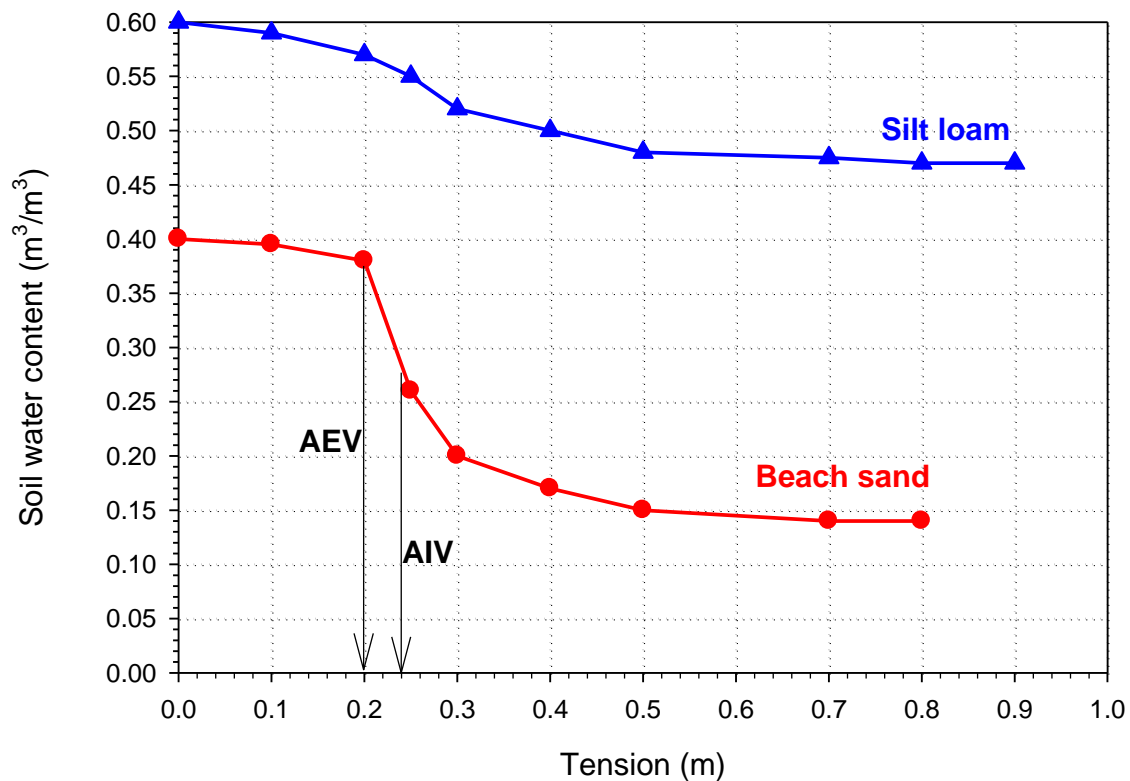


Figure 6: Partial water retention curves for a silt loam soil of good structure and for Spanish Banks beach sand.

The water retention curve (Fig. 6) is an illustration of **the relationship between water content and soil water tension.**

To obtain a water retention curve one must start with a **saturated** soil. A **tension** (suction) is then applied to the saturated soil and the volume of water leaving the soil (**outflow**) at each given tension is recorded.

On a water retention curve **the x axis represents the soil water tension T**. In most soils where the dominating force is capillarity,  $T \approx -$  matric potential  $\psi_m$ . **The y axis represents the water content of the soil**. Note that soil water content is unit less since it stands for the volume of water per given volume of soil ( $V_w / V_t$ ).

### ***Plant available water***

Plants must overcome the energy of the total water potential to extract water from the soil. How do we know how much water is available for plants in a soil?

Consider the situation that occurs when a soil becomes saturated. Under these conditions, the entire pore space (macropores plus micropores) is completely water-filled and the soil is said to be at its **maximum retentive capacity**. Under normal field conditions, much of the water held in the macropores soon drains (before plants get a chance to take up water) in response to gravitational force. After gravity has drained the macropores, a moisture content known as **field capacity** is attained. The soil at this point is unsaturated and water is held by adsorption and capillary forces (responsible for the matric potential), and sometimes other forces such as the osmotic force in saline soils. The total water potential corresponding to field capacity ranges from 1 to 3 m (or  $-10$  to  $-30$  kPa). Plants are able to readily access the water held at these potentials. Evaporation and plant use further deplete the soil water supply to a moisture content known as the **permanent wilting point**. Soil water present at the permanent wilting point is held at a total water potential value of approximately 150 m (or  $-1500$  kPa), and most plants cannot access this water. Soil water held between field capacity and permanent wilting point is termed **plant available water**.

### ***Factors influencing the water retention curve***

Soils have very different texture, structure, porosity, salt content, etc. All these factors determine the energy at which the water is held in soil and are reflected in the water retention curve.

The curves in Fig. 6 illustrate the influence of texture on the shape and slope of the retention curve. Texture and structure influence the porosity and pore size distribution of the soil. Small particles such as clay and silt tend to give rise to small pores, whereas sand size particles favour the occurrence of larger pores. Large pores drain easily whereas small pores retain water strongly due to adsorption and capillarity.

The silt loam exhibits greater water content than the sand at all water potential values. This reflects both the high porosity ( $f$ ) of the loam, probably due to its good structure, and the small pore size, due to the smaller particle size. The high porosity creates a large maximum retentive capacity and a high initial water content, while the small pore size allows the soil to hold large amounts of water at **low** matric potential corresponding to **strong** water retention force ( $\psi_t \approx \psi_m$  in most unsaturated non-saline soils =  $-T$ ).

An inverse relationship exists between the water content of a soil and the energy with which the water is held (the less water left in a soil, the stronger it is held). This energy

depends on the radius of the pore containing the water. The smaller the pore radius, the lower (more negative) the value of the matric potential of the water contained in the pore and, hence the greater the energy required to remove the water.

In the context of a water retention curve the **capillary rise equation** can be used to determine the relationship between the soil water tension ( $h$ ) and the corresponding radius of the largest pores still filled with water ( $r$ ):

$$h = \frac{2\tau \cos \phi}{r\rho_w g}$$

$h$  = water tension or height of rise at equilibrium  
 $\tau$  = surface tension of water against air, ~ 0.074 N/m [note: N stands for Newton, unit for force]  
 $\phi$  = wetting angle (~0 ° for clean glass capillary or wettable soil, hence  $\cos \phi = 1$ )  
 $\rho_w$  = 1000 kg/m<sup>3</sup>  
 $g$  = gravitational acceleration, 9.81 m/s<sup>2</sup>  
 $r$  = radius of capillary or pore radius

### ***Air Entry Value and Air Intrusion Value***

On the water retention curve for the sand we can notice two important values:

**AEV = air entry value.** This is the value of the **soil water tension when the water content starts to drop** significantly. AEV corresponds to the tension that is just large enough to begin to pull water from the largest pores and from the sample surface, and for **air to begin entering the largest pores.**

**AIV = air intrusion value** is the **tension at the “flex point”**, i.e. at the steepest part of the curve. More generally, AIV is the tension in the middle of the steep part of the water retention curve, where a large change of water content occurs with a small change of tension. The AIV is the tension corresponding to air intrusion into the **pore size dominating the porosity.**

Note that beach sand has a distinct AEV and AIV because it is a well-sorted material (i.e. most pores have roughly the same size because all the particles have approximately the same size; only a few pores have larger or smaller size). The silt loam soil has an AEV of nearly zero and an indistinct AIV, because of the wide distribution of pore sizes.

## **2. MEASUREMENT**

To obtain water retention data, a variety of equipment is used:

<b>Approximate tension range (m)</b>	<b>Method</b>
0 - 1	Hanging water column device, tension table
1 - 10	Low pressure ceramic plate extractor
10 - 200	High pressure ceramic plate extractor

A partial water retention curve usually covers the tension range between 0 and 1 m. Its practical usefulness lies in the fact that its shape **reflects soil texture and structure.**

## DATA COLLECTION

During the lab you will use the hanging water column apparatus shown in Fig. 7 to estimate the partial water retention curve.

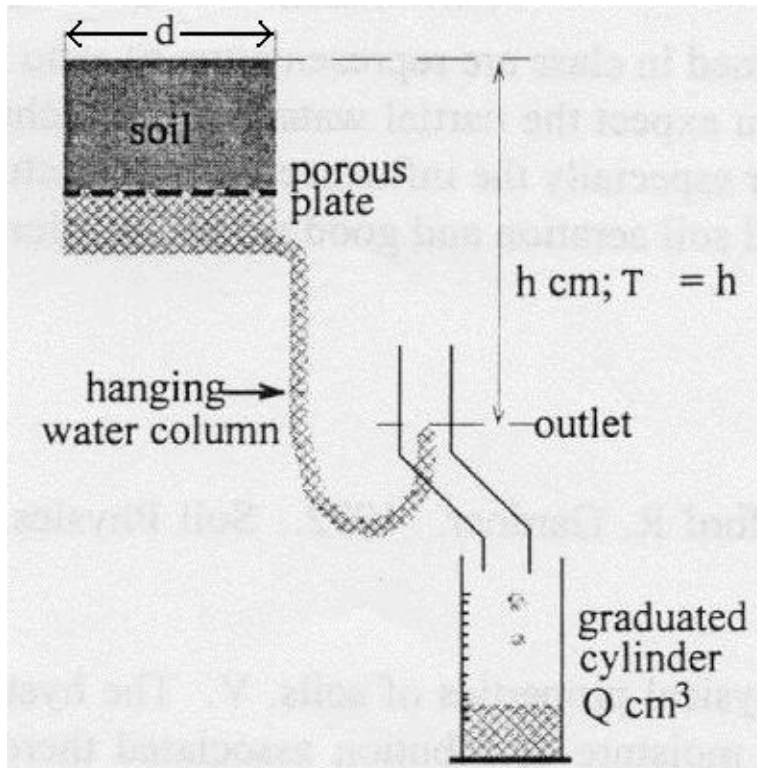


Figure 7. Partial water retention curve apparatus.

### ⇒ What you need to do during the lab:

During this lab we will investigate the water retention properties of two soils of different texture: a medium sand (light colour) and a fine sand (dark colour). Each group will work with one of the soils and data corresponding to the other soil will be given to you so that at the end of the lab everybody has the complete data sets corresponding to both soils.

A saturated soil sample of known bulk density is placed on the porous plate prior to the lab. At complete saturation  $T=0$ . Note that at saturation the volume of soil water ( $V_w$ ) is equal to the pore volume ( $V_f$ ), while the volume of air ( $V_a$ ) = 0. As  $T$  increases,  $V_w$  decreases and  $V_a$  increases (remember:  $V_w + V_a = V_f$ ).

-Increase the soil water tension in a step-wise manner by lowering the outflow unit. A schedule of recommended soil water tensions and appropriate equilibration times is found in table on next page.

Table 1. Schedule of recommended soil water tensions and equilibration times for medium and fine sand.

T (cm)	Equilibration time, t (min)	T (cm)	Equilibration time, t (min)
<b>Medium sand (0.25-0.50 mm)</b>		<b>Fine sand (0.15-0.25 mm)</b>	
0	0	0	0
10	3	20	3
20	8	40	3
25	15	50	5
30	15	60	15
40	5	70	12
60	3	80	8
-	-	90	When water stops dripping

- Keep a running account of the cumulative outflow by measuring the volume of water released in response to each tension increase. Use a graduated cylinder (note that 1 cm<sup>3</sup> = 1 mL). Report these data in the “cumulative outflow volume” column on the data collection sheet on p. 30 of your lab manual.
- Measure the height and inside diameter of the soil cylinder. Report these data on the data collection sheet. They will be used to calculate total soil volume.
- Perform the following calculations:

### **CALCULATIONS**

For each soil sample:

- Calculate the total volume of soil used ( $V_t$ )
- Calculate the soil porosity ( $f$ )
- Calculate the pore volume ( $V_f$ )
- Record the volume of soil water ( $V_w$ ) at saturation ( $T = 0$ )
- Calculate the volume of water ( $V_w$ ) left in soil at each tension. The volume of soil water should decrease as tension increases
- Calculate the volumetric water content ( $\theta$ ) corresponding to each tension
- Plot the partial water retention curve for each sample. Graph paper will be available during the lab.
- Identify and mark the air entry value (AEV) and air intrusion value (AIV). Enter these values on line h and i of the data collection sheet.
- Using the capillary rise equation, calculate the pore diameters corresponding to the AEV and AIV of each sample after rearranging to solve for  $r$  (radius).

### **Reference**

Hillel, D. 1971. Soil and water, physical principles and processes. Chapter no. 3: State of water in soils. Academic press. New York. USA.

## DATA COLLECTION

Data for MEDIUM SAND		Data for FINE SAND	
a) Cylinder height (h)		a) Cylinder height (h)	
b) Cylinder inside diameter (d)		b) Cylinder inside diameter (d)	
c) Total volume ( $V_t$ )		c) Total volume ( $V_t$ )	
d) Bulk density ( $\rho_b$ )	1.61 g/cm <sup>3</sup>	d) Bulk density ( $\rho_b$ )	1.49 g/cm <sup>3</sup>
e) Particle density ( $\rho_s$ )	2.65 g/cm <sup>3</sup>	e) Particle density ( $\rho_s$ )	2.65 g/cm <sup>3</sup>
f) Soil porosity (f)		f) Soil porosity (f)	
g) Pore volume ( $V_f$ )		g) Pore volume ( $V_f$ )	

MEDIUM SAND				FINE SAND			
Tension (cm)	Cumulative outflow Vol. (cm <sup>3</sup> )	Soil water $V_w$ (cm <sup>3</sup> )	$\theta$ (cm <sup>3</sup> /cm <sup>3</sup> ) $V_w/V_t$	Tension (cm)	Cumulative outflow Vol. (cm <sup>3</sup> )	Soil water $V_w$ (cm <sup>3</sup> )	$\theta$ (cm <sup>3</sup> /cm <sup>3</sup> ) $V_w/V_t$
0	0.0			0	0.0		
10				20			
20				40			
25				50			
30				60			
40				70			
60				80			
-	-	-	-	90			
h) Air Entry Value (AEV) (m)				h) Air Entry Value (AEV) (m)			
i) Air Intrusion Value (AIV) (m)				i) Air Intrusion Value (AIV) (m)			
j) Radius (mm) of pores corresponding to AEV				j) Radius (mm) of pores corresponding to AEV			
k) Radius (mm) of pores corresponding to AIV				k) Radius (mm) of pores corresponding to AIV			

Don't forget to attach these tables to the lab assignment



# LAB 4 – SOIL PARENT MATERIAL

General objectives of this lab are to:

- Define the term parent material
- Identify various types of parent material
- Understand the effects of parent material on soil properties

## 1. INTRODUCTION

Soils develop from materials at the earth's surface due to the influence of climate, biota, topography, and time.

The precursor material from which soils form is called the **parent material**. It consists of unconsolidated and more or less chemically changed (weathered) mineral or organic material from which soils are developed.

In British Columbia (and in fact, most of Canada), most soils have developed from deposits left on the Earth's surface by the last glaciation. Hence, most of our soils are 'young' in the geological sense (i.e. around 10,000 years old).

The nature of the parent material strongly influences soil properties such as texture, pH, fertility, and mineralogy. For example, coarse-grained, quartz-rich parent material such as glacial outwash generates soils with a coarse sandy texture. Nutrient content in the parent material also influences the productivity of soils. For example, soils rich in available potassium are found on parent materials that are well supplied with this element. However, intense weathering and leaching may produce soils low in available potassium, or any other essential element, even though these nutrients are abundant in the parent material. Note that nitrogen does not come from minerals and rocks to any significant extent. Nitrogen in soil has its origin in bacterial and lightning fixation of atmospheric nitrogen.

## 2. CLASSIFICATION OF PARENT MATERIAL

Soil parent material may be broadly grouped into the following classes:

1) **Residual** or **sedentary** – developed in place (*in situ*) from the underlying rock. Typically it experienced long and intense weathering. Residual parent materials can be found overlying any rock type – provided that the landscape has been stable for a sufficient period of time for weathering to occur.

2) **Transported**: loose sediments or surficial materials that have been transported and deposited by gravity, water, ice, or wind. This is the most important group of soil parent materials. These materials are classified on the basis of the agents responsible for their movement and deposition. They are weathering products of rocks and are not cemented or consolidated.

3) **Cumulose** – organic deposits that have developed in place from plant residues and have been preserved by a high water table (or some other factor retarding decomposition). These deposits are widespread and not restricted to any climatic zone. In British Columbia

they are most abundant in the northern parts (e.g., Queen Charlotte Island, Fort Nelson Lowland, and Liard Plain). In the rest of the province, organic materials are restricted to relatively small areas in depressions. Examples are **peat** (undecomposed or slightly decomposed organic matter) and **muck** (highly decomposed organic material).



For additional information on parent materials go to the website “**Soil Formation and Parent Material**” at <http://soilweb.landfood.ubc.ca/landscape/> and focus on material presented at the page entitled “**Parent Material**” at <http://soilweb.landfood.ubc.ca/landscape/parent-material>.

Inorganic parent materials (residual or transported) ultimately originate from rocks. There are 3 main types of rocks at the Earth’s surface:

- **Igneous rocks:** developed from cooling and solidification of magma originating from the Earth’s mantle. They have not been changed significantly since their formation. An example of igneous rock is **gabbro**.
- **Sedimentary rocks:** formed near the Earth’s surface from the weathered products (minerals) of igneous or metamorphic rocks, held together by different cementing agents. An example of sedimentary rock is **sandstone**. In sandstone quartz grains originally from granite are cemented together by minerals such as carbonates or gypsum.
- **Metamorphic rocks:** either igneous or sedimentary rocks which have been altered by heat, pressure and/or fluids after they were buried deep in the Earth’s lithosphere. An example of metamorphic rock is **gneiss**, which results from metamorphism of granite or sedimentary rock.



*[Photo credit: Wikimedia Commons]*

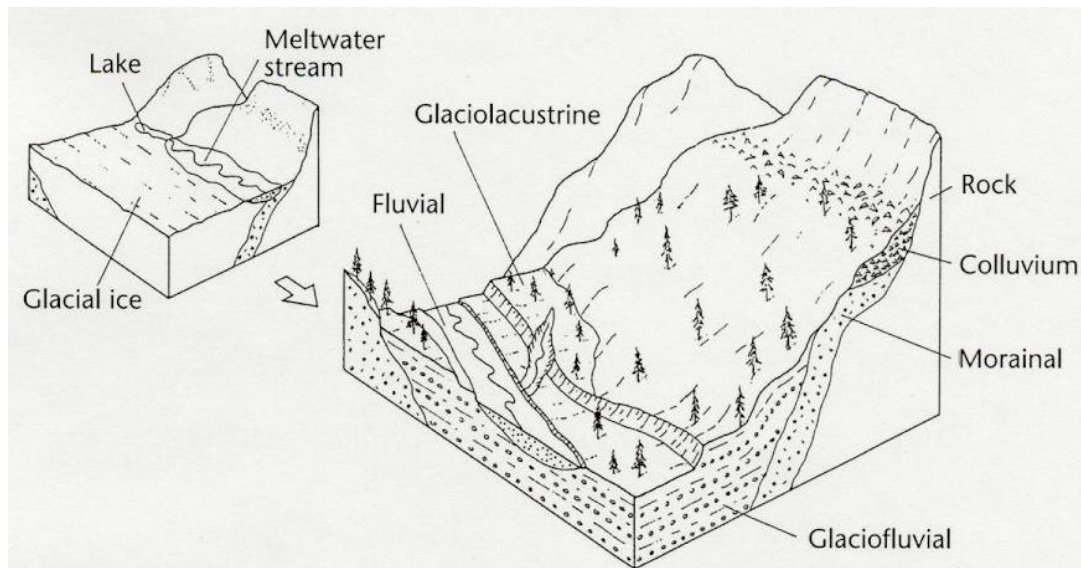
## 1. TRANSPORTED PARENT MATERIAL

Transported parent materials are divided into five groups (see table 7) based on the method of transportation to their present location. The agents of transportation will

influence the characteristics of the parent material, such as texture and types of secondary minerals that can develop as the soil evolves. Some of the transported parent materials are shown in Fig. 9.

*Table 7: Transportation agents and resulting sediment or parent material.*

Mode of deposition	Resulting parent material
Water	Alluvial or fluvial (deposited from flowing water) Lacustrine (sediments in still water, especially lakes) Marine (deposited in oceans or re-worked by oceans)
Water and ice	Glacio-fluvial (interactions between ice and river water) Glacio-lacustrine (interactions between ice and lake water) Glacio-marine (interactions between ice and ocean water)
Ice	Till (morainal material)
Wind	Loess Volcanic ash Sand
Gravity	Colluvium



*Figure 9: Cross-sectional diagram of valley landforms (from Curran et al. 2000).*

## **WATER DEPOSITED MATERIALS**

Water is an effective mean of moving earth materials. In fact, it is the main agent responsible for the leveling of mountains and filling of valleys.

### **(1) Alluvial or fluvial parent material**

Alluvial (= fluvial) parent materials were deposited by moving water bodies such as **rivers and streams**. The **texture of the deposit depends on the energy** of the water

body. Fast-moving water deposits only coarse material such as rocks and gravel. If the water velocity decreases, finer particles (sand and silt) are deposited, while fine silt and clay particles are deposited by slow-moving water such as that found associated with deltas. Alluvial type of parent material is associated with such landforms as old streambeds, flood plains, deltas, fans, and levees.



Alluvial materials often have thick layers (**strata**) of different size material (see Fig. 10). This deposition occurs over time, as the speed of the water transporting the material changes. Inside strata materials moved by water are **well sorted** and coarse fragments are **rounded**.

*Figure 10: Alluvial deposit. Credit: Canadian Soil Information Service (CanSIS)*

## (2) Lacustrine parent material

Still water in **lakes** permits very fine particles (**fine sand, silt, and clay**) to settle out and to form lacustrine deposits. These deposits got exposed by elevation of old lakebeds. Lacustrine deposits are **very well sorted**, devoid of coarse particles such as coarse sand or gravels, and are characterized by **thin layers** that reflect annual deposition of sediments.

## (3) Marine parent material

Fine particles (predominantly of **clay size** that occasionally may contain some shells) can also be deposited as marine sediments in the waters of **oceans and seas**. Subsequently, these deposits can get exposed by elevation of the land or the lowering of the water level. Marine deposits are **very well sorted**, devoid of coarse particles, and usually **unstratified** (show no layers).

## ICE DEPOSITED MATERIAL

**Glacial ice** can transport various materials by pushing it ahead, carrying material along on the top or inside of a glacier. When these materials are dropped or exposed as the ice melts, **morainal material = till** is laid down. Till is **unsorted**, and **non-stratified** sediment that consists of a mixture of materials from fine clay particles to coarse **angular** cobbles and boulders. Sandy tills are porous and water can rapidly pass through them, while clay tills tend to be impervious and poorly drained. Till is probably the most extensive of all parent materials in British Columbia. It covers leveled to moderately sloping surfaces that lie above valley floor areas affected by recent fluvial activity and below rock or colluvial slopes of the alpine zones. Landforms characterized by till deposits include drumlins and moraines (Fig. 11).

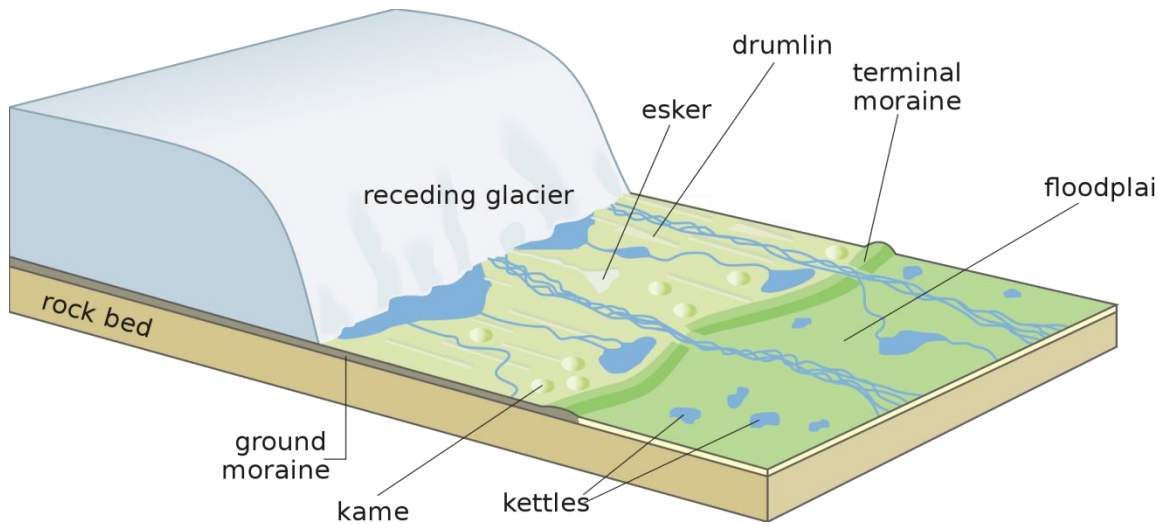


Figure 11: Receding glacier and associated landforms. Credit: Wikimedia Commons

Depending on how the material was transported and deposited by glaciers, till can be either:

**(4) Basal till**

Basal till is a dense **compacted** till that was plastered beneath the glacier, under high pressure.

**(5) Ablation till**

Ablation till is a **loose** deposit formed during glacial melting (ablation) when mineral particles, which have been suspended in or on the ice, fall onto the basal till deposits.

**WATER AND ICE DEPOSITED MATERIAL**

There is very commonly an interaction between ice and river water (resulting in a formation of glacio-fluvial deposits), ice and lake water (resulting in a formation of glacio-lacustrine deposits), or ice and ocean water (resulting in a formation of glacio-marine deposits).

**(6) Glacio-fluvial deposits (outwash)**

Glacio-fluvial deposits are formed by the interaction of river water and ice, usually during glacier melting.



These deposits are coarse, usually dominated by **gravels and/or sands**. They are lacking fine particles (silt and clay) but the coarse fractions are generally **unsorted** (Fig. 12). The meltwater streams have partially or thoroughly reworked the rock debris carried by the glacier; hence coarse fragments vary from **sub-angular to well rounded**.

*Figure 12: Glacio-fluvial deposit exposed on a road cut. Credit: Maja Krzic (UBC).*

#### **(7) Glacio-lacustrine deposits**

Glacio-lacustrine deposits are materials laid down in old glacial lakes fed by glacial melt rivers. Particle sizes normally range from sands to clays, often with **fine sand and silt** predominating. The glacio-lacustrine are usually annually laminated or “varved” with each **varve** representing an annual cycle of deposition. Coarser, light-coloured material is deposited during the summer and finer, organic-rich material settles out in the winter while the lake surface is frozen. Material within the varves is **well sorted**.

#### **(8) Glacio-marine deposits**

Glacio-marine deposits are **compact, unstratified, silty to clayey** sediments laid down in near-shore locations during glacial recession and subsequently exposed through isostatic rebound (land rising above sea level following removal of glacial weight due to melting). These deposits contain variable amounts of **stones, gravels, and cobbles** released from floating ice. **Dark colored coatings** (probably Mn and organic matter) and salt crystals are common along cracks and fractures.

### **WIND DEPOSITED MATERIALS**

Wind deposited materials (= eolian deposits) usually consist of **silt or fine sand**. These wind deposited parent materials are associated with such landforms as sand dunes or blanket cover at the surface. Eolian materials tend to **be extremely well sorted and free of coarse fragments**. Some rounding and **frosting** of mineral grains is detectable.

#### **(9) Loess**

The term loess is sometimes used to describe **silt** textured eolian material. Typically it has **no horizontal stratification**, but occurs in a single massive layer. A large proportion of the material may consist of fresh, sharp-cornered particles of minerals such as feldspars, quartz, calcite, mica etc. mingled with clay particles. Loess can be interpreted as an accumulation of wind-blown dust, usually of glacial origin.

### (10) Volcanic ash

Volcanic ash is produced by volcanic eruptions. It consists of medium size particles (**sand and silt**) and it tends to diminish downwind from the source.

### (11) Eolian sand

**Sand** wind-blown debris often accumulates to form rounded hillocks known as dunes (Fig. 13). Originally the growth of dune is started by an obstacle, such as a stone, a brush, or an irregularity in the surface of the ground, which breaks the force of the wind. After the resulting heap of sand has grown to appreciable size it acts as its own wind-break and causes further deposition.



*Figure 13: Sand dunes. Credit: Kent Watson (TRU).*

## **GRAVITY DEPOSITED MATERIALS**

**Colluvium** is a type of parent material that moved down slope due to gravitational forces (in some cases water may play a role in initiation of the movement). Colluvium material is heterogeneous, **unsorted** deposits that contain many very sharp, **angular** rock fragments accumulated at the base of steep slopes (Fig. 14).



*Figure 14: Recent colluvial deposit. Credit: Maja Krzic (UBC)*

## 2. PARENT MATERIAL RECOGNITION

Parent materials in the field can be recognized by direct visual examination of the material in soil pits, road cuts, etc. This entails observations regarding uniformity of particle sizes (**degree of sorting**), sizes (**texture**) and shapes (**angular / rounded**) of individual particles, absence or presence of water-worked features, glacial striations on pebbles, etc. Parent materials can also be inferred from terrain features, in the field or on aerial photographs (paired aerial photographs of the same terrain, taken from somewhat different positions, may be examined under a stereoscope, to provide a 3-dimensional view of landforms). The observer identifies **landforms**, patterns and tones with which particular kinds of materials are likely to be associated, and also notes evidence suggesting the location of boundaries between different materials.

⇒ What you need to do during the lab:

- Examine the samples of parent material provided.
- Identify and describe the parent material in 3 “mystery” monoliths. Record the monolith number (or letter, whichever is given), your observations, and your conclusion about the type of parent material.



⇒ What you need to do after the lab:



Upon completion of this lab, you should continue practicing your newly acquired skills on soil parent material identification by visiting **Virtual Soil Monoliths** at <http://monoliths.soilweb.ca/>. This interactive website provides a brief instruction on soil parent material identification as well as practice questions (and answers); to be found in the **Tutorial** at <http://monoliths.soilweb.ca/tutorial/>

## Reference

- Curran, M., Davis, I., and Mitchell, B. 2000. Silviculture prescription data collection field handbook: Interpretive guide for data collection, site stratification, and sensitivity evaluation for silviculture prescriptions. BCMOF and Management Handbook No. 47. 156 pp.
- Valentine, K.W.G., Sprout, P.N., Baker, T.E., and Lavkulich, L.M. 1978. The soil landscapes of British Columbia. B.C. Ministry of Environment. Victoria, BC. 187 pp.

## DATA COLLECTION

Property	Monolith A	Monolith B	Monolith C
Degree of sorting (the uniformity of particle sizes)			
Texture (i.e., are individual particles visible by naked eye)			
Presence or absence of stones			
Angularity of coarse fragments (angular, sub-rounded, rounded)			
Presence / absence of stratification (i.e., layers)			
Other distinguishing characteristics (e.g., presence of varves, coatings)			
Type of parent material			

**Don't forget to attach this table to the lab assignment**

# LAB 5 – SOIL CHEMISTRY

The purpose of this lab is to help you learn the following important principles and concepts of:

- 1) Soil acidity and pH
- 2) Soil organic matter
- 3) Available phosphorus

## SECTION 1 - SOIL ACIDITY AND PH

General objectives:

- 1) Define the term pH
- 2) List and explain the three types of soil acidity
- 3) Identify five factors contributing to soil acidity

### 1. INTRODUCTION

Soil reaction is described in terms of pH values. Soil pH is a measurement of the **hydrogen ion (H<sup>+</sup>) concentration** within the soil. It is an extremely important soil chemical property, which has a profound effect on the availability of nutrients and pollutants to plants and activity of soil microorganisms.

#### *The pH scale*

pH is defined by the equation:

$$\text{pH} = -\log [\text{H}^+]$$

**pH decreases (or becomes more acidic) as the concentration of hydrogen ions increases.**

The pH scale ranges from 0 to 14, while soil pH values usually range from extremely acidic (pH 2-3) to extremely basic or alkaline (pH 11-12). Because pH is defined as the negative decimal logarithm of [H<sup>+</sup>], each pH increase of one unit is a 10-fold jump in actual H<sup>+</sup> concentration.

Most soils pH range from 4.5 (considered strongly acidic for soils) to 8.5 (medium alkaline). The best plant growth takes place within pH 6 to 7 (i.e., in slightly acidic to neutral soils); however, some plants thrive in an alkaline environment while others prefer more acidic soils. Extreme acidity and alkalinity are conditions that usually need to be corrected if satisfactory crop production is to be achieved.

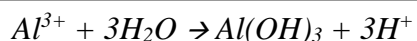
#### *Active, exchangeable, and residual acidity*

The amount of hydrogen ions (H<sup>+</sup>) present in the soil solution (i.e., soil water + solutes) represents **active acidity**. The **exchangeable acidity** is represented by the quantity of

hydrogen and aluminum ions present on exchange sites on colloids. They can be easily replaced by a salt solution (such as 0.01 M CaCl<sub>2</sub>). Recall that cations in the soil solution are in equilibrium with adsorbed cations. A third category, **residual** or **reserve acidity**, reflects the amount of hydrogen and aluminum ions strongly bound to soil particles. They are not replaced by a salt solution but can be neutralized by limestone.

### *Causes of soil acidity*

Several factors are known to contribute to soil acidity. Prolonged **leaching** favors the high concentration of hydrogen in solution and on the exchange complexes. The normal biological activity of soil produces **organic acids** (e.g. carbonic and citric acids). As you will learn later in this course, the process of **nitrification** (transformation of ammonium NH<sub>4</sub><sup>+</sup> into nitrate NO<sub>3</sub><sup>-</sup>) releases hydrogen ions. **Acid rain**, an environmental problem in many parts of the world, results in the deposition of nitric and sulfuric acids. Finally, **aluminum ions** increase soil acidity by producing hydrogen ions via a hydrolysis reaction:



## 2. MEASUREMENT

Several methods are available to estimate the pH of a soil. These include electronic devices known as pH electrodes (together with voltmeters are called pH meters), and indicator solutions, which change color at different pH values. These methods are discussed in your textbook - "Elements of the nature and properties of soils" by Brady and Weil.

### ⇒ What you need to do during the lab:

During the lab you will:

- ✓ Use a pH meter to measure soil pH in water and in 0.01 M CaCl<sub>2</sub> (Note: 1 M = 1 mol/L).
- ✓ Use a field test kit (based on indicator solutions) to estimate soil pH. The test kit is an inexpensive but less accurate method to measure soil pH.

#### **pH meter**

The pH meter is a delicate instrument and must be handled with care. The electrodes are particularly fragile. Do not attempt to use the meter until you have received the instructions.

Note that the pH meter must be calibrated against two (or more) standard buffer solutions before accurate measurements are possible. Calibration will be done for you before the lab.

- **pH of the soil samples in water**

- 1) Prepare a 1:5 soil : water suspension by adding 50 mL of distilled water to 10 g soil in a clean beaker. Mix thoroughly with stirring rod.
- 2) Let suspension equilibrate for 30 minutes, during which time most of the soil solids should settle out.
- 3) Insert pH electrodes into supernatant solution and when a stable reading is displayed ('S' appears on the screen) record the pH to one decimal place on the data collection table provided below.
- 4) Rinse the electrodes well using distilled water.

- **pH of the soil samples in CaCl<sub>2</sub> solution**

- 1) Prepare a 1:5 soil : CaCl<sub>2</sub> suspension by adding 50 mL of 0.01 M CaCl<sub>2</sub> to 10 g soil in a clean beaker. Mix thoroughly with stirring rod.

Note: the symbol *M* denotes moles of solute per liter of solution:  $M = \text{mol/L}$

-Repeat steps 2-4 above.

### Determination of soil reaction using field test kit

Follow instructions printed on the colour comparison card in the test kit and record your estimate on the data collection sheet below. The indicator solution is a mixture of various pH-sensitive dyes. The white powder provides uniform background for assessing the dye colour with minimal confusion due to soil colour.

## Reference

Thomas, G.W. 1996. Soil pH and soil acidity. p. 475-490. In D.L. Sparks et al. (ed.) Methods of soil analysis. Part 3. Chemical Methods. Soil Sci. Soc. Am. Book Series No. 5. ASA-SSSA, Madison, WI.

## DATA COLLECTION

Sample name:	Method	pH
	pH meter – determination in water	
	pH meter – determination in 0.01 M CaCl <sub>2</sub>	
	Field test kit	

Don't forget to copy this table onto the lab assignment

## SECTION 2 - SOIL ORGANIC MATTER

The objective of this lab section is to determine the organic matter concentration of a soil sample using the **weight loss on ignition** method.

### 1. INTRODUCTION

Soil organic matter is a complex and varied mixture of a range of organic substances. It encompasses living biomass, dead plant residues, and re-synthesized organic compounds of varying degree of complexity. Organic matter is an essential constituent of soil. It influences such soil properties as cation exchange capacity, acidity and buffering, structure, nutrient content, water retention, thermal conductivity, heat capacity, and biological activity.

The carbon (C) concentration in soil organic matter is relatively constant, often assumed to average 58% (mass basis), i.e. **0.58 kg C /kg dry organic matter**. Thus, the organic matter concentration of soil can be estimated by dividing organic carbon concentration by 0.58:

$$\% \text{ organic matter} = \frac{\% \text{ organic carbon}}{0.58} \quad \text{or}$$

$$\% \text{ organic matter} = \% \text{ organic carbon} \times 1.724 \frac{\text{kg organic matter}}{\text{kg organic carbon}}$$

where 1.724 is 100/58; and the factor 1.724 is sometimes referred as van Bemmelen factor.

### 2. METHODS USED FOR ESTIMATING ORGANIC MATTER CONTENT OF SOIL

Organic matter content is estimated by measuring the weight loss during combustion (weight loss on ignition), measuring CO<sub>2</sub> production during combustion (dry combustion), or measuring C released during chemical oxidation in solution (wet oxidation).

#### A. WEIGHT LOSS ON IGNITION

This method involves **removal of organic matter by combustion** of the soil sample in a muffle furnace. The substance remaining after ignition is called the ash and is made of inorganic constituents such as minerals. The difference between the initial weight and the ash weight represents the organic matter content. The soil must be dry and combustion temperatures usually range from 350°C to 600°C.

This procedure is useful for very heterogeneous soils, as large samples can easily be used, reducing the need for replicate analyses. This method is not appropriate for clay-rich soils or for calcareous soils, which may lose significant amounts of inorganic constituents during ignition.

## **B. DRY COMBUSTION**

By **measuring the amount of CO<sub>2</sub> produced during combustion**, one can evaluate the total C and calculate the organic matter content of a sample. Special induction furnaces (e.g. LECO carbon analyzer) have been designed to use this method not only for soil analysis, but also for C analysis in other materials, such as plant biomass. Like the weight loss on ignition, dry combustion is not appropriate for clay-rich and calcareous soils.

## **C. WET OXIDATION**

There are several procedures that may be used to evaluate organic matter and organic C by wet (conducted in solution) **chemical oxidation**. One of these methods is the Walkley-Black method, which is useful for a wide variety of soils, including calcareous soils. In this method potassium dichromate (K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub>), in strong acid solution, is used to oxidize soil organic matter. Disadvantages of the method include safety hazards and chemical waste disposal requirements.

# **3. MEASUREMENTS**

In this lab we will use the **weight loss on ignition method**.

Because we are using air-dried samples that still contain some water bound to the soil particles (i.e., **hygroscopic moisture**) you will need to determine soil water content and use it to correct the loss on ignition values.

## **⇒ What you need to do during the lab:**

### **Soil water content determination:**

- Take a clean, dry tin and record the sample number in your notebook.
- Weigh the empty tin and record the weight.
- Add about 10 g of soil to the tin and record the **total** weight.
- Enter your values into the Google Sheet; a link will be posted on the UBC Wiki for APBI200.
- Lab staff will dry the sample in a forced draft oven at 105°C for 16 hours. The tin will then be removed from the oven, cooled to room temperature in a desiccator, and weighed.
- The weight of dry soil (+ tin) will be posted on the UBC Wiki site for this course within 2 days of lab completion.

### **Loss on ignition:**

- Take a porcelain crucible and record the sample number (written in pencil on the bottom of the crucible) in your notebook.
- Weigh the empty crucible and record the weight.
- Weigh 2 g of soil into the crucible and record the **total** weight.
- Enter your values into the Google Sheet; a link will be posted on the UBC Wiki for APBI200.

-Lab staff will place the crucible in a muffle furnace, heat it at 350°C for 1 hour, then raise the temperature to 600°C for 6 hours. The crucible will then be removed from the furnace, cooled in a desiccator, and weighed.

-The weight of ashes (+ crucible) will be posted on the UBC Wiki site for this course within 2 days of lab completion.

## 4. CALCULATIONS

Retrieve data from UBC Wiki site pertaining to your sample. Please note that you will need (i) the weight of oven-dry soil + tin and (ii) weight of ashes + crucible.

### % SOIL WATER

Sample number	Wt of tin (g) (1)	Wt of air-dried soil + tin (g) (2)	Wt of oven-dried soil + tin (g) (3)	Wt of air-dried soil (g) (4)	Wt of oven-dried soil (g) (5)	Gravimetric soil water content (g/g) $\theta$

Fill out the first 3 columns of the table using weights you recorded during the lab and data provided on the UBC Wiki site, then perform the following calculations:

#### (12) Subtract tin weight

Calculate the weight of air-dried soil and oven-dried soil by subtracting the weight of tin (1) from columns (2) and (3). Enter your values in columns (4) and (5).

#### (13) Calculate the gravimetric soil water content $\theta$

Determine the gravimetric soil water content  $\theta$ , expressed on an oven-dry soil basis:

$$\theta = \frac{\text{Wt air dry soil (4)} - \text{Wt oven dry soil (5)}}{\text{Wt oven dry soil (5)}}$$

Note that the unit of  $\theta$  is g/g since it is the gravimetric water content (not to be confused with the volumetric water content, which has units  $\text{cm}^3/\text{cm}^3$ ).



**ORGANIC MATTER CONTENT (WEIGHT LOSS ON IGNITION METHOD)**

Sample no.	Wt of crucible (g) <b>(A)</b>	Wt of air-dried soil and crucible (g) <b>(B)</b>	Wt of ash and crucible (g) <b>(C)</b>	Wt of air-dried soil (g) <b>(D)</b>	Wt of ash (g) <b>(E)</b>	Equivalent oven-dried soil (g) <b>(F)</b>	Soil organic matter content (%)

**Don't forget to attach both tables to the lab assignment**

Fill out the first 3 columns of the table using weights you recorded during the lab and data provided on the UBC Wiki site. Then perform the following calculations:

**(14) Correct for the crucible weight**

Use the same approach as above.

**(15) Determination of the oven-dry weight corresponding to the air-dry weight**

Organic matter content is expressed on an oven-dry basis, but we used an air-dried sample that still contains some water. You need to calculate the oven-dried weight (column (F)) corresponding to the weight of air-dried soil (column (D)) you placed in the crucible during the lab.

In the previous table you calculated the gravimetric soil water content  $\theta$ . We will use  $\theta$  to determine the equivalent oven-dry weight:

$$\theta = \frac{\text{Wt airdry soil (D)} - \text{Wt oven-dry soil (F)}}{\text{Wt oven-dry soil (F)}} = \frac{D}{F} - 1 \Leftrightarrow \frac{D}{F} = \theta + 1 \Leftrightarrow F = \frac{D}{\theta + 1}$$

**(16) Determination of the soil organic matter content**

The soil organic matter content can be calculated using:

$\text{Organic matter content (\%)} = \frac{\text{Wt oven-dry soil (F)} - \text{Wt ashes (E)}}{\text{Wt oven-dry soil (F)}} \times 100$
---

The organic matter content is expressed as a gravimetric %.

**Reference**

McKeague, J.A. 1978. Manual of soil sampling and methods of analysis. 2nd ed. Canadian Society of Soil Science.

Nelson, D.W., and L.E. Sommers. 1982. Total carbon, organic carbon, and organic matter. p. 539-580. In A.L. Page, R.H. Miller, and D.R. Keeney (ed.) Methods of soil analysis. Part 2. 2nd ed., Agron. Monogr. 9. ASA-SSSA, Madison, WI.

## SECTION 3 – AVAILABLE PHOSPHORUS

General objectives are to:

1. Understand the concept of plant available nutrients.
2. Perform available phosphorus extraction from soil and determine available P concentration in the soil based on spectrophotometer readings and a standard curve.

### 3. INTRODUCTION

Phosphorus (P) is an essential plant macro-nutrient, but it is not as abundant in soils as other macro-nutrients such as nitrogen or potassium. In addition, the concentration of plant available P in soil solution is very low, generally <0.01% of total soil P (Brady and Weil, 2017). Plant available P is limited in most soils because it is released very slowly from insoluble phosphates. Consequently, it is important to know the concentration of available P as opposed to total soil P when considering optimum plant growth.

The majority of soil P exists in three groups of compounds: organic P, Ca-bound inorganic P and Fe/Al-bound inorganic P. Most of the P in all three groups is of very low solubility, and thus only slowly contributes to P in the soil solution.

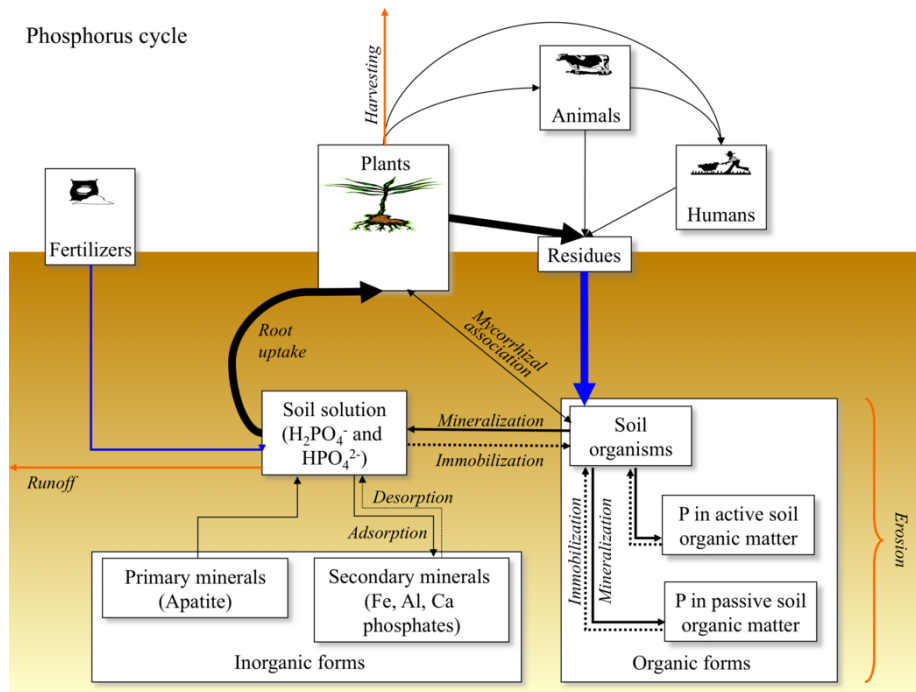


Figure 8. Soil P cycle (source: SoilWeb200).

The primary forms of P taken up by plants are orthophosphate ions, H<sub>2</sub>PO<sub>4</sub><sup>-</sup> and HPO<sub>4</sub><sup>2-</sup>. As the concentration of orthophosphates in soil solution decreases due to plant uptake, P will be released from labile inorganic and organic fractions.

### ***Available phosphorous soil tests***

As only a small proportion of total soil P is available to plants, soil test procedures attempt to extract a similar fraction of P that is accessible to plants over the growing season (i.e., P in solution + labile fraction). The most commonly used laboratory methods are Mehlich, Bray and Olsen P tests. The three methods use different chemical extraction solutions but work on the same principle - an acid extractant dissolves portions of the calcium, iron and aluminum phosphates in the soil. Thus, tests for the available P soil provide an index of availability. Note that the Olsen test is suitable for soils with high pH, while Bray is commonly used in acid soils, and Mehlich for acidic and neutral soils. In this lab we will use the Mehlich method.

Available soil P = P in solution + labile P fraction

## **4. MEASUREMENTS**

### **PRINCIPLE FOR MEHLICH METHOD**

The Mehlich method uses a combination of acids, ammonium salts and a chelating agent to dissolve Al- and Fe-phosphates and to extract P adsorbed on colloidal surfaces. Acetic acid (HOAc) and nitric acid (HNO<sub>3</sub>) dissolve Al- and Fe-PO<sub>4</sub>, the common forms of PO<sub>4</sub> bound in acid soils, and release PO<sub>4</sub> in soluble form. Ammonium salts (NH<sub>4</sub>F and NH<sub>4</sub>NO<sub>3</sub>) react with Al and Fe so that the PO<sub>4</sub> does not re-precipitate (or go again into an insoluble form). Similarly EDTA chelates the Fe and Al so they cannot react with PO<sub>4</sub>. Thus, PO<sub>4</sub> remains in soluble form and can be measured colourimetrically. Additionally F is a strong oxidizing agent and releases PO<sub>4</sub> associated with R-OH groups (where R = organic matter or Al/Fe).

### **PRINCIPLE FOR COLOURIMETRIC TECHNIQUE**

Phosphate (PO<sub>4</sub><sup>3-</sup>) will readily react with ammonium molybdate in the presence of a reducing agent to form a blue coloured complex, the intensity of which is directly proportional to the concentration of phosphate in the solution. First, a standard or calibration curve is generated by plotting the absorbances of a series of standard solutions against the corresponding concentrations. The phosphate content of an unknown sample can then be determined from the graph by comparing the colour of the extract once the colour has been developed to the calibration curve.

### **MATERIALS**

- Soil sample
- 25 mL conical tubes with screw top lid
- Filter funnels
- Filter paper (Whatman No. 42)
- 50 mL plastic bottles for collecting filtrate
- 25 mL volumetric flask with parafilm or 25 mL conical tubes with screw top lid
- 1 and 2 mL pipettes
- Glass cuvette
- Kimwipes and gloves



## 5. Cleaning

While you are waiting, empty any excess soil from the tube into the disposal bin. Place the lid back on the tube and place it in the washing bin.

## PART B. DETERMINATION OF P BY COLORIMETRIC METHOD

### 6. Pipet

Pipet 2 mL of the clear filtrate into a 25 mL volumetric flask or a clean 25 mL conical tube (one of these will be provided to you).

### 7. Dilution + coloring agent

Add 15 mL distilled water and 4 mL of solution B, dilute to 25 mL with distilled water. If using a volumetric flask, seal with parafilm and mix by inverting the flask about 15 times. If using a conical tube, tightly screw on the cap, and mix by inverting the flask about 15 times.

### 8. Colour development

Wait a minimum of 10 minutes (but not longer than 15 minutes) for colour development.

### 9. Readings

Carefully pour your solution into a glass cuvette, leaving approximately 1 cm of air space at the top. Wipe the cuvette with a Kimwipe, ensuring no fingerprints or dust are on the exterior of the glass. The absorbance of the soil extracts will be determined using the spectrophotometer at 845 nm; readings to be taken immediately. Place the cuvette into the spectrophotometer and collect the reading.

See video at <https://www.youtube.com/watch?v=pxC6F7bK8CU> for an explanation on the principles of a spectrophotometer.

## PART C. STANDARD CURVE

Standard solutions with known concentrations of P were prepared and spectrophotometer readings were obtained (Table 6).

*Table 6. Standard curve data with pre-determined concentrations for standard solutions*

Standard solution concentration* (ppm)	Spectrophotometer reading (nm)
0	
2	
4	
6	
8	
10	

\*These concentrations match a typical range of plant available phosphate concentrations found in most soils

### ⇒ What you need to do:

Plot the spectrophotometer readings on the ordinate (“y” axis) and the concentration on the abscissa (“x” axis). Fit a smooth (“best fit”) curve to the standard data points. From this **standard curve** read the concentration (mg/L) corresponding to your sample.

### Calculation of Available P

The purpose of the calculation is to transform the concentration, expressed in  $\mu\text{g P} / \text{mL}$  solution, into ppm (parts per million) or  $\mu\text{g P} / \text{g soil}$ :

$$\text{ppm P} = [X \mu\text{g/mL} - b \mu\text{g/mL}] [30 \text{ mL solution} / 3 \text{ g soil}] \times \text{d.f.}$$

where: X = sample reading ( $\mu\text{g/mL}$ )  
b = blank reading ( $\mu\text{g/mL}$ )  
d.f. = dilution factor

**Example:** Suppose that spectrophotometer reading for your sample corresponds to a phosphorus concentration of 3.8 mg/L on the standard curve, using the equation above, available P = 38 ppm

Unit conversion tips:

When the solvent is water, 1 L water = 1000 g, and .... ppm = mg/L =  $\mu\text{g/mL}$

$$1 \text{ mg/L} \times 1000 \mu\text{g/mg} \times 1 \text{ L}/1000 \text{ mL} = \mu\text{g/mL}$$

$$1 \text{ mg/L} \times 1 \text{ L}/1000 \text{ g} \times 1 \text{ g}/1000 \text{ mg} = 1/1,000,000 \text{ or } 1 \text{ ppm}$$

### ⇒ What you need to do:

Calculate the available P for your spectrophotometer reading. Fill out the table on the next page and write out all calculations for your sample.

## Reference

Soil Survey Laboratory Staff. 1992. Soil survey laboratory methods manual. Soil Surv. Invest. Repts. 42. USDA-SCS, Washington, D.C.

Sumner, M.E., and W.P. Miller. 1996. Cation exchange capacity and exchange coefficients. p. 1201-1229. *In* D.L. Sparks et al. (ed.) Methods of soil analysis. Part 3. Chemical Methods. Soil Sci. Soc. Am. Book Series No. 5. ASA-SSSA, Madison, WI.

### DATA COLLECTION

Sample #	
Soil sample mass (g)	
Spectrophotometer reading (nm)	
P conc. in sample solution ( $\mu\text{g/mL}$ )	
Available P ( $\mu\text{g/g}$ of dry soil)	

Don't forget to attach this table and the standard curve to the lab assignment

# LAB 6 – FOREST FLOOR & HUMUS FORMS

General objectives of this lab are to:

- Describe key properties of forest floor
- Describe main types of organic horizons that occur under well drained and poorly drained soil conditions
- Distinguish among the three main humus form orders

## 1. INTRODUCTION



To prepare for this lab and to find more information about the forest floor, visit online educational resource “Forest Floor” at <http://forestfloor.soilweb.ca/>

The **forest floor** is one of the most distinctive features of terrestrial forest ecosystems. The major pools for the storage of organic matter and nutrients within forest systems are the living vegetation, forest floor, and soil. The forest floor can be viewed as a link between the vegetation and the soil, and it is a crucial component in nutrient cycling. The **forest floor** consists of organic residues (leaves, branches, bark, stems) in various stages of decomposition present on the top of the mineral soil.

The amount of organic material in the forest floor depends on the balance between inputs from litter production and outputs due to decomposition. Both litter production and decomposition are functions of the site characteristics (e.g., soil water content, temperature, nutrient status) and vegetation present on the site (e.g., coniferous, deciduous). The forest floor is important for supporting rich biodiversity, carbon storage, nutrient cycling and effects on soil moisture and temperature.

### IMPORTANT DISCTINCTION:

**Forest floor** refers to just organic (L, F, H) horizons, while **forest humus form** includes both forest floor (i.e., L, F, H organic horizons) and Ah horizon.

## 2. ORGANIC HORIZONS

According to the Soil Classification Working Group (1998), organic horizons contain more than 17% organic carbon (or more than 30% of organic matter) by weight. Organic horizons occur in Organic soils, but they also may be present at the surface of mineral soils. There are two groups of organic horizons – those (LFH) that are formed in relatively well-drained conditions and those (O) that are formed in poorly drained conditions.

### 2.1. WELL-DRAINED CONDITIONS



Under well-drained (upland) conditions, organic horizons are composed of mostly leaves or needles, twigs and woody material and include: L, F and H horizons.

Tree litter falls to the forest floor and acts as a source of food for soil organisms. As organisms decompose litter, long-lasting humic compounds are formed and the litter becomes more discoloured and fragmented, over time shifting from litter (L) to humic (H) material.

Organic horizon descriptions and designations shown on this page follow taxonomic classification derived by Green et al. (1993).

**L – Litter:** Relatively fresh organic residues, identifiable plant material, such as leaves, wood or twigs resting on the surface of the forest floor. Some discolouration or other signs of early decomposition may be visible, but the origins of the plant residue are still easy to discern.

**F – Fermented, Fibric, Fragmented:** Decomposition of plant material is apparent, but the origins of plant residues are still distinguishable. Often, roots are present. The kind of F horizons present in the forest floor is important to determine what type of decomposition is dominant at a site.

**Fm – Mycogenous:** Plant residues are aggregated in a matted structure with a tenacious consistence (difficult to pull apart). Abundant fungal mycelia and roots, but few or no faunal droppings are visible.

**Fz – Zoogenous:** Plant residues are weakly aggregated with a loose friable consistency due to faunal droppings and active mixing of organic and mineral material by fauna. Few fungal mycelia if present. Faunal droppings are typically numerous and easily observed under magnification with a hand lens. Root residues are present, but are less abundant than in Fm horizons.

**Fa – Amphi:** Plant residues are aggregated into a weak to moderate, non-compact matted structure. Fabric is variable, featuring clumps of aggregated material with pockets of loose material. This is an intergrade between Fm and Fz horizons. There is presence of fungal mycelia and/or faunal droppings.

**H – Humic:** Well-humified plant material to the point that plant residues are not recognizable, with the exception of some roots or wood. This material is in an advanced stage of humification in which fine organic particles predominate over plant residues.

## **2.2. POORLY DRAINED CONDITIONS**

Where soils are saturated for prolonged periods, decomposition is limited by low oxygen availability. Thick organic horizons develop primarily from mosses and woody materials and are classified as Organic soils in the Canadian system of soil classification. The organic horizons in poorly drained Organic soils are classified as O horizons.

**O – Organic:** Organic material, variably decomposed and influenced by a water table near the soil surface for extended periods of time. Associated with wetlands where the water table is at or near the soil surface for a significant amount of time during frost-free periods.

**Of:** Identifiable plant residues (poorly decomposed).

**Om:** Plant residues are partly decomposed. This is an intermediate extent of decomposition between Of and Oh horizons.

**Oh:** Well-decomposed plant residues, largely transformed into humic materials.

### 3. Ah HORIZONS

**Ah:** Containing less than 30% organic matter (or less than 17% carbon) by mass, the Ah is the only mineral horizon included in forest humus form classification.

## 4. FOREST FLOOR DESCRIPTION AND PROPERTIES

A forest floor description is based on close inspection of organic horizons and the following steps:

1. Determine horizon boundaries and designations. Remember, possible horizons in a forest floor are L, F, H and Ah.
2. Pay particular attention to determining the type of F horizon as this will be used to classify your forest humus form. You may designate Fm, Fz or Fa.
3. Record the horizon depths using the mineral - organic interface as your 0 point. For example, L (7-5 cm), F (5-2 cm), H (2-0 cm), Ah (0-2 cm).
4. You can then use the methods of humus form assessment to record other properties such as structure, consistence, roots and what fauna and flora you observe in the sample.

For more detailed description notes, visit “Forest Floor” website <http://forestfloor.soilweb.ca/>

### **4.1. FOREST FLOOR DEPTH**

The depth of organic horizons is measured upward from zero depth, with zero being the interface between the organic and mineral horizons. That means the bottom of your sample should be taken as zero depth, unless you have part of a mineral horizon in your sample. (In Organic soils the depth is measured downward from the top of the profile, and this is taken as zero depth.)

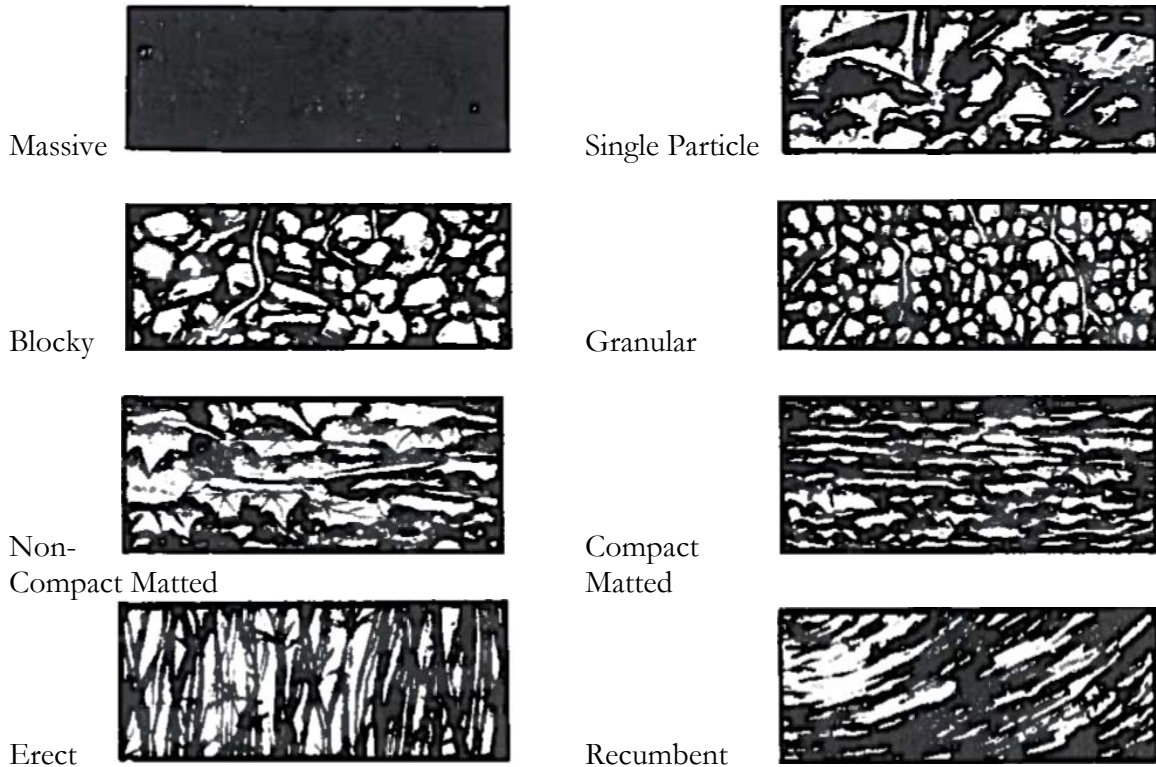
## **4.2. FOREST FLOOR STRUCTURE**

Forest floor structure is classified according to the type, kind, and size of macromorphological aggregations of the material within a horizon. The structure of forest floor horizons is an indication of what organisms are active in that soil.

### **Type and Kind of Forest Floor Structure**

<b>Type</b>		<b>Kind</b>	
<b>Class</b>	<b>Description</b>	<b>Class</b>	<b>Description</b>
Structureless	No observable aggregation	Massive	A coherent mass showing no evidence of aggregation
		Single Particle	An incoherent mass of individual particles (may be of various sizes) with no aggregation
Block-like	Materials arranged around a point bounded by flat or rounded surfaces	Blocky	Faces rectangular and flattened; vertices sharply angular
		Granular	Spheroidal and characterized by rounded or sub-rounded vertices
Plate-like	Materials arranged horizontally and parallel to each other, generally bounded by relatively flat horizontal surfaces	Non-Compact Matted	Materials arranged along horizontal planes with no evidence of compaction
		Compact Matted	Materials arranged along horizontal planes with evident compaction
Column-like	Materials arranged vertically	Erect	Materials in vertical position
		Recumbent	Materials in recumbent (reclining) position

## Examples of Forest Floor Structure



### 4.3. CONSISTENCE OF FOREST FLOOR

This is a measure of the strength and nature of forces combining materials together, assessed by deformation or rupture when pressure is applied. Consistence can give an indication of the moisture status and strength of aggregates in the forest floor horizons.

Class	Description
Loose	There is no consistence of the material
Friable	A material that crumbles easily under gentle pressure
Firm	A material that can be crushed under moderate pressure; resistance is noticeable
Pliable	Material is soft and plastic
Resilient	Material that is springy or elastic and assumes original state after forces of deformation have been applied and released
Tenacious	Material is cohesive, not easily pulled apart

#### **4.4. ROOTS**

For root abundance assessment, both living and dead roots are counted within a specific area. For **fine and very fine roots**, the surface area of the profile viewed is **2.5 cm x 2.5 cm**, while for **medium, coarse and very coarse roots**, a **25 cm x 25 cm** area is viewed.

##### **Root Abundance**

<b>Class</b>	<b>Number of roots/unit surface area</b>
Very few	< 3
Few	3 – 10
Common	11 – 20
Plentiful	21 – 30
Abundant	>30

##### **Root Size**

<b>Class</b>	<b>Size (diameter in mm)</b>
Very fine	< 1
Fine	3 – 10
Medium	11 – 20
Coarse	21 – 30
Very Coarse	>30

##### **Root Orientation**

<b>Class</b>	<b>Description</b>
Random	Roots are oriented in all directions
Oblique	Roots are oriented along oblique planes
Horizontal	Roots are oriented along horizontal planes
Vertical	Roots are oriented along vertical planes

#### **4.5. SOIL FLORA**

Soil flora include bacteria, actinomycetes, algae and fungi. Field **description is usually narrowed to fungi**. Fungi include: rusts, moulds, yeasts and mushrooms. Presence is detected by observing a mass of hyphae (thread-like filaments) called mycelium.

Colours of fungal mycelium can be brown, black, grey, white, red, yellow and blends of these, and also transparent. Description of soil flora includes abundance, colour and distribution.

### Abundance of Fungal Mycelia

Class	Description
None	Mycelia not visible
Few	Mycelia occasionally present but scattered and not easily observed
Common	Mycelia commonly observed
Abundant	Mycelia observed continuously throughout the horizon, often “matting” materials together and creating a “felty” tactility

### Distribution of Fungal Mycelia

Class	Description
Random	Mycelia are distributed randomly, there is no recognizable pattern of distribution
Clustered	Mycelia are distributed in clusters or groups
Banded	Mycelia are distributed in bands, sheets or layers

## 4.6. SOIL FAUNA

Soil fauna includes those organisms that complete at least one life stage in the soil or surface litter, excluding those species which occur there only in passive stages such as eggs, cysts or pupae.

Direct observation of fauna or indirect observation through the presence of casts can be used to determine faunal presence – casts (or droppings) provide a good indication of faunal activity.

Size distribution, shape, colour and level of humification in casts are indicative of the type of soil fauna that produced them.

- **Mite-type:** Small (<0.1 mm diameter) spherical/oval, humified, rust to dark brown, lacking mineral grains
- **Enchytraeid-type (potworms):** Small (0.05-0.2 mm diameter) sub-spherical, generally well-humified, brown with varying amounts of mineral grains and clay
- **Arthropod-type (and small surface-feeding earthworms):** Visible without hand lens (1-3 mm long) well-humified, dark brown, containing mineral grains but low in clay
- **Worm casts:** Well-humified, generally brown or greyish brown, containing mineral grains and clay, spongy or coarse granular particles (5-10 mm diameter)

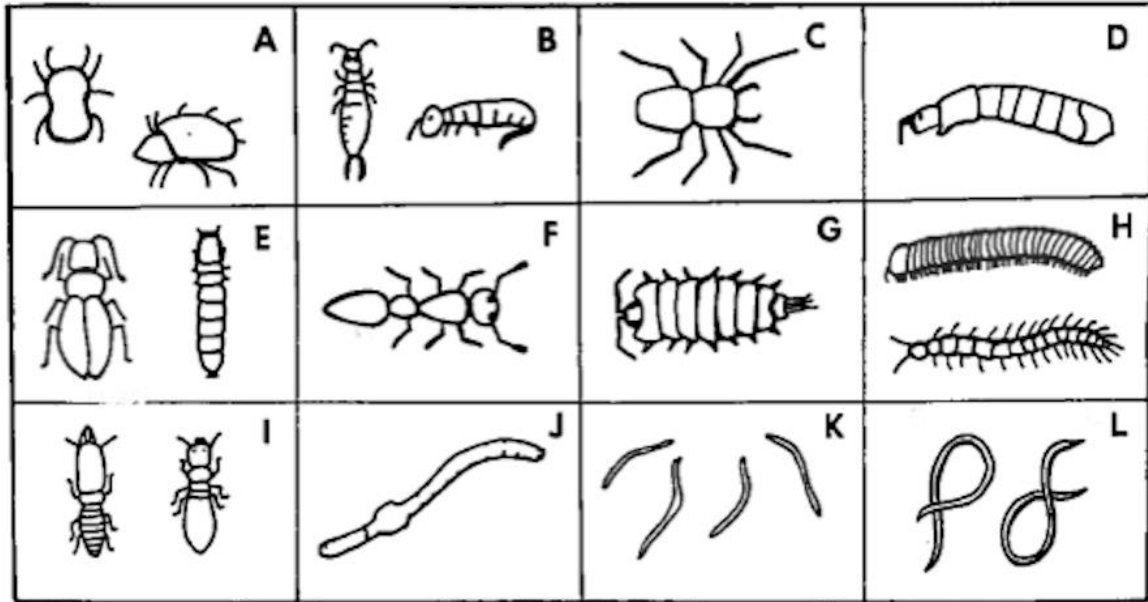


Figure 1: Soil Macrofauna from: Klinka, K., Green, R.N., Trowbridge, R.L., and Lowe, L.E. 1981. Taxonomic classification of humus forms in ecosystems of British Columbia. Land Management Report Number 8. BC Ministry of Forests.

- A. Mites (*Acarina*)
- B. Springtails (*Collembola*)
- C. Spiders (*Areneida*)
- D. Fly larvae (*Diptera*)
- E. Beetles and Larvae (*Coleoptera*)
- F. Ants (*Hymenoptera*)
- G. Woodlice (*Isopoda*)
- H. Centipedes and millipedes (*Myriapoda*)
- I. Termites (*Isoptera*)
- J. Earthworms (*Lumbricida*)
- K. Potworms (*Enchytraeida*)
- L. Nematodes (*Nematoda*)

### Soil Fauna Sizes for Forest Floor Classification

Class	Description
Macrofauna	Animals with a body size greater than 1 cm (in longest dimension); earthworms, vertebrates, molluscs and large arthropods
Mesofauna	Animals ranging in body size from 1cm to 0.2 mm including some mites, springtails, potworms and most of the larger nematodes. The lower limit is about the limit of viewing with a 10x hand lens.
Microfauna	Organisms less than 0.2 mm in size; includes the protozoa as well as many of the smaller mites and nematodes

## Abundance of Droppings (or Casts)

Class	Description
None	No visible droppings
Few	Droppings occasional observed but scattered
Common	Droppings commonly observed
Abundant	Droppings frequently observed in relatively large numbers throughout the horizon

## Distinction of Droppings (or Casts)

Class	Description
Random	Droppings are distributed randomly, there is no recognizable pattern of distribution
Clustered	Droppings are distributed in clusters or groups
Banded	Droppings are distributed in bands, sheets or layers

## 5. FOREST HUMUS FORM ORDERS

The purpose of forest humus form classification is to organize knowledge about humus forms and to enhance our understanding about relationships between humus forms and factors involved in their formation. Information presented here follows the system developed by Green et al. (1993) focused on the forest humus forms known to occur in British Columbia and other regions under the influence of comparable climate.

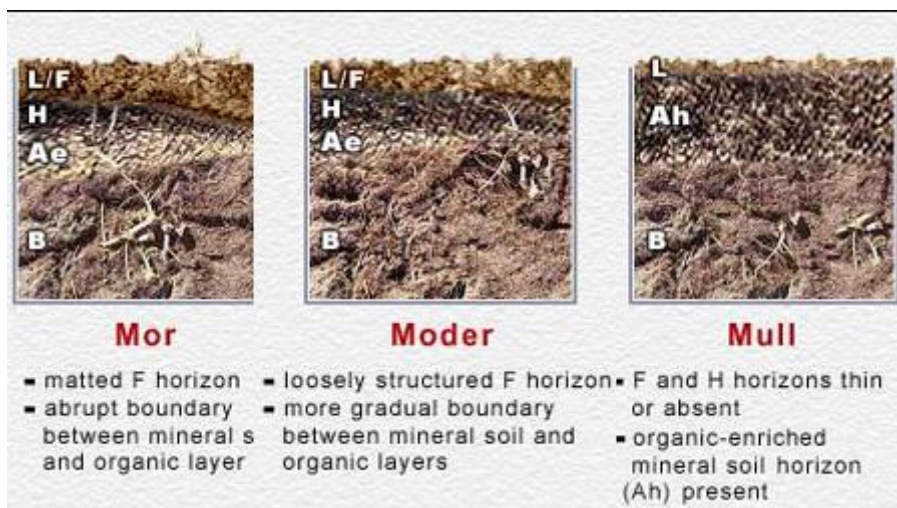
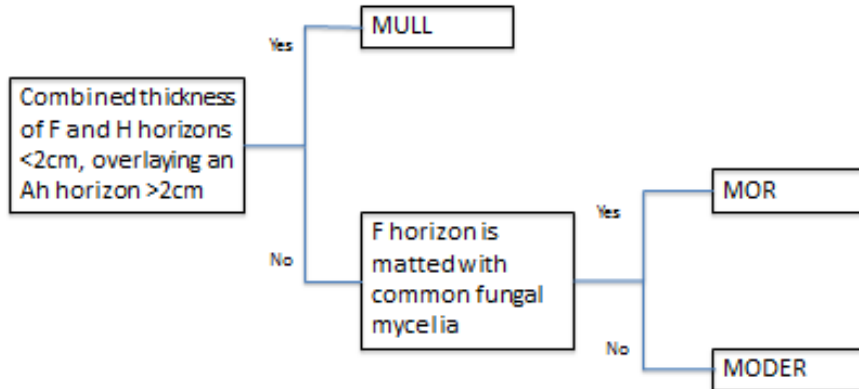


Figure 2. Three main groups of forest humus forms. Credit: Gabriel Lascu (UBC, Center for Teaching, Learning and Technology)



As in soil classification, forest humus forms are divided into orders. The main orders are **mor**, **moder** and **mull**. They are subdivided further into humus form groups.

### Simple Key for Humus Form Orders



From: Klinka, K., Green, R.N., Courtin, P.J., and Nuszdorfer, F.C., 1984. Site diagnosis, tree species selection and slashburning guidelines for the Vancouver Forest Region. BC Ministry of Forests.

## **MOR**

In a mor, plant litter is decomposed more slowly and accumulates on top of mineral horizons with a sharp transition between organic and mineral horizons. Fauna are uncommon and undecomposed plant material accumulates over time to form a compact matted Fm horizon containing scarce or no faunal droppings. Without soil fauna, decomposition is often incomplete and accumulation of undecomposed organic material occurs. A mor forms due to incomplete fungal decomposition, resulting in some immobilization of nutrients in the forest floor – removing them from cycling and accessibility to plants.

Mors tend to occur under less optimal climatic conditions over nutrient poor parent material. In boreal and some coastal forests of British Columbia, humus accumulations can immobilize a large portion of the nutrient capital of a site.

**Characteristic Horizon(s):** Fm

## **Summary of Mor's Properties**

- Layered, compact-matted structure
- Chemical properties: very acid to acid, high C:N ratios leading to a storage of nutrients, which are slowly released and made available to plants
- Present under unfavorable climatic conditions
- Fungal dominated decomposition, limited bacterial and faunal activity
- Roots prevalent in the plant residues of the Fm horizon
- Thick Fm horizons and usually lacking Ah horizons

## **MODER**

Moders tend to have upper organic horizons with fungal mycelia and faunal casts, overlying Ah horizons of mixed organic faunal casts and mineral soil.

**Characteristic Horizon(s):** Fz or Fa

## **Summary of Moder's Properties**

- Loose, non-compact structure comprised largely of faunal droppings
- Chemical properties: higher pH than mor, lower C:N ratios, higher mineralizable N and base saturation than mors, indicating better nutrient availability
- Fungal decomposition important, but decomposition by bacteria, actinomycetes, and fauna is even more important
- Limited mixing of organic matter into mineral soil (Ah)

## **MULL**

The mixing of organic material with mineral soil carried out by soil fauna followed by rapid bacterial decomposition, results in the formation of a mull. The mull is characterized by more complete decomposition and higher nutrient availability than the other two orders. Generally, mulls are associated with more fertile soil and greater species richness. Macro-fauna create casts and burrows, distributing and providing access to food for smaller organisms. Mulls have Ah horizons in which soil organic matter is intermixed with mineral soil in crumbly organo-mineral aggregates resulting from the activities of roots, fauna and microbes. These organo-mineral aggregates are generally associated with earthworm activity but can also result from the actions of other agents such as other animals, roots, white-rot fungi, termites, or ants. Soil fauna can increase decomposition by fragmenting or comminuting litter and altering the microbial community.

**Characteristic Horizon(s):** Ah

## Summary of Mull's Properties

- Well decomposed organic matter that is incorporated in mineral soil (Ah)
- Chemical properties: among the three orders, mull has the highest pH, lowest C:N ratio, and highest nutrient availability and biological activity
- Rapid decomposition by bacteria and soil fauna
- Thin L, F and H if present

## FOREST HUMUS FORM GROUPS

Humus form orders and their groups as per Green et al. (1993)

Mor Order	Moder Order	Mull Order
Hemimor	Mormoder	Vermimull
Humimor	Leptomoder	Rhizomull
Resimor	Mullmoder	Hydromull (wet)
Lignomor	Lignomoder	
Hydromor (wet)	Hydromoder (wet)	
Fibrimor (wet)	Saprimoder (wet)	
Mesimore (wet)		

### IMPORTANT DISCTINCTION:

**Forest floor** refers to just organic (L, F, H) horizons, while **forest humus form** includes both forest floor (i.e., L, F, H organic horizons) and Ah horizon

## 6. FOREST HUMUS FORM QUEST

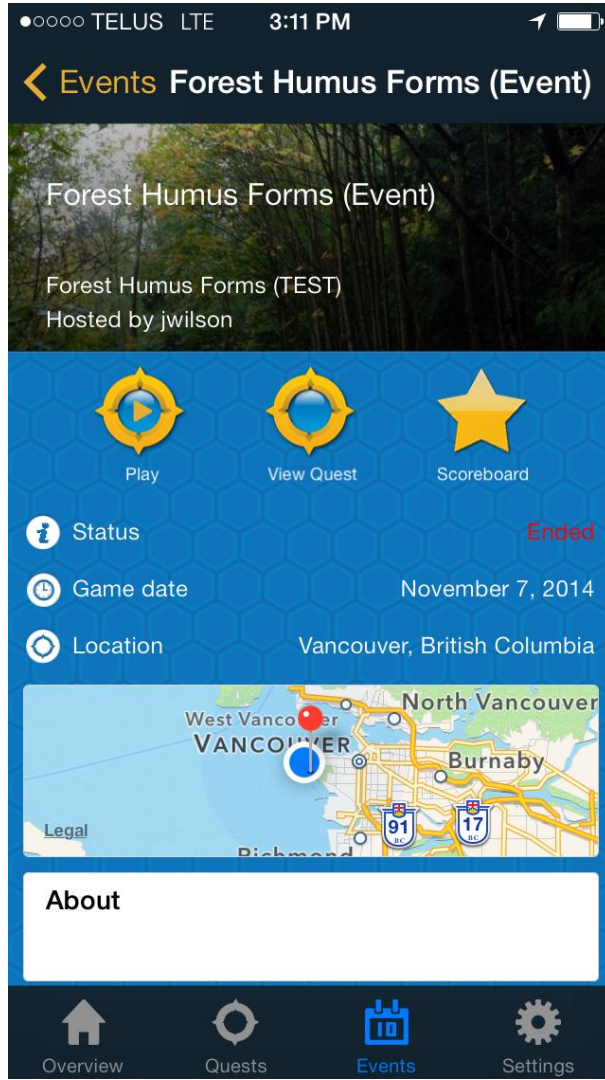
### 6.1. DESCRIPTION

This outdoor, self-guided educational “Quest” is a team-based activity that accompanies the APBI 200 lab #6 on Forest Floor and Humus Forms. The Quest takes place at the **UBC Farm** (3461 Ross Drive), featuring forest floor and forest humus forms in two different forest types: a mixed coniferous stand and a deciduous stand.

This Quest is designed as a scavenger hunt, where a series of questions based on directions and subject matter must be answered in the Questogo app to progress through the quest. The background information to help you answer the questions correctly is provided in the online Forest Floor resource (<http://forestfloor.soilweb.ca/activities/quest-activities/>). The quest includes instructional, location-based, and question and answer-type tasks to test your knowledge of the forest floor and humus forms in an outdoor setting.

It is powered by *Questogo*, a free smartphone app, available for iOS smartphones.

The Quest is available for 2 weeks in the App in an “Event” (the exact dates will be posted in UBC Wiki for APBI200 course. Up to 5 bonus marks will be given to all students who participate in the Quest!



## **6.2. INSTRUCTIONS**

### **Before you go to the UBC Farm:**

1. Form a team of 4-5 people with your classmates. Choose one person on the team to use their smartphone for this Quest (must have iOS). Come up with a fantastic team name and **post the group name and all group members** at this page [http://wiki.ubc.ca/Course:APBI200/Lab\\_Assign](http://wiki.ubc.ca/Course:APBI200/Lab_Assign). of the APBI 200 wiki site under “Lab 6 assignment”.

2. Download the Questogo App from the App Store (iOS). Find it by searching for “Questogo”.
3. Open Questogo on your smartphone and create an account using your email address and a new password. Sign in. Please ensure that the GPS on your phone is enabled so the app can find your location (Note: If prompted, allow Questogo to access your current location).
4. Tap on “Events” at the bottom of the screen. Under “All Events” you will see the “APBI 200 Event: Forest Humus Forms 2016”. Tap on this Event.
5. The next screen will provide you with more information about the Event and the Forest Humus Forms Quest. Read all the details on this screen and on the “View Quest Details” button.
6. Tap the “Play” button on the Event screen.  
**Note:** You will not be able to play this event before it opens (date will be announced in the lectures and posted at UBC Wiki for APBI 200).
7. Enter your super fantastic team name here. This will appear on the scoreboard for this event, where you can check and see how you compare to other teams in the class. Tap “Play Now”. The tasks for the Quest will be loaded onto your smartphone.  
**Note:** Complete steps 1-7 BEFORE you come to the UBC Farm. You can close the app, and re-open it to resume the event once you arrive at the UBC Farm.

### **Travel to UBC Farm**

(Located at 3461 Ross Drive, south of W. 16<sup>th</sup> Avenue).

Visit the UBC Farm [website](#) for directions on how to get there on foot, by bike or by public transit. It is about a 20 minute walk from the H. R. MacMillan Building.

### **Start playing!**

At the entrance to the UBC Farm Gate, open Questogo and start playing (resume) the Event! Instructions will guide you through the Quest.

### **Useful Information:**

- The Quest will take approximately 1.5 hours to complete, including travel time.
- You can expect the ground to be wet and possibly muddy. Wear appropriate clothing and footwear.
- Hints are available for many of the questions. You may use them, but know that points will be deducted for every hint used.
- If you are absolutely stumped, you can skip a question, but you will receive zero points.
- You can check the scoreboard anytime during the Event by tapping the “Scoreboard” link at the top right-hand corner of the screen.
- After 2 weeks, the scoreboard will be closed and the winning team(s) will be announced in class. Bonus marks for the lab assignment #6 will be given to all students who participate in the Quest!

## What you need to do during the lab:

- Observe your forest floor sample as a whole
  - Examine the types of litter present
  - Think about how decomposition is occurring (what organisms are present)
  - How is the material structured? Is it loose or matted?
  - Try to find the boundaries between horizons
- In the data entry form provided, identify and describe the horizons of your sample
  - Identify the boundaries of L, F, H and Ah horizons if present.
  - Measure the depth of horizons (try not to disturb the sample too much before this step): measure from the bottom up, recording the depths as in the following example: L 8-6 cm, F 6-1 cm, H 1-0 cm.
  - To the best of your ability, describe the structure, consistence, and roots in each horizon of your sample according to the tables and instructions provided.
- Identify any flora or fauna present in your sample.
- If an F horizon is present in your sample, designate this horizon as Fm, Fa or Fz.
- Discuss with your group: according to your sample description, to what forest humus form order does your sample belong? What is the diagnostic horizon?

## What you need to do after the lab:

- Visit the Forest Floor Resource: <http://forestfloor.soilweb.ca/> to review videos and other information about the forest floor. You can find a number of practice questions on the Tutorial page (under Activities). Completing the tutorial will help you to explore and find specific information while reinforcing and expanding your knowledge about the forest floor.
- Complete the Forest Humus Form Quest at the UBC Farm for up to 5 bonus marks on this assignment!

## **References**

- Green, R.N., Trowbridge, R.L., and Klinka, K. 1993. Towards a taxonomic classification of humus forms. Forest Science, Monograph 29, Vol. 39. 49 pp.
- Soil Classification Working Group. 1998. The Canadian System of Soil Classification, 3rd edition. Agriculture and Agri-Food Canada Publication 1646. 187 pp.

## DATA COLLECTION

Horizon	Depth (cm)	Forest Floor Structure	Forest Floor Consistence	Roots		
				Abundance	Size	Orientation
Flora Observed:		Fauna Observed:		Diagnostic Horizon:		Humus Form Order:
Notes:						

# LAB 7 – SOIL CLASSIFICATION

## SECTION 1 - SOIL HORIZONS AND LAYERS

The objectives of this lab are to learn what are the common soil horizons and layers and how to identify them.

### 1. INTRODUCTION

The clear definition and designation of soil horizons and other layers is essential to soil classification. Definitions of classes in the Canadian Soil Classification System are based mainly on the kinds and degrees of development of soil horizons and on their sequence in pedons<sup>1</sup>.

A **soil horizon** is defined as a layer of mineral or organic soil or soil material, lying approximately parallel to the land surface, whose characteristics are the result of soil forming processes. It differs from adjacent horizons in properties such as colour, texture, structure, consistency and chemical, biological, and mineralogical composition.

The **layers** are either non-soil layers such as rock and water or layers of unconsolidated material considered to be unaffected by soil forming processes. For brevity, these other layers are referred to simply as layers, although it is recognized that soil horizons are also layers.

### 2. MINERAL HORIZONS AND LAYERS

Mineral horizons are those that contain 17% or less of organic carbon (or 30% organic matter) by weight. For more detailed description of horizons and layers refer to the “The Canadian system of soil classification” (1998), 3rd edition prepared by the Soil Classification Working Group (Agriculture and Agri-Food Canada Publication 1646).

#### MINERAL HORIZONS

There are 3 types of mineral horizons: the A, B, and C horizons.

##### **A horizon**

The A horizon is a mineral horizon formed at or **near the soil surface**, in the zone of:

- leaching and **eluviation** of materials in solution,
- maximum *in situ* **accumulation of organic matter**, or
- both processes mentioned above

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<sup>1</sup> Pedon is the smallest volume that can be called a *soil*. It has three dimensions. It extends downward to the depth of plant roots or to the lower limit of the genetic soil horizons. Its lateral cross section is roughly hexagonal and ranges from 1 to 10 m<sup>2</sup> in size, depending on the variability in the horizons.



## **B horizon**

The B horizon is usually found **beneath the A horizon**. It is characterized by one of the following factors:

- **enrichment** in organic matter, sesquioxides (i.e. Fe and Al oxides), or clay
- development of soil **structure**
- a change of **colour** denoting hydrolysis, reduction or oxidation.

## **C horizon**

The C horizon is a mineral horizon comparatively **unaffected by the pedogenic processes** operative in A and B, with the exception of gleying or accumulation of carbonates or soluble salts. It is the **deepest** of all 3 soil horizons.

## **OTHER LAYERS**

Other layers include R and W layers.

### **R layer**

R layer is a consolidated **bedrock** layer that is too hard to break with hands or to dig with a spade even when moist, and that does not meet the requirements of a C horizon. The boundary between the R layer and any overlying unconsolidated material is called a lithic contact.

### **W layer**

W layer is a layer of **water** that may be present in Gleysolic, Organic or Cryosolic soils. When present in Organic soils it is called a hydric layer.

## **LOWER CASE SUFFIXES**

The lowercase suffixes are used to describe the dominant soil forming process in a horizon (see next page). Please note that detailed description of lowercase suffixes is provided in the “The Canadian System of Soil Classification” (1998).

**b - buried** soil horizon

**c - cemented** irreversibly

**ca** – horizon of secondary **carbonate** enrichment in which the concentration of  $\text{CaCO}_3$  exceeds that in the enriched parent material

**e - eluvial** horizon, showing losses (eluviation) of clay, organic matter, and Fe and Al oxides. It is used with an A horizon (Ae)

**f - enrichment with Fe and Al** oxides. It is used with B alone (Bf), with B and h (Bfh), with B and g (Bfg), and with other suffixes

**g - gleyed** horizon of gray color or mottling or both as a result of permanent or periodic intense anaerobic conditions. It is used with A and e (Aeg), with B alone (Bg), with B and f (Bfg, Bgf), with B, h, and f (Bhfg), with B and t (Btg), with C alone (Cg), with C and k (Ckg), and several others (Ccag, Csg, Csag).

**h** - enrichment with **organic matter**. It is used with A alone (Ah), or with A and e (Ahe), with B alone (Bh), or with B and f (Bhf or Bfh).

**j** – denotes a ‘**juvenile**’ horizon. It is used as a modifier of suffixes e, f, g, n, and t to denote an expression of, but failure to meet, the specified limits of the suffix it modifies. For example, Ae<sub>j</sub> is an eluvial horizon that is thin, discontinuous or slightly noticeable.

**k** – denotes the presence of **carbonates**, as indicated by visible effervescence when dilute HCl is added. Most often it is used with B and m (Bmk), or C alone (Ck), and occasionally with A and h (Ahk) or A and p (Apk), or organic horizons (Ofk, Omk).

**m** - **modified** horizon of slight development by hydrolysis, oxidation, and/or solution. It has a different colour and/or structure than the underlying horizon. It can be used as Bm, Bmgj, Bmk, and Bms.

**n** - presence of a high % of **Na** ions (ratio of exchangeable Ca to exchangeable Na is 10 or less). This leads to distinctive prismatic or columnar structure, dark coatings on aggregate surfaces, and hard to very hard consistency when dry. It is used with B alone (Bn), or B and t (Bnt).

**p** – a horizon disturbed by human’s activities, such as **plowing**, cultivation, logging, habitation, etc. It is used with A and O.

**s** – accumulation of soluble **salts** including gypsum (CaSO<sub>4</sub>), which may be detected as crystals, veins, surface crusts, or by depressed plant growth, or by the presence of salt-tolerant plant species. It is commonly used with C and k (Csk) but can be used with any other horizon.

**sa**- secondary enrichment of **salts more soluble than Ca and Mg** carbonates (generally Na). The concentration of salts exceeds that in the unenriched parent material.

**ss** – presence of several (more than two) **slickensides** (smooth shear clayey surfaces).

**t** – an illuvial horizon enriched with silicate **clay** (usually from Ae horizon above). It is used with B alone (Bt), with B and g (Btg), with B and n (Bnt), etc.

**v** – horizon affected by **argillipedoturbation** (disruption and mixing of soil as a result of shrinking and swelling of clays).

**y** - horizon affected by **cryoturbation** (mixing caused by freeze/thaw action) as manifested by disrupted and broken horizons and incorporation of material from other horizons. It is used with A, B, and C alone or in combination with other lowercase suffixes, e.g. Ahy, Ahgy, Bmy, Cy, Cgy, Cygj, etc.

**z** – a frozen layer. It may be used with any horizon or layer, e.g. Ohz, Bmz, Cz, Wz.

### ***Soil forming processes in the A horizons and common resulting suffixes***

The removal (eluviation) of clay from the upper part of the solum is expressed by a coarser soil texture relative to the underlying layers and formation of an **Ae** horizon. The removal (eluviation) of iron is indicated by paler or less red colour in the upper part of the solum and formation of an Ae horizon as well. The 3<sup>rd</sup> process that leads to the formation of an Ae is the removal of organic matter, expressed by a lightening of the soil colour usually in the upper part of the solum. Conversely, the accumulation of organic matter is usually expressed by a darkening of the surface soil and formation of an **Ah** horizon.

### ***Soil forming processes in the B horizons and common resulting suffixes***

The accumulation in B horizons of organic matter (**Bh**) is evidenced usually by dark colour relative to the C horizon, while enrichment in iron and aluminum (**Bf**) is often indicated by bright reddish-brown color. Clay accumulation is indicated by finer soil textures and by clay coating aggregates and lining pores (**Bt**). Soil structure developed in B horizons may include prismatic or columnar units with coatings and significant amounts of exchangeable sodium (**Bn**), and other changes of structure (**Bm**) from that of the horizons above or below. Colour changes include relatively uniform browning due to oxidation of iron (Bm as well), and mottling (**Bg**) associated with periodic reduction (i.e. absence of oxygen, generally due to high water table). Bg is indicated by solid grayish or bluish colour (gleying) or prominent mottling (e.g. bright rust-colored mottle in a grayish or bluish matrix).

### ***Soil forming processes in the C horizons and common resulting suffixes***

The accumulation in C horizons of calcium and magnesium carbonates produces Cca horizons while the accumulation of soluble salts produces Cs or Csa horizons. Mottling or gleying (Cg) are common and associated with high or fluctuating water table levels.

## **NAMED DIAGNOSTIC HORIZONS AND LAYERS OF MINERAL SOILS**

There are three named horizons for mineral soils: chernozemic A, podzolic B, and solonetzic B. Horizons that meet these requirements are diagnostic of the Chernozemic, Podzolic, and Solonetzic soil orders, respectively (i.e. their presence is sufficient to classify the soil in that order). A simplified list of the requirements for these three horizons is given below, while for more detailed description of the requirements please refer to the “The Canadian System of Soil Classification” (1998).

### **Chernozemic A horizon**

A chernozemic A horizon must have the following characteristics:

- It is at least **10 cm** thick
- Its organic **carbon content** is between 1 and 17% ( if > 17% it becomes an organic horizon) and its C/N ratio is less than 17
- It has sufficiently **good structure** that is neither massive nor single grained
- Its base saturation is more than 80% and calcium is the dominant exchangeable cation
- It is restricted to soils having a mean annual soil temperature of 0°C or higher and a relatively dry soil moisture regime

### **Podzolic B horizons (Bf, Bh, Bhf)**

Podzolic B horizons must be at least **10 cm thick**, must have accumulation of amorphous material (indicated by brown to black coatings on some mineral grains or small aggregates), must have a texture coarser than clay, and meet specific requirements for color, organic carbon, iron and aluminum content.

### **Solonchic B horizons (Bn and Bnt)**

Solonchic B horizons have **prismatic or columnar structure** that breaks to blocky structure. Soil aggregates have hard to extremely hard consistence when dry. The ratio of exchangeable Ca to Na is 10 or less.

## **3. ORGANIC HORIZONS AND LAYERS**

Organic horizons are found in Organic soils, and commonly at the surface of mineral soils. They may occur at any depth beneath the surface in buried soils, or overlying geological deposits. Organic horizons contain **more than 17% of organic carbon** (or more than 30% organic matter) by weight.

### **THE TWO GROUPS OF ORGANIC HORIZONS**

Two groups of organic horizons are recognized: O horizons (peat materials) and L, F, H horizons (folic materials).

#### **O horizons**

O horizons are organic horizons developed mainly from mosses, rushes, and woody materials. Usually they are saturated with water for prolonged periods. There are following types of O horizons:

- The **Of (fibric) horizon** consists dominantly of well-preserved fibers that are readily identifiable as to botanical origin.
- The **Om (mesic) horizon** is an O horizon at a stage of decomposition intermediate between fibric and humic horizons. The material is partly altered both physically and biochemically.
- The **Oh (humic) horizon** is an O horizon at an advanced stage of decomposition. It has the lowest amount of fiber, the highest bulk density, and the lowest saturated water-holding capacity of the O horizons. It is very stable and changes very little physically and chemically with time unless it is drained.
- The **Oco horizon** is referred to as coprogenous earth, which occurs in some Organic soils. It is deposited in water by aquatic organisms.

#### **L, F, and H horizons**

L, F, and H horizons are organic horizons developed primarily from the accumulation of leaves, twigs and woody materials with or without a minor component of mosses. They are found in relatively well-drained areas and are widespread in forested areas. They are sometimes collectively referred to as '**forest floor**'.

- The **L horizon** consists in undecomposed organic matter in which the original plant structures are easily discernible.
- The **F horizon** is partly decomposed and some of the original structures are difficult to recognize.

- The **H horizon** consists in decomposed organic matter in which the original structures are indiscernible. This material differs from the F horizon by its greatest humification due chiefly to the action of organisms. It is frequently intermixed with mineral grains, especially near the junction with a mineral layer.

## 4. RULES CONCERNING HORIZON AND LAYER DESIGNATIONS

When naming a layer or a horizon observe the following rules:

1. Do not use the uppercase letters A, B, and O singly for horizons in pedon description, but accompany them by a lowercase suffix (e.g. Ah, Bf, or Om) indicating the estimated nature of the modification of the horizon from the parent material. The horizon and layer designations L, F, H, R, and W may be used alone, and the horizon designation C may be used alone except when the material is affected by reducing conditions (Cg), cementation (Cc), salinity (Cs and Csa) or CaCO<sub>3</sub> (Ck or Cca).
2. All horizons except AB and BA may be vertically subdivided by consecutive numeral suffixes. The uppermost subdivision is indicated by the numeral "1" and each successive subdivision with depth is indicated by the next numeral. For example Ae1, Ae2, Bt, C.
3. Roman numerals are prefixed to horizon and layer designations (e.g. A, B, C) to indicate parent material discontinuities in the profile. The Roman numeral I is understood for the uppermost material and is not written. Subsequently, contrasting materials are numbered consecutively in the order in which they are encountered downward, that is II, III, etc. For example, a sequence from the surface downward might be Ah, Bm, IIBm, IICca, in which IIBm and IICca formed from a different (deeper) parent material than Ah and Bm.
4. For transitional horizons, only uppercases are used. The dominance of horizons in the transitional zone is shown by order, AB or BA, etc.
5. Generally the suffixes are printed in order of decreasing importance, e.g. in Bhf the enrichment of organic matter is a stronger process than the accumulation of sesquioxides.
6. Where j is used, the suffix or suffixes that it modifies are written after other horizon suffixes, e.g., Bthj, Bfjtj, Bfcjgj.

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## SECTION 2 - Canadian Soil Classification System

General objectives are to:

- 1) Become familiar with the Canadian Soil Classification System
- 2) Identify 10 soil orders of the Canadian Soil Classification System

To be able to classify soils, one first needs to develop soil identification skills. These include ability to identify soil horizons and parent material types. Soil horizon identification is important to decide on the diagnostic soil horizon, while parent material identification helps with understanding of soil properties and its response to management practices.



Both identification of soil horizons and parent materials are based on visual interpretation skills, which can be developed by viewing and reviewing numerous soil pits in the field and/or monolith photographs. The later can be found at **Virtual Soil Monoliths** website at <http://soilweb.landfood.ubc.ca/monoliths/>

### 1.TAXA (CLASSES)

The Canadian Soil Classification System (Taxonomic) was first proposed in 1955. Since that time many revisions have been made, the latest in 1998. Five classes (taxa) are recognized in the hierarchical scheme used for the Canadian System of Soil Classification (CSSC), and these are presented in table 9 (from the highest to lowest levels of generalization).

Table 9: Summary of the principles used for differentiating taxa of the Canadian System of Soil Classification

Taxa	Principles used	No. of classes
Order	Dominant soil-forming process	10
Great group	Strength of soil-forming process	31
Subgroup	Kind and arrangement of horizons	231
Family	Parent material characteristics	about 10,000
Series	Detailed features of the pedon	about 100,000

#### Orders

Taxa at the order level are based on properties of the pedon that reflect the effects of the **dominant soil-forming processes**. This is the highest level of generalization and is the most inclusive category of soils. For example, in the soils of the Chernozemic order the overall effect of soil processes is the accumulation of organic matter in the topsoil under a grassland vegetation. The Canadian System of Soil Classification has 10 orders.

*Example: Chernozem*

## Great groups

Great groups are soil taxa formed by subdividing each order. Great groups are based on properties that reflect differences in **strengths of dominant processes**. The great groups of the Chernozemic order are differentiated on the basis of the colour of the topsoil, which is an indication of organic matter content. The Brown Chernozems, formed in the driest regions, have the least and the Black Chernozems, formed in the coolest and wettest regions, the most organic matter. The Dark Gray Chernozems occur near the grassland-forest transition zones where leaching of organic matter and clay from the topsoil is pronounced leading to the characteristic gray or brownish colors of higher value or chroma.

*Example: Brown Chernozem*

## Subgroups

Subgroups are soil taxa formed by subdividing each great group. Subgroups are differentiated on the basis of the **kind and arrangement of horizons** that reflect:

- a) similarity to the central concept of the great group (e.g., Orthic Brown Chernozem),
- b) intergrading towards soils of another order (e.g., Gleyed Brown Chernozem), or
- c) additional features within the control section (e.g., Gleyed Calcareous Brown Chernozem). A control section is the vertical section of soil upon which classification is based.

The subgroup has a particular assemblage of horizons. The Canadian System of Soil Classification specifies the horizons that each subgroup must have, along with other horizons that it may have.

## Family

Taxa at the family level are formed by subdividing subgroups. Families are differentiated on the basis of the **parent material characteristics**, such as texture, mineralogy, soil climate, pH, and depth. Due to the more precise nature of this class many statements can be made about the use and management of the soils in relation to plant growth, hydrology, and engineering characteristics. The nomenclature of the taxonomy becomes more descriptive at the family level.

*Example: Orthic Brown Chernozem, silt loam, mixed mineralogy, alkaline pH*

## Series

Taxa at the series level are formed by subdividing families. Series within a family are differentiated on basis of **detailed features of the pedon**. Pedons belonging to a series have similar kinds and arrangements of horizons whose colour, texture, structure, consistency, thickness, pH, and composition fall within a narrow range. This is the most important class of soils from the stand point of use and management, since it applies to real soil bodies (i.e. polypedons).

The names used for the four higher classes are descriptive of either the soil morphology or the type of environment in which the soils are found. The soil series, on the other hand, is named after a geographic or cultural feature near the site where the soil was first observed. (e.g. Abbotsford soils = Podzol, Capilano soils = Podzol, Westham soils = Gleysol).

*Example: Penticton Orthic Brown Chernozem*



## 2.SOIL ORDERS



For illustrations and descriptions of 10 soil orders in the Canadian Soil Classification System go to following two web sites:

Canadian Soil Orders at <http://soilweb.landfood.ubc.ca/classification/>

Soils of Canada at <http://www.soilsofcanada.ca/>

### **DESCRIPTION OF THE 10 SOIL ORDERS**

Soil orders are a reflection of the dominant soil forming process. Each soil order is characterized by a diagnostic feature, which is usually the presence of a diagnostic horizon. In the case of the Regosolic order the diagnostic feature is the absence of a B horizon.

#### **Regosolic order**

Regosolic soils are well to imperfectly drained mineral soils with profile development too weakly expressed to meet the classification requirements for other orders. They do **not have a B horizon** (this is their diagnostic feature) and may even lack an A horizon. The reasons for this can be the following: youthfulness of the material, recent alluvium, nature of parent material (pure quartz sand), dry and cold climate, colluvium on steep slopes, etc.

Regosolic soils may have an organic horizon (L, F, H) or a weakly developed mineral Ah horizon, as long as it is insufficiently thick or dark to qualify as a chernozemic A horizon. Regosolic soils reflect the characteristics of the C horizon and of their parent materials. Surface horizon development in virgin Regosolic soils tend to reflect the characteristics of regionally well-developed soils with which they are associated.

Regosolic soils do not contain a recognizable B horizon that is thicker than 5 cm. Therefore, these soils are referred to as weakly developed soils. Regosolic soils may have L, F, and H horizons or O horizons on top of a C horizon. When there is a case of buried soil that is usually a Regosol.

#### **Brunisolic Order**

Soils classified in the Brunisolic order have undergone only slight development from the parent material, i.e. more so than Regosols. There are several reasons for the restricted development of Brunisols and they include severe climate (e.g., low temperatures and lack of soil water), coarse parent material, and limited time available for soil development.

Brunisolic soils are imperfectly to well-drained mineral soils developed under a wide range of climatic and vegetative conditions including Boreal forest, mixed forest, shrubs, grasses, and tundra.

The main soil-formation process in Brunisolic soils is the leaching of soluble salts and carbonates, the formation of iron and aluminum secondary minerals, and structure development in the finer textured materials different from the original structure of the parent material. These processes lead to the formation of a **Bm horizon**, which is the diagnostic horizon of Brunisolic soils. They can also have Bfj horizon (accumulation of amorphous Al/Fe compounds), or Btj (at least 5 cm thick), or Bf<10 cm thick or a combination of horizons mentioned above.

### **Luvisolic Order**

Soils of the Luvisolic order are well to imperfectly drained mineral soils that have developed under deciduous, mixed deciduous-coniferous boreal forests, or under mixed forest in the forest-grassland transition zone in mild to cold climates. They usually occur in areas with effective precipitation greater than in areas having Chernozemic or Brunisolic soils. Leaching of soil particles and weathering is more intense in Luvisolic soils relative to Chernozemic or Brunisolic soils.

The dominant soil-forming process in Luvisolic soils is the translocation of clay-sized mineral particles from the A to the B horizon. These particles form shiny layers of clays (clay skins, visible with a magnifying glass) on crack faces accompanied with dramatic change in soil structure (prismatic to blocky structure) in the **Bt horizon** characteristic of Luvisolic soils.

The Bt horizon may restrict root penetration and water movement (percolation). These soils can be very wet in the spring.

### **Gleysolic Order**

Soils of the Gleysolic order are poorly drained mineral soils that are saturated for long periods of the year. Their profiles show evidence of reducing conditions caused by a lack of oxygen. These conditions lead to **gleyed horizons** (mainly **Bg**, but it can also be Ag and Cg that is 10 cm thick and present within 50 cm of the soil surface) having dull gray to olive, greenish or bluish-gray moist colours, frequently accompanied by prominent rusty-colored mottles due to localized oxidation and reduction of iron.

These soils develop whenever surface water accumulates (e.g., in depressions or on flat plains). Gleysols occur in association with other soil types in shallow depressions or on level lowlands. Once drained Gleysols change into some other soil type (given enough time).

### **Chernozemic Order**

Chernozemic soils are associated with grassland vegetation and are an important rangeland soil type in British Columbia. They are well to imperfectly drained mineral soils of good structure that have a dark-colored **chernozemic A horizon** (diagnostic horizon), which is >10 cm thick (usually 20-40 cm), has 1-17% org. C, C/N <17, and base saturation >80% with Ca as a dominant cation. The organic matter comes from the decomposition of leaves and grass roots and results in a dark colored surface Ah horizon

Chernozemic soils develop in areas of subhumid to subarid continental climate characterized by low rainfall, high summer temperatures, and high evapotranspiration rates. The climatic conditions inhibits tree growth, limits soil leaching, and leads to the accumulation of organic matter in the topsoil. Chernozemic soils are found in the Canadian prairies and the rangelands of the southern central interior of British Columbia.

### **Solonetzic Order**

Solonetzic soils are well to imperfectly drained mineral soils that contain a high proportion of exchangeable Na relative to Ca ion (or Na and Mg salts) in their B horizon, called **solonetzic B (Bn or Bnt)** (diagnostic horizons). The C horizon is usually saline and calcareous. When these soils become wet, the sodium causes the soil aggregates to break down into individual particles. The soil, especially the B horizon, becomes an impermeable sticky mass. On drying the B horizon becomes extremely hard and columnar structural

aggregates develop.

These soils have developed mainly under grass or grass-forest cover within subhumid to subarid continental climates, on saline parent materials that are high in sodium.

Chernozems and Solonetz are very similar, the only difference is high Na content in the latter. Hence, intensive fertilization of Chernozems can lead (over time) to formation of Solonetz. Sometimes Solonetz is called “salty Chernozem”.

### **Podzolic Order**

The Podzolic order consists of well to imperfectly drained mineral soils. They are the most common soils in British Columbia and the most developed and hence the most colourful soils in Canada.

Podzolic soils have characteristics and features of coniferous forests or heath vegetation in climatic conditions ranging from cold to mild, and humid to pre-humid.

Chemical and biological transformations are intense in the upper horizons, resulting in the transformation of the primary minerals and decomposition of organic matter. Soluble organic matter and mobile compounds of Al and Fe are readily leached from the A horizon into the B horizon where they accumulate, or form, a discrete horizon called a **podzolic B (Bh, Bhf, Bf)**. Podzolic soils have podzolic B horizon and have accumulations of organic matter, iron, or aluminum. The podzolic B must be at least 10 cm thick, have a texture coarser than clay, and meet specific requirements for color, organic carbon, iron and aluminum content.

### **Organic Order**

Organic soils are defined in the Canadian System of Soil Classification as soils that have developed largely from organic deposits. Most organic soils develop under saturated conditions and are commonly known as peat, muck, or bog soils. These soils are derived dominantly from vegetation that grows in poorly and very poorly drained areas. When the soil is saturated for only part of the year organic soils transition into Gleysolic soils, with only a thin surface accumulation of organic matter. These soils are saturated with water from prolonged periods that retard the decomposition of organic materials (because lack of oxygen restricts microbial activity).

Organic soils contain > 17% organic C (>30% organic matter) by weight and have a specific depth, degree of decomposition and properties in the middle tier (40 to 120 cm). These soils must have Of (at least 60 cm thick), Om (at least 40 cm thick), or Oh (at least 40 cm thick) organic horizons. Up to 40 cm mineral material is allowed to be present in a soil that is classified as Organic soil as long as organic material is at least 40 cm in thickness.

To convert Organic soils for agricultural production they have to be drained, and over time due to increased decomposition we lose them (e.g. organic soils in Cloverdale where we can see light-colored patches of exposed parent material).

### **Cryosolic Order**

Cryosolic soils are found in northern Canada where **permafrost** (permanently frozen ground) exists close to the surface. Permafrost is found in regions where the soil temperature remains below 0°C constantly for a number of years. Under these conditions, soil water in

the lower part of the profile remains frozen during summer months, but the upper part or the “active layer” thaws.

Cryosolic soils have permafrost horizons (**z**) within 1 m of the soil surface or within 2 m of the soil surface if the soil is strongly cryoturbated, i.e. mixed by freezing/thawing action (e.g. Bzy). The estimation of depth of permafrost is the differentiating criteria for Cryosols.

These are very sensitive soil. Hence, when we disturb vegetation on a top of these soils their thermal regime will change (increase in soil temperature) resulting in changes of the permafrost. These soils are studied because of global warming effects that can impact the depth of the permafrost.

### **Vertisolic Order**

This is the newest order of the Canadian System of Soil Classification, added in 1998. Vertisolic soils develop in fine-textured soil materials with >60% clay, of which at least half must be montmorillonite.

The dominant soil-forming processes in Vertisols are: cracking, argilli-pedoturbation (mixing of clay in the pedon) and mass movement of materials due to shrinkage and swelling of clays during drying/wetting cycles.

These soils have two characteristic horizons (either B or C):

**slickensides** (ss = clayey subsurface horizons which have polished and grooved ped surfaces -'slickensides', or wedge-shaped structural aggregates ) and

**vertic** (v = horizon with deep and wide **cracks** when dry, that allow the surface material to fall down the cracks causing the soil to heave). The wetting and drying cycles cause the clays to expand and contract.

### **DIAGNOSTIC HORIZON AND CLASSIFICATION AT THE ORDER LEVEL**

The following table is meant to help you remember the diagnostic feature for each order and classify soils at the order level. Remember that it is a summary and not a substitute for the text above. To use table 10 start at Step 1. If the criteria is true, classify the soil according to the column to the right. If not, go to the next step.

Table 10: Simplified key to classify soils at an order level in the Canadian System of Soil Classification

Step	Criteria	Result
1	Does soil have <b>permafrost</b> within 1 m of the surface or within 2 m if strongly cryoturbated?	<b>Cryosolic</b> order
2	Does the soil have <b>organic horizons (Of, Om, Oh)</b> at least 40 cm thick (60 cm in the case of Of)?	<b>Organic</b> order
3	Does the soil have both <b>vertic</b> and <b>slickenside</b> horizons within 1 m of mineral surface?	<b>Vertisolic</b> order
4	Is there a podzolic B horizon ( <b>Bf, Bhf, or Bh</b> at least 10 cm thick)?	<b>Podzolic</b> order
5	Is there a <b>Bg</b> (or <b>Cg</b> within 50 cm of surface) at least 10 cm thick?	<b>Gleysolic</b> order
6	Is <b>solonetzic B (Bn or Bnt)</b> horizon present?	<b>Solonetzic</b> order
7	Is <b>chernozemic A (Ah or Ap)</b> present?	<b>Chernozemic</b> order
8	Is there a <b>Bt</b> horizon at least 5 cm thick?	<b>Luvisolic</b> order
9	Is there a <b>Bm, Btj, Bf, or Bfj</b> at least 5 cm thick?	<b>Brunisolic</b> order
10	Does this soil <u>not</u> meet any of the criteria above?	<b>Regosolic</b> order

### ⇒ What you need to do during the lab:

- Examine the soil monoliths that illustrate the different soil orders
- Examine the 3 “mystery” monoliths
- Record all horizons present
- Describe each horizon as follows:
  - depth: measured from top of mineral profile in cm  
Depth 0 is the top of the mineral soil. Measure the mineral horizons depth from top to bottom (e.g. Ae 0-8 cm, Bf 8-30 cm). Indicate the thickness of organic horizons above depth 0 (e.g. LFH 10-0 cm).
  - colour (dry): use the Munsell color book and give Munsell notation and colour name (e.g. brown, 10YR 5/3)<sup>2</sup>

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<sup>2</sup> **The Munsell colour system** uses three elements of colour – hue, value, and chroma to make up a specific colour notation. For example, notation dark brown, 10YR 4/3 stands for 10YR = hue, 4= value, and 3 = chroma. The **hue** represents the dominant spectral or rainbow colour. The symbol for hue is the letter abbreviation of the colour of the rainbow (R for red, YR for yellow-red) preceded by numbers from 0 to 10. Within each letter range, the hue becomes more yellow and less red as the numbers increase. The notation for **value** indicates the degree of lightness of a colour and consists of numbers from 0 (for absolute black) to 10 (for absolute white). The notation for **chroma** indicates colour strength or relative purity (degree of dilution by neutral gray of the same value) and consists of numbers from 0 (for neutral grays) to 8 (the strongest expression of colour used in soils). Colours of low chroma are sometimes called weak, while those of high chroma are said to highly saturated, strong or vivid.

- structure: determine kind (shape) of aggregates in each horizon
- Identify soil order and indicate the diagnostic horizon for each of the 3 “mystery” monoliths

⇒ What you need to do after the lab



Upon completion of this lab, you should continue practicing your newly acquired skills on soil identification and classification by visiting **Virtual Soil Monoliths** website at <http://soilweb.landfood.ubc.ca/monoliths/>. This interactive website provides a brief instruction on soil identification and classification as well as practice questions (and answers); to be found in the **Tutorial** at <http://soilweb.landfood.ubc.ca/monoliths/tutorial>.

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## DATA COLLECTION

<b>Monolith A</b>				
Horizons	Depth	Colour	Structure	Other observation
Diagnostic horizon				
Soil classification				
Other comment				

<b>Monolith B</b>				
Horizons	Depth	Colour	Structure	Other observation
Diagnostic horizon:				
Soil classification				
Other comment:				

<b>Monolith C</b>				
Horizons	Depth	Colour	Structure	Other observation
Diagnostic horizon:				
Soil classification				
Other comment:				

**Don't forget to attach these 3 tables to the lab assignment**



## LAB 8: SOIL DESCRIPTION

The purpose of this lab is to learn how to identify soils in the field and derive meaning from our observations in terms of soil formation and soil management.

**For this lab, we will meet at the UBC Farm**, located at 3461 Ross Drive. To get to the UBC Farm please check the directions provided at the Farm's website at <http://ubcfarm.ubc.ca/about/directions-hours-and-contact-information/>

We will meet at the **Farm Centre** and to reach it, please go through the Farm gate, turn right, and follow the gravel road until you reach a red roofed building (the Farm Centre) located beside a small glass greenhouse.

GPS coordinates for the two soil pits are as follows:

Agricultural soil pit    49.249156 N, 123.237402 W

Forest soil pit            49.250649 N, 123.241359 W



*Photo of the Farm Centre. Credit: UBC Farm*

To learn more about the UBC Farm visit the web site <http://ubcfarm.ubc.ca/>

### ***Soil description***

The description of a soil is based on its morphology (i.e. the kinds soil horizons that make up the soil profile). An understanding of soil morphology is important as it allows us to classify a soil as well as infer its properties and behaviour. Soil horizons are usually identified and differentiated from adjacent horizons on the basis of characteristics that can be seen and measured in the field, as well as additional information gathered by laboratory analysis. This exercise will demonstrate how to identify soil morphology in the field.

⇒ What you need to do during the lab:

- Examine the two soil profiles at the “UBC Farm”
- Describe the **vegetation and topography** at each site
- Identify and describe the **parent material**
- Identify and describe all soil **horizons** in the two soil profiles
- Identify the soil **order**
- Record your thoughts about the **factors of soil formation** and the **soil-forming processes** at each site
- Record your thoughts about **management** of these soils

**DATA COLLECTION**

Stop number: <b>1</b>					
Location:					
Parent material:					
Elevation:					
Aspect:					
Vegetation:					
<b>Soil profile description</b>					
Horizon	Depth (cm)	Colour	Texture	Structure	Soil pH
Soil classification					
Factors of soil formation and soil-forming processes					
Other comments (management, etc.)					

**DATA COLLECTION**

Stop number: <b>2</b>					
Location:					
Parent material:					
Elevation:					
Aspect:					
Vegetation:					
<b>Soil profile description</b>					
Horizon	Depth (cm)	Colour	Texture	Structure	Soil pH
Soil classification					
Factors of soil formation and soil-forming processes					
Other comments (management, etc.)					

**Don't forget to attach this table to the lab assignment**

# APPENDIX A

## SAMPLE DATA SHEET FOR WATER RETENTION CURVE

Data for MEDIUM SAND		Data for FINE SAND	
h) Cylinder height (h)	4 cm	l) Cylinder height (h)	4 cm
i) Cylinder inside diameter (d)	7 cm	m) Cylinder inside diameter (d)	7 cm
j) Total volume ( $V_t$ )		n) Total volume ( $V_t$ )	
k) Bulk density ( $\rho_b$ )	1.61 g/cm <sup>3</sup>	o) Bulk density ( $\rho_b$ )	1.49 g/cm <sup>3</sup>
l) Particle density ( $\rho_s$ )	2.65 g/cm <sup>3</sup>	p) Particle density ( $\rho_s$ )	2.65 g/cm <sup>3</sup>
m) Soil porosity (f)		q) Soil porosity (f)	
n) Pore volume ( $V_f$ )		r) Pore volume ( $V_f$ )	

MEDIUM SAND				FINE SAND			
Tension (cm)	Cumulative outflow Vol. (cm <sup>3</sup> )	Soil water $V_w$ (cm <sup>3</sup> )	$\theta$ $V_w/V_t$	Tension (cm)	Cumulative outflow Vol. (cm <sup>3</sup> )	Soil water $V_w$ (cm <sup>3</sup> )	$\theta$ $V_w/V_t$
0	0.0			0	0.0		
10	1.9			20	4.0		
20	3.1			40	8.0		
25	29.3			50	28.0		
30	47.0			60	45.0		
40	53.9			70	47.5		
60	56.0			80	51.0		
-	-	-	-	90	61.0		
s) Air Entry Value (AEV) (m)				a) Air Entry Value (AEV) (m)			
t) Air Intrusion Value (AIV) (m)				b) Air Intrusion Value (AIV) (m)			
u) Radius of pores corresponding to AEV (mm)				c) Radius of pores corresponding to AEV (mm)			
v) Radius of pores corresponding to AIV (mm)				d) Radius of pores corresponding to AIV (mm)			

# APPENDIX B

## PERIODIC TABLE OF THE ELEMENTS

1a	2a	3a	4a	5a	6a	7a	0	Orbit
1 H 1.00797 +1 -1	2 He 4.0026 +2	3 Li 6.939 2-1 +1	4 Be 9.0122 2-2 +2	5 B 10.811 2-3 +3	6 C 12.01115 2-4 +4	7 N 14.0067 2-5 +3 -2 +4 +5	8 O 15.9994 2-6 -2	K
11 Na 22.9898 2-8-1 +1	12 Mg 24.312 2-8-2 +2	13 Al 26.9815 2-8-3 +3	14 Si 28.086 2-8-4 +4	15 P 30.9738 2-8-5 +3 -2 +4	16 S 32.064 2-8-6 +2 -2 +3 +4 +5	17 Cl 35.453 2-8-7 +1 -1 +2 +3 +4 +5 +6 +7	18 Ar 39.948 2-8-8 0	K-L
19 K 39.0983 -8-8-1 +1	20 Ca 40.08 -8-8-2 +2	21 Sc 44.956 -8-9-2 +3	22 Ti 47.88 -8-10-2 +4	23 V 50.942 -8-11-2 +5	24 Cr 51.996 -8-13-1 +6	25 Mn 54.938 -8-13-2 +7	26 Fe 55.847 -8-14-2 +2 +3 +4	K-L-M
37 Rb 85.47 -18-8-1 +1	38 Sr 87.62 -18-8-2 +2	39 Y 88.905 -18-9-2 +3	40 Zr 91.22 -18-10-2 +4	41 Nb 92.906 -18-12-1 +5	42 Mo 95.94 -18-13-1 +6	43 Tc 98 -18-13-2 +7	44 Ru 101.07 -18-15-1 +2 +3 +4	K-L-M
55 Cs 132.905 -18-8-1 +1	56 Ba 137.34 -18-8-2 +2	57* La 138.91 -18-9-2 +3	72 Hf 178.49 -32-10-2 +4	73 Ta 180.948 -32-11-2 +5	74 W 183.85 -32-12-2 +6	75 Re 186.2 -32-13-2 +7	76 Os 190.2 -32-14-2 +2 +3 +4	-L-M-N
87 Fr 223 -18-8-1 +1	88 Ra 226 -18-8-2 +2	89** Ac 227 -18-9-2 +3	49 In 114.82 -18-18-3 +3	50 Sn 118.69 -18-18-4 +4	51 Sb 121.75 -18-18-5 +3 -2 +4	52 Te 127.60 -18-18-6 +2 +3 +4	53 I 126.9044 -18-18-7 +1 -1 +2 +3 +4 +5 +6 +7	-M-N-O
			81 Tl 204.37 -32-18-3 +3	82 Pb 207.19 -32-18-4 +4	83 Bi 208.980 -32-18-5 +3	84 Po 209 -32-18-6 +2 +3 +4	85 At 210 -32-18-7 +1 -1 +2 +3 +4 +5 +6 +7	-N-O-P
			69 Tm 168.934 -31-8-2 +3	70 Yb 173.04 -32-8-2 +3	71 Lu 174.97 -32-9-2 +3			-O-P-Q
			101 Md 258 -31-8-2 +3	102 Fm 257 -30-8-2 +2	103 Lw 260 -32-8-2 +2			-O-P-Q

Numbers in parentheses are mass numbers of most stable isotope of that element.