Field Handbook for the Soils of Western Canada

Section 3

Soil Profile Description

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This is one section of a Field Handbook for the Soils of Western Canada. Our intent for the field guide is two-fold: 1) to simplify the use of the Canadian System of Soil Classification in the field and 2) to allow field testing of a new soil order for Anthroposolic soils, which has been proposed for inclusion in the Canadian System of Soil Classification. Other than the inclusion of the provisional Anthroposolic order there is no other (intentional) revision to the 3rd Edition of the Canadian System of Soil Classification.

Although the Handbook overall is focused on the soils of western Canada, this section can be used anywhere in Canada.

This section draws very heavily on material from the following:
Watson, Kent. 2009. Soils Illustrated – Field Descriptions. Available from the author at ekwatson@telus.net.

Soil Classification Working Group. 1998. The Canadian System of Soil Classification. 3rd Ed. Research Branch, Agriculture and Agri-Food Canada. Publication 1646. NRC Research Press, Ottawa, Ontario.

The 3rd edition of the CSSC is available on-line at http://sis.agr.gc.ca/cansis/taxa/cssc3/index.html.

The correct citation for this section is:

Watson, K. and D. Pennock 2016. Section 3. Soil Profile Description. From: D. Pennock, K. Watson, and P. Sanborn. 2016. Field Handbook for the Soils of Western Canada. Pedology Subcommittee, Canadian Society of Soil Science.

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3.1 SOIL PIT EXCAVATION

Before digging the soil pit determine the face that will be described. Do not disturb the surface at the top of the face. Do not walk on it or place soil on it. Plan the pit so that the description face is entirely illuminated by the sun or is in full shade. Take your photographs either in full sun or full shade. Clean the face and square it up in preparation for photographs. Place rules or scale bars down the side of the profile, not in the middle. Take multiple exposures at different settings. Position your camera as low in the pit as possible and take your photographs as square to the face as possible.

3.2 SOIL PROFILE DESCRIPTION

The information that is included in a profile description will differ depending on the type of inventory being undertaken. The focus in this handbook is on the main properties of relevance for classification and for most interpretations for management. Information on properties not included in this handbook can be found in the comprehensive manual by Watson (2009).

Mineral horizons:
The components are listed for each mineral horizon and are (in order):

1. Horizon designation according to the Canadian System of Soil Classification.
2. Horizon depth.
3. Colour according to the Munsell system of colour notation.
4. Soil texture.
5. Mottling.
6. Structure.
7. Consistence.
8. Roots.
9. Pores.
10. Clay films.
11. Concretions.
12. Carbonates (Effervescence).
13. Salts.
14. Coarse fragments.
15. Horizon boundary and thickness range.
16. Reaction (pH).

Note that roots, pores, concretions, and reaction are not covered in this handbook.

For organic horizons the following components are listed:

1. Horizon designation according to the Canadian System of Soil Classification.
2. Horizon depth.
3. Colour according to the Munsell system of colour notation.
4. Von Post decomposition class and material description..

5. Roots.
6. Horizon boundary and thickness range.
7. Reaction (pH).

3.3 HORIZON DESIGNATION

Soil horizons are mineral or organic layers or soil materials that develop approximately parallel to the land surface. They differ from adjacent horizons in properties such as colour, structure, texture, consistence, chemical, biological or mineral composition. The first step is to identify the master horizons (e.g. A, B etc.). Lower case suffixes are then added to reflect the soil processes or properties in each horizon.

Horizon designations are discussed in section 4 of this handbook. Initially the horizons can be given a tentative designation, which can then be finalized once the horizon has been described.

Horizons are listed from top to bottom in the order they occur in the profile (Figure 3-1 and Error! Reference source not found.).

Figure 3-1: Example of horizon designations

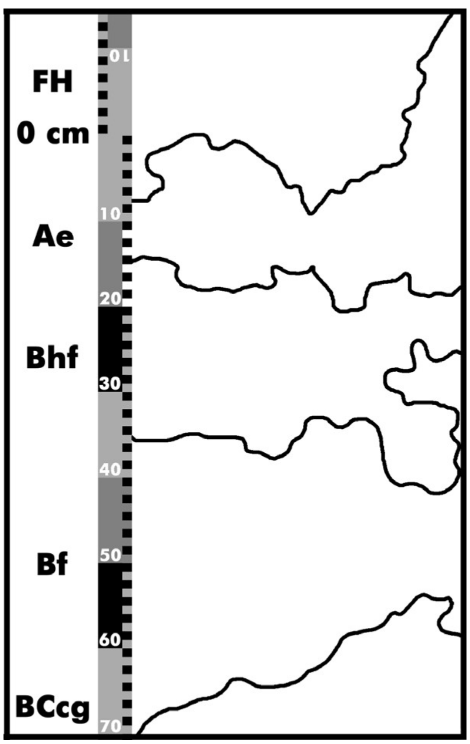


Table 3-1: Example of horizon depth

Horizon designation	Horizon depth
FH	15-0
Ae	0-15
Bhf	15-36
Bf	36-60
BCcg	60-71

3.4 HORIZON DEPTH AND THICKNESS

3.4.1 MINERAL HORIZONS DEPTH

Record the average depth for each horizon. Measurements begin with zero at the mineral soil surface or at the organic / mineral material contact. Increasing cumulative depths (e.g., 0 to 10 cm, 10 – 25 cm) are recorded for each mineral horizon beginning with zero at the soil surface. Overlying organic material depths are recorded upwards from the organic mineral / contact beginning with zero (e.g., 10 – 0 cm)

3.4.2 ORGANIC SOILS DEPTH

For soils in the Organic order measurements start with zero at the organic soil surface and increase cumulatively with depth. Soils are classified into the Organic order if there are 40 cm or more organic material overlying mineral or organic material.

3.4.3 HORIZON THICKNESS

Record the minimum and maximum thickness for each horizon. A soil with a horizon depth from 0 - 10 cm may have a minimum thickness of 3 cm and a maximum of 14 cm. A horizon with a smooth boundary may have a minimum and maximum boundary thickness of 10 cm (Figure 3-2). There is no minimum or maximum recorded for the bottom horizon because the total depth is not known.

3.5 HORIZON BOUNDARY

Horizon boundary has two components: distinctness and form**,** which are described for the lower boundary of each horizon. The transition width between two adjacent horizons is distinctness (Figure 3-3 and Table 3-2). Form describes the horizon boundary topography (Figure 3-4 and Table 3-3).

Figure 3-2: Horizon thicknesses for horizons with different boundary forms

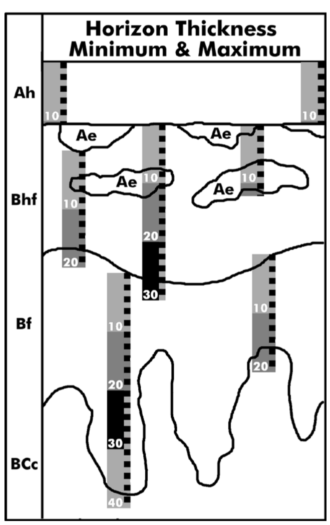


Figure 3-3: Examples of horizon distinctness

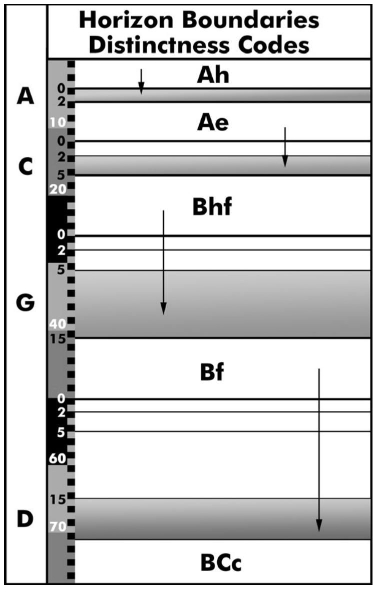


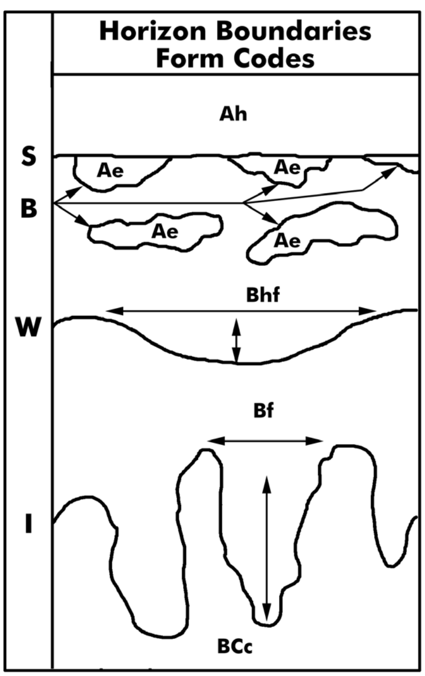
Table 3-2: Vertical change for boundaries and distinctness codes

DISTINCTNESS CODES		VERTICAL CHANGE
A	Abrupt	< 2 cm
C	Clear	2 - 5 cm
G	Gradual	5 - 15 cm
D	Diffuse	> 15 cm

Table 3-3: Horizon form descriptions and codes

FORM CODES		HORIZON SURFACE TOPOGRAPHY
S	Smooth	Horizon surface nearly a plane
W	Wavy	Horizon surface has pockets wider than deep
I	Irregular	Horizon surface has pockets deeper than wide
B	Broken	Some parts are unconnected; at least one horizon is one horizon is discontinuous

Figure 3-4: Examples of horizon forms



3.6 SOIL COLOUR

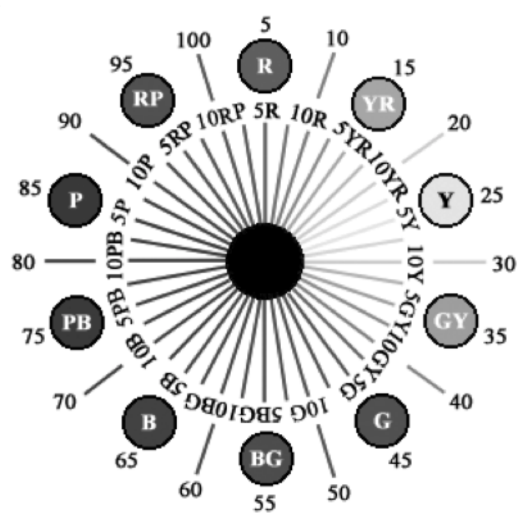
Colour is a key component used in the Canadian System of Soil Classification. Soil colour is used in identifying soil horizons (e.g. Bf, Bg) and in classifying soils to the great group (Chernozemic) and subgroup levels (Solonetzic). It is also used to determine the extent of gleying in soils (Gleysolic).

Soil colour is determined using the Munsell System of Color Notation. Munsell defines every colour according to Hue (colour), Value (lightness) and Chroma (saturation or intensity).

3.6.1 HUE

In the Munsell systems, colours are arranged the five principal hues, red, yellow, green, blue and purple, in equal intervals around a circle (Figure 3-5). Five intermediate or transitional hues, yellow-red, green-yellow, blue-green, purple-blue and red-purple, are placed among the five principal hues.

Figure 3-5: Munsell colour wheel



3.6.2 VALUE

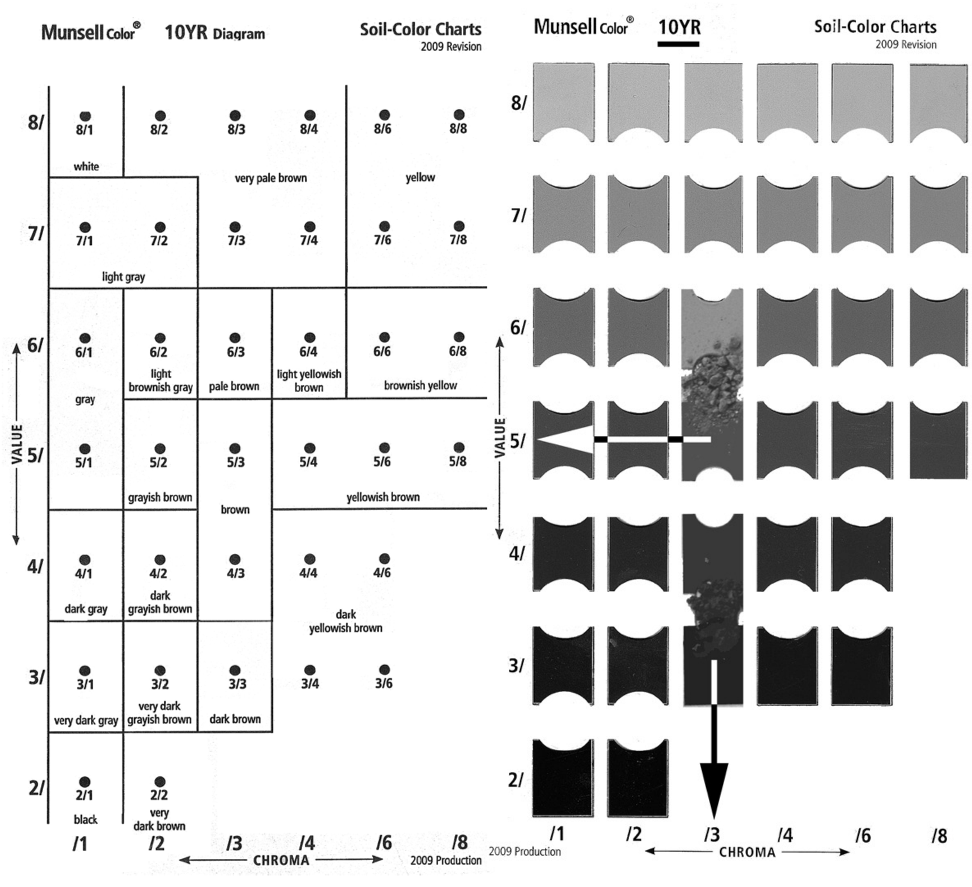
Value is the lightness of the hue or colour. The value ranges from 0, pure black to 10, pure white. The grays, 1 through 9, along with white and black are called neutral because they have no hue or colour. Figure 3-6 shows the 10YR hue card. Value goes from the bottom of the chart 2/(black) to the top 8/ (white)

3.6.3 CHROMA

Using Figure 3-6**,** as one moves out from the left side of the chart to the right along the chroma axis, the colour strength increases in intensity or saturation (i.e., the chroma). Given a neutral gray value, the chroma is the change in intensity from the neutral. The strongest expression of a chroma in soils is 8.

The Hue Soil-Color chips are located on the right page of the Munsell book and their corresponding colour name diagrams are on the left side (Figure 3-6). The Hue name is located on the top of the chart. In Figure 3-6 the Hue is 10YR. The Value begins at the bottom of the page with 2/ (black) and progresses to the top of the page 8/ (white). Chroma starts on the left side of the page /1 and progresses to the right side to /8. In this example two soil samples from the same horizon have been placed on two chips. **Note: One views the sample through the holes in the page. Samples are not placed directly on the chips**. The Munsell colour notations are recorded as Hue/Value/Chroma as follows: 10YR 5/3 for the top dry sample and 10YR 3/3 for the moist sample. The 10YR colour name diagram is found on the left page. For the 10YR 5/3 locate 5/3 on the colour name diagram; the colour name is brown. For the 10YR 3/3 sample the colour is dark brown.

Figure 3-6: 10YR page from a Munsell colour chart



3.6.4 LIGHTING CONDITIONS FOR MEASURING COLOUR

Lighting condition, soil moisture content and sample surface roughness influence the colours we see. Light sources should be as close to white light as possible. Viewing a soil sample under fluorescent lighting and full sunlight will usually yield different colours. The light source must be bright enough to see the difference among the chips. Colours should not be determined in the early morning or evening when the low sun angle creates a reddish cast on the sample.

3.6.5 DOMINANT COLOUR

The initial colour determination is for the colour that dominates the greatest volume in the soil horizon. This is also termed the matrix colour. Dry and moist colours are recorded when feasible. Dry samples can be moistened and moist samples can be dried. When the soil pit is dug, a sample from each horizon can be set aside to dry or the sample can be taken indoors to dry. Attempt to use the same lighting conditions if samples are assessed for colour indoors.

Table 3-4: Example of dominant colour description for a Luvisolic soil.

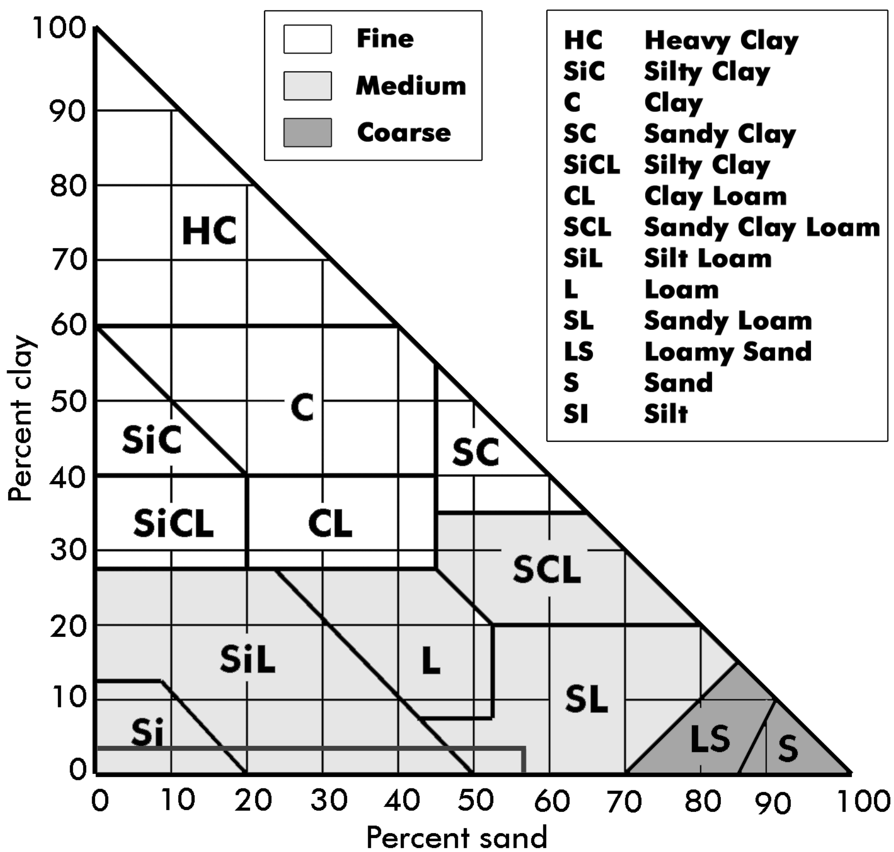
Moist colours			Dry colours		
Horizon	Matrix Hue Value/ Chroma	Munsell Colour Name	Horizon	Matrix Hue Value/ Chroma	Munsell Colour Name
Ah	10YR 2/1	black	Ah	10YR 3/2	very dark grayish brown
Bt	10YR 3/2	very dark grayish brown	Bt	10YR 4/2	dark grayish brown
Bmk	10YR 5/3	brown	Bmk	10YR 6/3	pale brown
Cca	10YR 4/2	dark grayish brown	Cca	10YR 6/2	light brownish gray
Ck	10YR 4/2	dark grayish brown	Ck	10YR 6/3	pale brown

3.7 SOIL TEXTURE

The fine earth fraction contains particle sizes <= 2 mm. Soil texture is the percent sand, silt and clay in the fine earth fraction. Soil texture is usually determined by hand in the field, and by jar, by sieve or sedimentation (hydrometer) or pipette analysis in the lab.

Sand particles, generally rounded in shape, range in size from 0.05 -2.00 mm. Particles less than 0.10 mm cannot be seen by the eye. Sand feels grainy when rubbed between the fingers and is not smooth or grainy (silt) or sticky (clay). Silt diameters range from 0.05 to 0.002 mm. Silt particles are visible under a microscope and are usually rounded. Silt, when dry, is like a fine powder (sometimes compared to talcum powder) which can be moved by gently blowing on it. When wet it feels smooth, slippery, soapy or gritty when ground between the teeth (not a recommended practice). The clay fraction contains particles less than 0.002 mm and particles form flat plates. When clay is dry, it forms very hard masses, which are very difficult to break. When moist it is plastic and sticky and can be moulded in the hands. Scanning electron microscopes are required to see clay particles.

Figure 3-7: Soil textural triangle



3.7.1 TEXTURAL TRIANGLE

The textural triangle (Figure 3-7) is used to classify different combinations of sand, silt, and clay into into thirteen texture classes. In the field our objective is to determine the appropriate textural class for a sample. The specific particle size can be assessed later in the laboratory.

When recording soil texture class names on the description form the abbreviations are used. The broad textural group terms fine, medium and coarse are sometimes employed. These groups and their textural classes are shown in shades of gray (adapted from Watson 2009). The sand, loamy sand, and sandy loam classes are typically further modified by the dominant size class of sand present. This classification by dominant sand size is very important for management, as soil physical properties differ greatly across the size classes.

3.7.2 HAND TEXTURING CHART

Hand texturing is very important skill for field pedologists. Several approaches to hand texturing exist, and in this section we will present several of the major ones.

The main methods used are:

1) Forming a ball with the soil: This is used as the initial stage to separate the Sand and Silt classes from the other classes. Because these classes low in clay, the ball will either not form or will fall apart when tossed in the air.
2) Forming a wire with the soil (Figure 3-8): The thinner the wire that can be formed, the higher the clay content of the sample. The wire can also be subjected to stress by a) dangling it from two fingers to see where a break occurs or b) attempting to form a circle with the wire and assessing the diameter of the circle that can be formed (this latter approach is used in the FAO Guidelines for Soil description).
3) Forming a ribbon with the soil (Figure 3-9): Begin by forming a thick wire and then squeeze it between your thumb and forefinger to form a ribbon. The longer the ribbon that you can form, the higher the clay content.
4) Feel test: This involves rubbing a small sample between your thumb and forefinger and assessing if the sample feels gritty, smooth/soapy, or none of the above.

Figure 3-8: Wire formation for hand texturing.

Figure 3-9: Ribbon method for hand texturing.

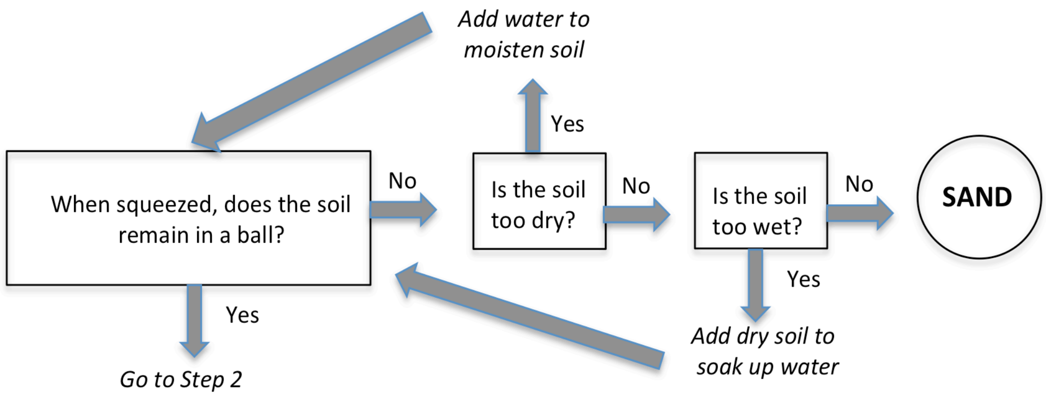
Complete the textural evaluation in the following diagrams: Note that you complete either Step 2a (Wire test) or 2b (Ribbon test).

Step 1: Ball test

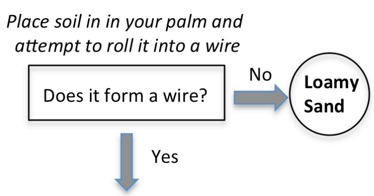
Place approximately 25 g (about one to two tablespoons) of soil in your hand.

Moisten the soil and work it to break down all aggregates (this can be time-consuming in a clay soil).

Squeeze the soil and try to make a ball.



Step 2a: Wire test

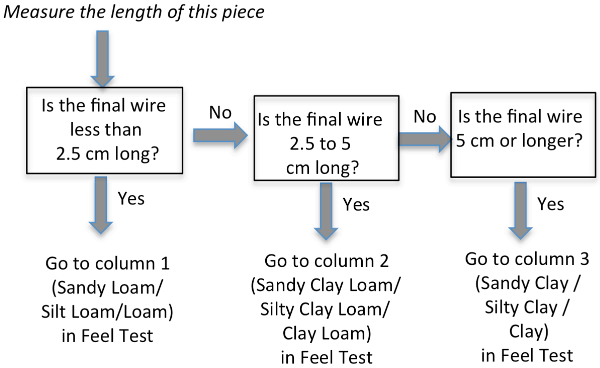


Dangle the soil from two fingers. A piece of the wire will break off.

Pick up the piece that dropped and dangle it again.

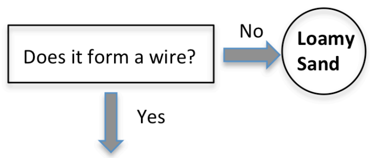
If it breaks again pick that piece up and dangle it again.

Repeat this process until the piece you are holding no longer breaks.
Measure the length of this piece



Step 2b: Ribbon test

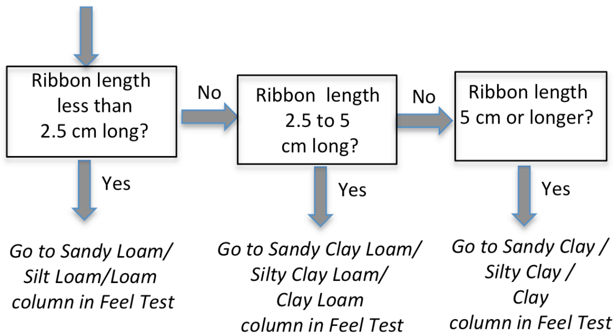
Place soil in in your palm and attempt to roll it into a wire.



Extrude the wire between your thumb and forefinger to form a ribbon.

Continue to extrude ribbon until it breaks.

Measure the length of the broken piece of the ribbon.



STEP 3: Feel Test

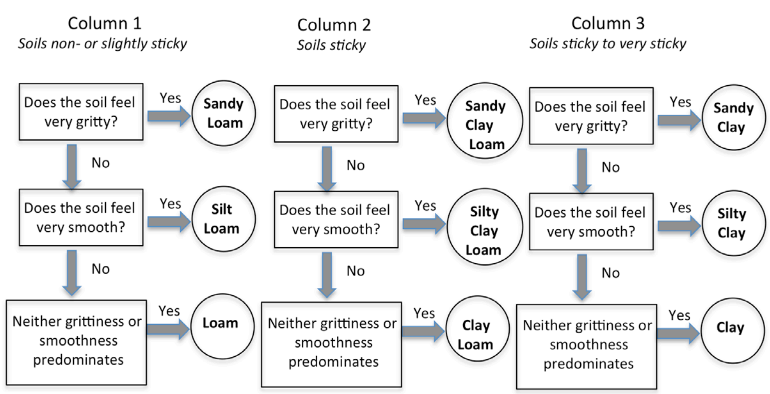
Select column based on Wire or Ribbon test

Wet a small amount of soil and rub between thumb and forefinger

Sand: Feels grainy/gritty; grains are visible for all but very fine grains

Silt: Non-sticky; feels smooth like flour or powder

Clay: Sticky –wet soil adheres to fingers and stretches before breaking when fingers are separated

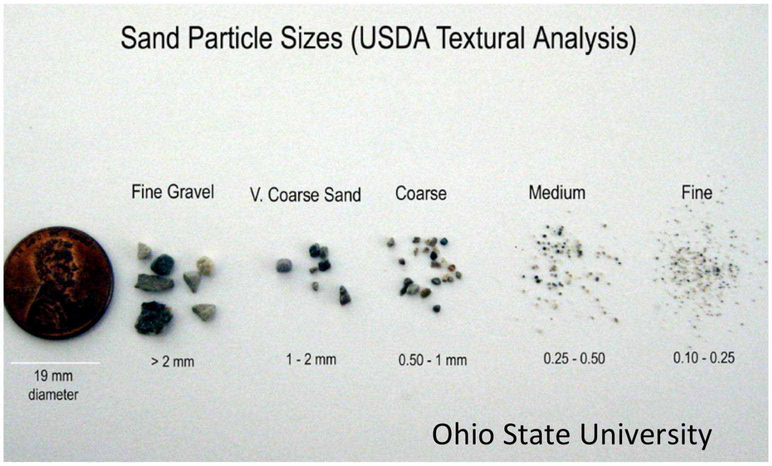


Step 4: For Sand, Loamy Sand, and Sandy Loam textures

Examine the sand fraction in the palm of your hand after completing Step 3

Compare the sand fractions to the diagram below or to prepared cards (e.g. Sand Gauge)

Determine the dominant or co-dominant sand fractions and add to texture class (e.g. fine-medium sandy loam)



3.8 SOIL STRUCTURE

Structure is the aggregation of primary soil particles (sand, silt and clay) into compound aggregates called peds. Soil structure is created by pedogenic (soil forming) processes. Aggregates are held together and cemented by iron oxides, organic substances, clays, carbonates and/or silica. Peds are separated by planes of weakness and develop from combinations of shrinking and swelling in conjunction with cementing agents. Swelling is caused by freezing and the addition of water. Shrinking occurs when the soil thaws or dries. When the soil shrinks, cracks develop, which generally form five and six sided shapes. Peds are naturally occurring and should not be confused with clods, fragments, concretions, nodules and orderly shapes. Clods develop when a field is ploughed. Ploughing rearranges primary particles and disrupts natural structure (Watson 2009). Three criteria are used to describe soil structure. **Grade** describes the distinctness or ped durability, **class** defines the ped size and **kind** describes the ped shape.

3.8.1 GRADE

Grade describes how distinct the ped aggregation appears in the profile and how the peds behave when they are removed and handled. It defines the difference between cohesion within the peds (i.e., how well the ped holds together) and adhesion between peds (i.e., how easily peds can be separated from one another). In the field, grade defines how the soil separates into discrete, persistent peds and the ped durability when it is separated from the soil volume.

Soil moisture content affects the grade. When writing soil descriptions, the structure is described for the soil moisture content present in the profile. The soil moisture state is included in the description.

Grade is determined by using a hand trowel or a knife to dig or pry a mass of soil from the horizon. Press the knife or trowel straight into the horizon as far as possible and gently work the soil out of the profile face and collect it in your other hand or a separate trowel **(**Figure 3-10 **and** Figure 3-11**)**.

Gently pass the soil from one hand to the other to see how it holds together. You may gently massage the soil with a knife to see how it breaks apart. Use the criteria that follow to determine the grade along with Figure 3-12 **and** Error! Reference source not found. to determine kind and class

Figure 3-10: Photo of structure grade assessment in loose soil.

A trowel is used to “pop” a hand full of soil into one’s hand (left). The soil is gently massaged to determine the grade (right). The larger peds fell apart easily and there is much unaggregated material. This is a weak grade.

Figure 3-11: Photo of structural grade assessment in heavier soil.

A knife (left) is used to remove soil onto a trowel. The soil was then moved gently around on the trowel to see how well the peds held together

Weak Grade (W)
Peds are:
1. Either indistinct and are barely evident in place or:
2. Observable in place but incompletely separated from adjacent peds

When gently disturbed soil breaks into a mixture of**:**
3. Few entire peds
4. Many broken peds
5. Much material exhibits no planes of weakness
6. Much unaggregated material. <20% distinctly aggregated.

When handled**:**
7. Peds crush easily under gentle pressure

Moderate Grade (M)
Peds are:
1. Moderately durable and
2. Are evident but not distinct in undisturbed soil

When disturbed soil breaks into:
3. Many well formed peds
4. Some broken peds
5. Little unaggregated material. 20 - 60% distinctly aggregated.

When handled:
6. Peds do not crush
7. Peds part from adjoining peds to display nearly entire faces that have properties distinct from inped fracture surfaces

Strong Grade (S)
Peds are:
1. Durable
2. Distinct in undisplaced soil
3. Adhere weakly to one another

When disturbed soil breaks into:
4. Separates cleanly into well formed peds
5. Withstands displacement
6. Aggregated materials are dominant. >60% distinctly aggregated.

When handled:
1. Soil material separates into entire peds
2. Unbroken ped faces have distinctive properties compared to inped faces

3.8.2 TYPE AND KIND

At the first level ped shapes are classified into five types (e.g. Blocklike). The types are subdivided into nine kinds. Table 3-5 lists and defines the five types, the nine kinds and kind codes. Figure 3-12 illustrates the various classes.

3.8.3 CLASS

Structure class codes are used for each kind of structure but the sizes vary depending on the kind of structure being described. Table 3-5 lists the class names, class codes and sizes. The direction of measurement is given for each kind. The dominant class is recorded if more than one class occurs in a single horizon.

3.8.4 PRIMARY AND SECONDARY STRUCTURE

Single structured soils are recorded under primary structure on the Soil Description Form. Primary and secondary structures are listed for soils displaying compound structure. Secondary structure is recorded when soils have large peds that break into smaller peds or when the kind changes from one form to another when primary peds are broken.

Table 3-5: Structure type, kind, and class

Type	Kind	Class	Size
Structureless: no observable aggregation or no definite orderly arrangement around structural lines of weakness	Single grain structure: loose, incoherent mass of individual particles as in sands		
	Amorphous (massive) structure: a coherent mass showing no evidence of any distinct arrangement of soil particles		
Blocklike: soil particles are arranged around a point and bounded by flat or rounded surfaces	Blocky (angular blocky): faces rectangular and flattened, vertices sharply angular. *Measure along longest axis.*	Fine	<10
		Medium	10-20
		Coarse	20-50
		Very coarse	>50
	Subangular blocky: faces Sub-rectangular, vertices mostly oblique or subrounded. *Measure along longest axis.*	Fine	<10
		Medium	10-20
		Coarse	20-50
		Very coarse	>50
	Granular: spheroidal and characterized by rounded vertices. *Measure along longest diameter.*	Fine	<2
		Medium	2-5
		Coarse	5-10
Platelike: soil	Platy: Horizontal planes more	Fine	<2

particles are arranged horizontally	or less developed. *Measure plate thickness.*	Medium	2-5
		Coarse	>5
Prismlike: soil particles are arranged around a vertical axis and bounded by relatively flat vertical surfaces	Prismatic structure: vertical faces well defined, and edges sharp. Measure widest diameter.	Fine	<20
		Medium	20-50
		Coarse	50-100
		Very coarse	>100
	Columnar structure: vertical edges near tops of columns not sharp; columns flat-topped, round-topped, or irregular. Measure widest diameter.	Fine	<20
		Medium	20-50
		Coarse	50-100
		Very coarse	>100
Wedgelike: elliptical lenses that resemble wedges and are bounded by slickensides; occur in clay-dominated soils	Wedge: wedge-shaped peds bounded by slickensides. *Measure widest part of wedge.*	Fine	<20
		Medium	20-50
		Coarse	50-100
		Very coarse	>100
Clody: oversized clods created by mechanical disturbance	Clody	Any size	

Figure 3-12: Types, kinds and classes of soil structure

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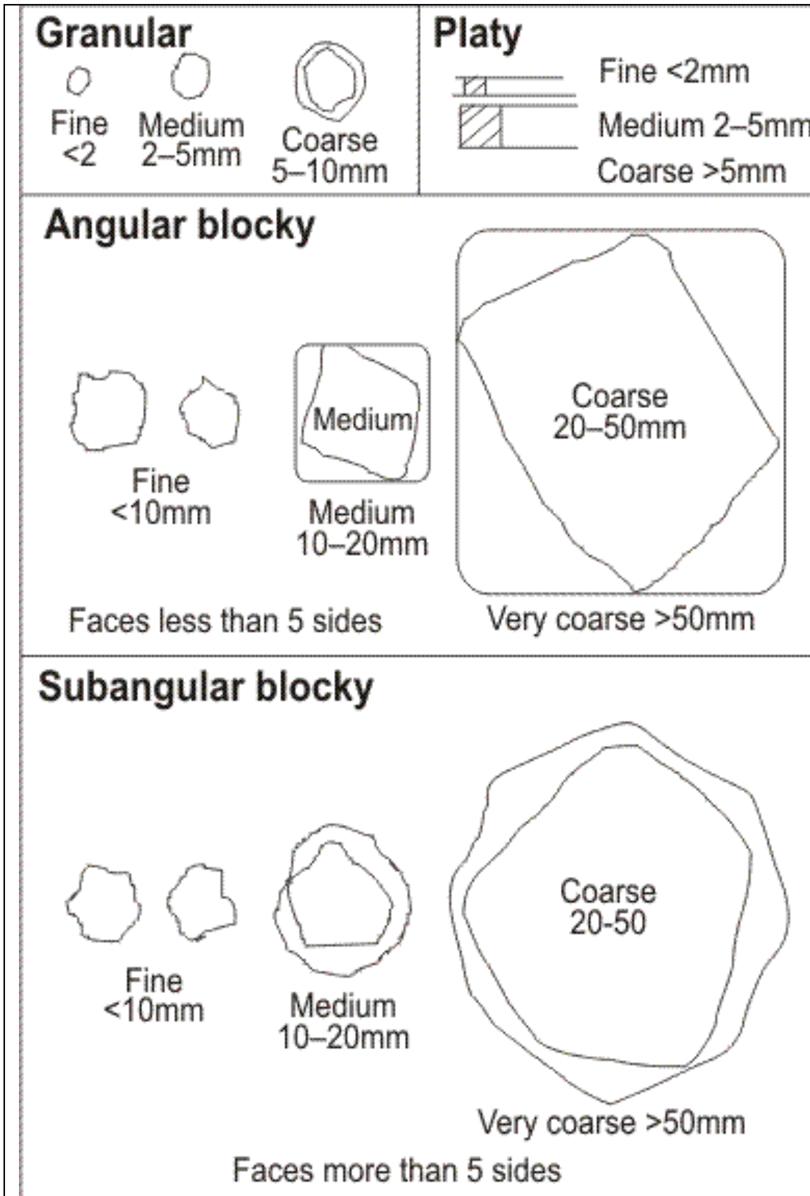
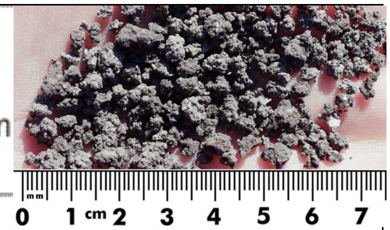


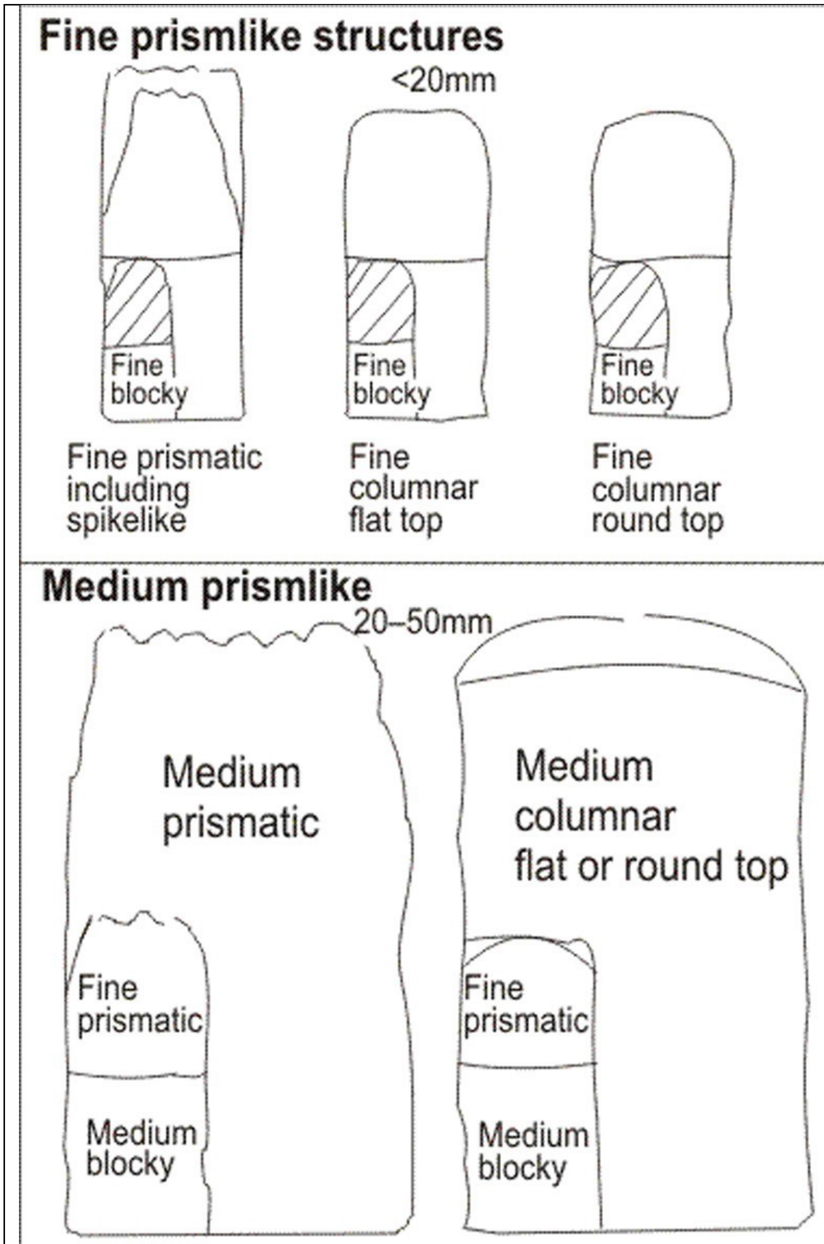


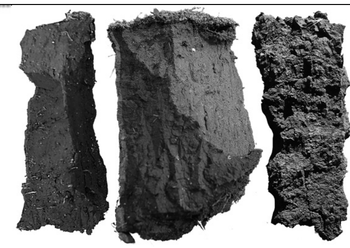
Granular

Platy

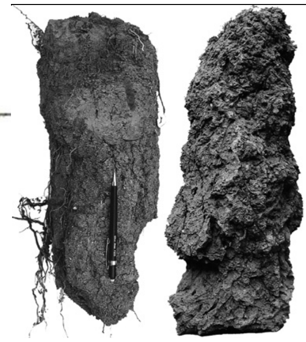
Angular blocky

Sub-angular blocky

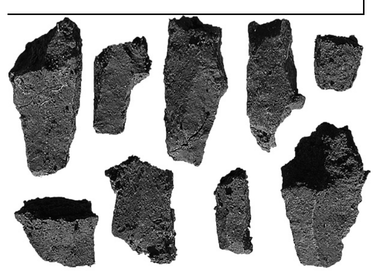




Prismatic



Columnar



Wedge

3.9 CONSISTENCE

Consistence is mineral soil resistance to rupture (soil strength), or deformation (plasticity) and its degree of internal cohesion and adhesion to other substances under three standard conditions (Watson 2009). Consistence is described for three moisture states: dry, moist, and wet. Typically in the field consistence is only evaluated at the moisture state the soil is in but ideally all three moisture states would be evaluated subsequently.

3.9.1 CONSISTENCE OF DRY AND MOIST SAMPLES

Consistence of dry and moist soils is estimated in the field by determining the soil strength by determining its resistance to crushing. Soil strength depends on the sample size, shape and the way the force is applied.

Uniform Test

1. A ped or soil fragment is removed from the profile.
2. It is trimmed into a cube with 2.5cm long sides with two roughly parallel surfaces.
3. Stress is applied slowly between the thumb and forefinger on the parallel surfaces until failure is just perceptible. Figure 3-13 illustrates the technique used to determine dry and moist consistence. The upper left frame shows initial pressure being applied to the ped. In the upper right frame the ped begins to fail and a circular pattern is seen forming at the tip of the thumb along with a vertical crack. In the lower left frame the ped fractures along the vertical crack. In the lower right the ped explodes due to the pressure. This is an example of Hard Dry Consistence.

Figure 3-13: Photos of dry consistence test.

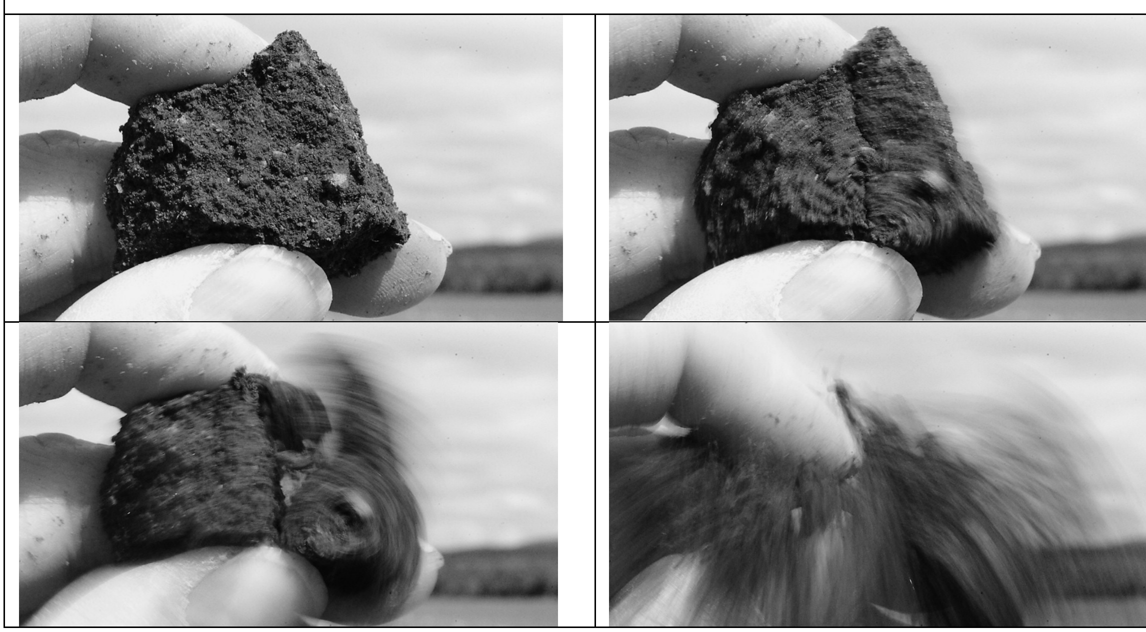


Table 3-6: Dry Consistence codes and definitions

1.	Loose	The soil material is noncoherent.
2.	Soft	The soil material is weakly coherent and fragile. It breaks into a powder or individual grains under very gentle pressure.
3.	Slightly hard	The soil material is weakly resistant to pressure and is easily crushed between the thumb and forefinger.
4.	Hard	The soil material is moderately resistant to pressure. Considerable pressure is required to crush it between the thumb and forefinger. It can be crushed in the hands without difficulty.
5.	Very hard	The soil material is very resistant to pressure and it is difficult to crush it in the hands. It cannot be crushed between the thumb and forefinger.
6.	Extremely hard	The soil material is very resistant to pressure and cannot be crushed in the hands. It will crush if placed on a hard surface and stepped on.
7.	Rigid	The soil material cannot be crushed except by extreme pressure. It will not crush under foot.

Table 3-7: Moist consistence codes and definitions

1.	Loose	The soil material is noncoherent.
2.	Very friable	The soil material is crushed under very gentle pressure and coheres when pressed together.
3.	Friable	The soil material is easily crushed under gentler to moderate pressure between the thumb and forefinger and coheres when pressed together.
4.	Firm	The soil material is crushed under moderate pressure between the thumb and forefinger. The resistance is distinctly noticeable.
5.	Very firm	The soil material can be crushed between the thumb and forefinger. Strong pressure is required. The force required is near the maximum that can be exerted by most people.
6.	Extremely firm	The soil material cannot be crushed between the thumb and forefinger.

3.9.2 WET CONSISTENCE

Wet consistence or stickiness is the degree of adhesion to other objects or materials. For this assessment the sample is crushed and water is added until the sample is puddled. The soil is then pressed between the thumb and forefinger and the adherence to the digits is noted (Figure 3-14). The higher the clay content is, the greater the stickiness. The codes and definitions for stickiness are given in Table 3-8.

Figure 3-14: Wet consistence or stickiness assessment.

You are assessing both the adhesion to the fingers and how far the soil can stretch before it breaks. The soil in this photo sequence was very sticky.

Table 3-8: Stickiness or wet consistence classes.

1.	Nonsticky	After the release of pressure practically no soil material adheres to either the thumb or forefinger
2.	Slightly sticky	After the release of pressure the soil material adheres to both the thumb and finger but comes off one or the other rather cleanly. The soil is not appreciably stretched when the digits are separated.
3.	Sticky	After the release of pressure the soil material adheres strongly to both the thumb and forefinger and tends to stretch somewhat and pulls apart rather then pulling free from either digit.
4.	Very sticky	After the release of pressure the soil material adheres strongly to both the thumb and forefinger and is decidedly stretched when they are separated, breaking and remaining on both digits.

3.9.5 PLASTICITY

Plasticity is the property of continuously changing shape under the influence of applied stress and of retaining the new shape after the stress is removed. The maximum expression of plasticity is recorded. At maximum plasticity moisture content is above the point where a roll 4mm in diameter crumbles, but below the water content at which stickiness exceeds slightly sticky.

To assess plasticity soil material is rolled between the palms or on a flat surface. The first step is to attempt to form a roll 4 cm long and 4 mm thick. If this is possible then the roll is dangled between the thumb and forefinger to see if it breaks (i.e., cannot support its own weight). If it does not then the roll is further rolled to a diameter of 2 mm, and again it is dangled from the thumb and forefinger. The specific plasticity classes are shown in Table 3-9.

Table 3-9: Plasticity codes and definitions.

1.	Nonplastic	A roll 4 cm long and 4 mm thick cannot be formed.
2.	Slightly plastic	A roll 4 cm long and 4 mm thick can be formed but cannot support its own weight.
3.	Plastic	A roll 4 cm long and 2 mm thick can be formed but cannot support its own weight.
4.	Very plastic	A roll 4 cm long and 2 mm thick can support its own weight.

3.10 MOTTLING AND GLEY COLOURS

Mottling and gley colours are associated with anaerobic or oxygen-depleted conditions caused by water saturation. Under permanent or near-permanent water saturation, iron is reduced and can be lost from the profile. This gives rise to development of blue, green, and gray matrix colours. These dull, gray colours are called gley colours, and the Munsell colour book has specialized charts for the Gley colours (Gley 1 and Gley 2 charts).

Mottles are red, brown, or yellow spots or blotches interspersed with the dominant matrix colour. They occur when oxygen re-enters the horizons and iron is oxidized ("rusted").

The term mottling does not include colours of identifiable bodies or surfaces such as concretions, nodules, red coatings, clay films, surface staining on pebbles, in-fillings of old root channels or animal burrows or local accumulations of carbonates or cementing agents. These colours are recorded elsewhere on the form or under comments and are not referred to as mottles on the soil description form.

Munsell colour or colours of the principal mottles and their pattern are recorded. Pattern includes abundance, size, contrast, colour difference with respect to the matrix and boundary distinctness.

3.10.1 MOTTLE ABUNDANCE AND SIZE

Abundance is the percentage of mottles seen on the exposed matrix surfa**ce.** Abundance codes are found in Table 3-10**. See section 3.17 for area-covered charts**. Mottle size is determined by measuring its average diameter in millimeters (Table 3-11).

Table 3-10: Mottle abundance codes.

MOTTLE ABUNDANCE		
Abundance Codes		
Code	Abundance	Exposed Matrix Surface
F	Few	<2%
C	Common	2 - 20%
M	Many	>20%

Table 3-11: Mottle size codes.

MOTTLE SIZE CODES		
Abundance Codes		
Code	Abundance	Exposed Matrix Surface
F	Fine	<5mm
M	Medium	5-15 mm
C	Coarse	>15mm

3.10.2 MOTTLE CONTRAST

Mottle contrast is the degree of visual distinction between the mottles and matrix and is determined by comparing the differences between the matrix and mottle colours.

Colour determination takes time and concentration to accurately record soil colours and colour patterns. Significant errors can result in contrasting two colours, depending on moisture state, the number, size and shape of the contrasting features and boundary distinction.

Mottle contrast codes, **Faint (F)**, **Distinct (D)** and **Prominent (P)**, are found in Table 3-12.

Table 3-12: Mottle contrast and distinctness codes

MOTTLE CONTRAST AND DISTINCTNESS CODES				
Contrast Codes		Boundary Distinctness Codes		
Code	Contrast	Code	Boundary	Description
F	Faint	S	Sharp	Knife Edge
D	Distinct	C	Clear	<2 mm Wide
P	Prominent	D	Diffuse	> 2 mm Wide

Different tabular methods have been developed to assess mottle contrast and are usually confusing to use. NRSC (2002) developed a set of simple tables for determining mottle contrast and Watson (2009) created a series of simple graphs to determine mottle contrast (Figure 3-15 **to** Figure 3-18**)**.

A: TO USE THESE CHARTS BEGIN BY DETERMINING THE DIFFERENCE IN HUE PAGES BETWEEN MATRIX AND MOTTLES. WORK YOUR WAY DOWN THE FOLLOWING LIST TO SEE WHICH ONE APPLIES TO THE HORIZON YOU ARE TRYING TO CLASSIFY. Note that one hue page is equal to a 2.5 unit interval difference.

1. If both matrix and mottle colours have **values of <= 3** and **chromas <= 2** then the colour contrast is **Faint** regardless of the difference in hue.

2. Matrix and Mottles colours on **SAME** hue page: Go to Figure 3-15.

3. Matrix and Mottles colours differ by **ONE** hue page (e.g. matrix 10YR, mottles 7.5YR): Go to Figure 3-16.

4. Matrix and Mottles colours differ by **TWO** hue pages (e.g. matrix 10YR, mottles 5YR): Go to Figure 3-17.

5. Matrix and Mottles colours differ by **THREE OR MORE** hue pages (e.g. matrix 10YR, mottles 2.5YR): Go to Figure 3-18.

B: THEN DETERMINE THE DIFFERENCE IN VALUE AND CHROMA BETWEEN MATRIX AND MOTTLES TO DETERMINE FINAL CONTRAST ON THE APPROPRIATE FIGURE. (Note that the Bg or Bgj suffixes shown on the figures only apply if other conditions specified in section 10.3.3 are met).

Examples:

1. The matrix colour is 10YR 4/3 and the mottle colour is 10YR 6/4. The hues are on the same page (Figure 3-15). The change in value is 2 and the change in chroma is 1. The mottle contrast is faint.

2. The matrix colour is 7.5YR 3/3 and the mottle colour is 7.5YR 7/6. The hues are on the same hue page (Figure 3-15). The change in value is 4 and the change in chroma is 3. The mottle contrast is prominent.

3. The matrix colour is 7.5YR 3/3 and the mottle colour is 5YR 5/5. The hues differ by one hue page (Figure 3-16). The change in value is 2 and in chroma is 2. The mottle contrast is distinct.

4. The matrix colour is 10YR 4/3 and the mottle colour is 5Y 5/4. The hues differ by two hue page (Figure 3-17). The change in value is 1 and the change in chroma is 1. The mottle contrast is distinct.

3.10.3 GLEY COLOURS AND THE CLASSIFICATION OF GLEY HORIZONS

The specific colors associated with gley conditions differ depending on the dominant hue of the soil – the redder the soil is to begin with, the brighter (i.e., higher chroma) the associated gley colours are. The CSSC has certain combinations of hues, chromas and mottles that are required to apply the suffix g (for Gleyed); if the horizon fails to meet the criteria, it would be a gj horizon (or no g suffix at all). The CSSC 3rd edition specifies criteria in both the horizon suffix section and in the chapter on the Gleysolic soils (Chapter 7) and this section draws upon both.

A g suffix is assigned if one of the following mottle colour or mottle/matrix combinations is met for any horizon Ae, B, or C horizon (note that Ah horizons, which naturally have low chromas cannot be assigned a g suffix). **Work your way down the list to see if any pertain to the horizon you are trying to classify.**

1. For red soil materials (matrix hues of 5YR. 2.5YR or redder): Distinct or prominent mottles at least 1 mm in diameter occupy 2% of the horizon. Note that soil horizons this red are very unusual in western Canada.

2. Matrix hues of 5GY, 10GY, 5G, 5G, 10G, 5BG, 10BG, 5B, 10B, 5PB (these are shown on Gley 1 and Gley 2 charts in Munsell Colour book) with or without mottles.

3. Matrix Hues of 7.5YR, 10YR, 2.5Y, 5Y: Chromas of 1 if mottles are not present;

4. Hues of 10YR or 7.5YR: Chromas of 2 or less on ped surfaces or in the matrix if peds are lacking **AND** common or many prominent mottles;

5. Hues of 2.5Y or 5Y: Chromas of 3 or less on ped surfaces or in the matrix if peds are lacking **AND** common or many prominent mottles.

Horizons that fail to meet any of the five criteria above but which show evidence of gleying are normally assigned a gj suffix indicating a juvenile g horizon. This is the case for horizons with faint or distinct mottles, or where prominent mottles occur but the chroma is too bright.

Classification into the Gleysol order (see section 5 of this handbook) also requires that certain minimum thickness and depth requirement must be met as well. Soils that fail to meet these thickness or depth requirements, or which have a gj horizon rather than a g horizon, would typically be classified as a Gleyed subgroup of another soil order (e.g. Gleyed Black Chernozem).

Figure 3-15: Mottles contrast codes for matrix and mottle colours on same hue page.

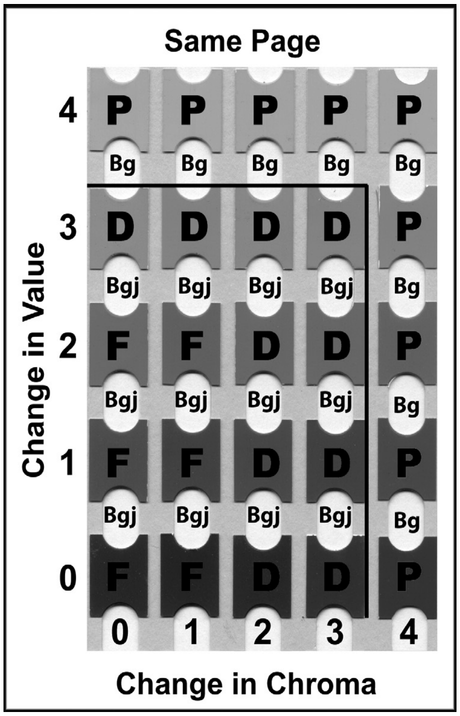


Figure 3-16: Mottle contrast codes for matrix and mottle colours that differ by one hue card.

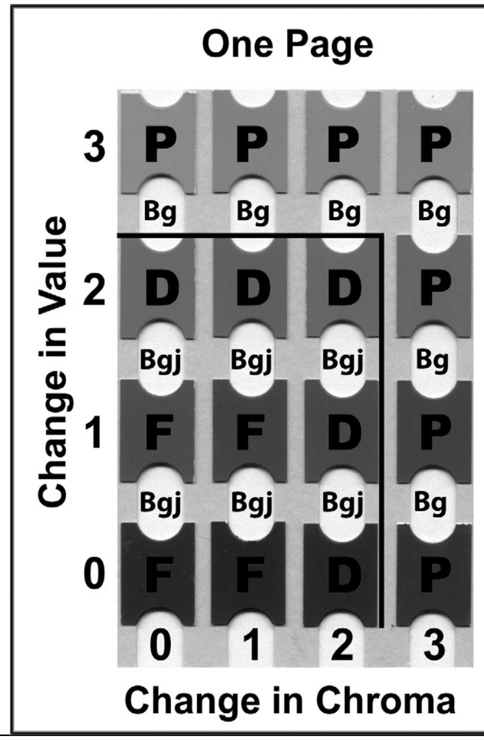


Figure 3-17: Mottle contrast codes for matrix and mottle colours that differ by two hue cards.

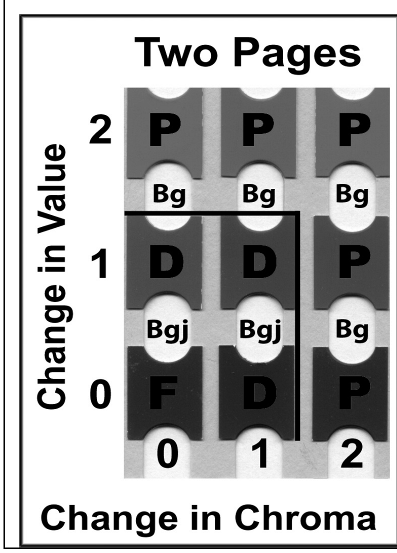
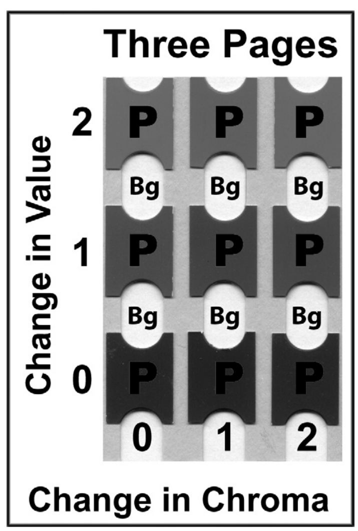


Figure 3-18: Mottle contrast codes fro matrix and mottle colours that differ by three or more hue cards.



3.11 CLAY FILMS

Clay films, clay skins or argillans, as they are variously called, are accumulations of orientated clays formed by translocation of clay from one place in the soil to another. Clay films are unlike the adjacent matrix and may cover ped surfaces, mineral grains, rock fragments and/or soil pores. They are probably the most difficult features to identify in the soil, especially if they are small. Look for clay films when you have clay-rich parent materials, such as lacustrine deposits, basal tills, etc. They may appear as small ridges, finger print like or honeycomb patterns if few are present. When the Bt is well developed they will be waxlike and shiny in appearance (Figure 3-19, Figure 3-20).

Figure 3-19: Clay films from a Luvisol, Dawson Creek, B.C.

Figure 3-20: Clay films from a Texan soil.

Frequency, thickness and location, in relation to other morphological features are recorded. Other properties such as colour, texture and contrast with the matrix are determined and may be recorded in horizons notes. Only the most common clay film form is recorded.

3.12.1 FREQUENCY

Clay film frequency, for the entire horizon extent, is the percentage of the specified surface clay film location that is coated by clay films. Frequency does not include total clay film volume or the continuity or distribution of clay films on individual surfaces. **See section 3.17 for the area covered charts.**

3.12.3 LOCATIONS

Location classes include areas where clay films are most commonly found **(**Table 3-14**)**.

Table 3-13: Clay film frequency classes.

CLAY FILM FREQUENCY CLASSES AND CODES			
Code	Class	% Surf-ace	Description
F	Few	<2	Films cover <2% of the total area of the specified surface(s). Patches of film are identifiable but their frequency is so low that the significance of their presence may be nil or doubtful.
C	Common	2 - 20	Films cover 2 - 20% of the total area of the specified surface(s).
M	Many	20 - 80	Films cover 20 - 80% of the total area of the specified surface(s).
CS	Contin-uous	>80	Films cover 20 - 80% of the total area of the specified surface(s). Patches of these surfaces may be clear of clay films but the films are essentially continuous.

Table 3-14: Clay film location guides.

CLAY FILM LOCATION CODES	
Cod	Location
1	In pores and / or channels only
2	On ped faces (unspecified)
3	In many pores / channels and on some vertical and horizontal ped faces
4	In all pore / channels and on all vertical and horizontal ped faces
5	Visible bridges between sand grains
6	Coating on sand grains
7	On lower surfaces of coarse fragments
8	On upper surfaces of coarse fragments

3.12 SLICKENSIDES

Soil Survey Division Staff (1993) refers to slickensides, coats, concentrations, stress formations, such as clay films, clay bridges and stress surfaces as internal surface features. **Slickensides** develop in high clay con- tent soils, such as Vertisols, as one massive clay mass slides past another as soils shrink with drying and swell with wetting due to large changes in water state. Fresh slickenside surfaces are polished and striated. They are usually longer than 5 cm and are most commonly found, but not always, below 50 cm in depth. Slickensides are recorded by **Abundance** and **Distinctness.**

The **Abundance** is the percentage of the total surface area of the horizon that is covered by slickensides. Table 3-15 lists the class codes and surface percentage covered. Figure 3-21 has photos of slickensides. **Distinctness** is the ease and degree of certainty with which a surface feature can be identified. Distinctness is related to thickness, color contrast with the adjacent material, and other properties. It is, however, not itself a measure of any one of them. Table 3-16 describes the distinctness criteria (Soil Survey Division Staff (1993).

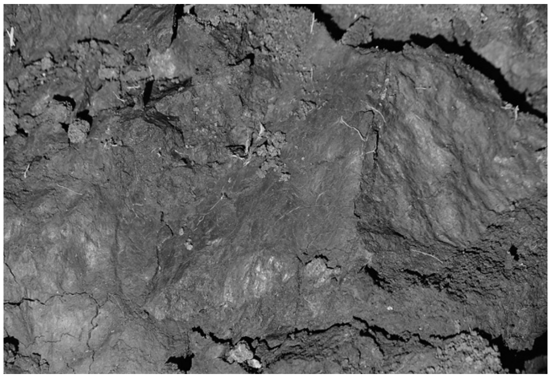
Table 3-15: Slickenside Abundance Codes and area percent coverage

SLICKENSIDE ABUNDANCE CODES		
Code	Abundance	Surface
VF	Very Few	<5%
F	Few	5 to <25%
C	Common	25 to <50%
M	Many	

Table 3-16: Slickenside Distinctness Codes and Definitions.

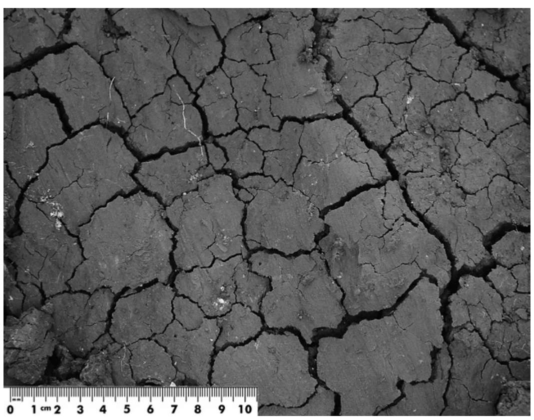
SLICKENSIDE DISTINCTNESS CODES		
Cod	Distinctness	Definition
F	Faint	Evident only on close examination with 10X magnification and cannot be identified positively in all places without greater magnification. The contrast with the adjacent material in color, texture, and other properties is small.
D	Distinct	Can be detected without magnification, although magnification or tests may be needed for positive identification. The feature contrasts enough with the adjacent material to make a difference in color, texture, or other properties evident.
P	Prominent	Conspicuous without magnification when compared with a surface broken through the soil. Color, texture, or some other property or combination of properties contrasts sharply with properties of the adjacent material or the feature is thick enough

Figure 3-21: Photos of slickensides



Slickensides in a vertisolic soil

Intersecting slickensides in a Vertisol



Cracked slickenside surface

Wedge structures

3.13 EFFERVESCENCE

Effervescence is the bubbling, hissing or foaming produced when 10% HCl (hydrochloric acid) or 10% H_2O_2 (hydrogen peroxide) is dripped onto a soil sample. The former indicates the presence of calcium carbonates and the latter manganese oxides. If a different concentration is used, it is recorded in horizon notes. Effervescence codes are found in Table 3-17**.**

Table 3-17: Effervescence codes

EFFERVESCENCE CODES		
Cod	Class	Description
VW	Very Weak	Few bubbles, slow to react, takes a second
W	Weak	Bubbles readily observed
M	Moderate	Bubbles form a low foam
S	Strong	Bubbles for a thick foam, reaction fast, explosive

3.14 SALINITY

Soluble salts in the soil and parent materials have implications for plant growth. Salts may occur as crystals, veins or as surface crusts of salt crystals. Inhibited crop growth and presence of salt tolerant plants are indicators of saline soils. Saline soils are found in arid and semiarid environments.

Lab analysis is required to determine the electrical conductivity (EC) of a soil. EC is measured in millisiemens (ms) per cm and is corrected for a standard temperature of 25°C. EC is related to the amount of salt more soluble than gypsum. Soluble salts in the soils include sodium chloride and potassium chloride salts, magnesium sulfate and calcium chloride.

In the field the presence of salts should be noted in the field notes. Crystals of gypsum formed in the soil look like coarse crystals of brown sugar, whereas more soluble salts tend to be light gray or white. The presence of any salts on the surface of the soil should also be noted.

Table 3-18: Salinity classes

SALINITY CLASSES AND CODES				
Code	Salinity Class	E.C. (mS/ cm)	Salt Content (by wt.)	Description
W	Weakly Saline	4 - 8	0.15 - 0.35%	Soils slightly affected by salt or alkali (sodium). Growth of sensitive crops are inhibited, but that of salt tolerant crops may not be.
M	Modera-tely Saline	8 - 15	0.35 - 0.65%	Soils moderately affected by salt or alkali. Crop growth inhibited and no crop does well.
S	Strongly Saline	> 15	>65%	Soils strongly affected by salt or alkali. Only a few kinds of plants survive

3.15 CEMENTATION

Cementation is the brittle, hard consistence caused by cementing agents other than clay minerals. The agent of cementation (usually required lab analysis), and the degree and continuity of cementation are recorded.

3.15.1 CEMENTING AGENT (AGENT)

The probable cementing agent is recorded in the field, but confirmation by lab analysis is usually required **(**Table 3-19**)**. Colour may assist in determining the cementing agent. Humus - aluminum will be dark brown or black. Iron will be reddish and lime will fizz with 10% HCl.

Table 3-19: Cementation agents

CEMENTATION AGENT CODES			
Code	Cementing Agent	Code	Cementing Agent
1	Humus - Aluminum	5	Lime and Silica
2	Iron	6	Other: (Comments)
3	Lime	7	Unspecified

3.15.2 DEGREE OF CEMENTATION (DEGREE)

Cementation strength is determined by estimating the force required to crush a wet cubic (2.5cm x 2.5cm), test sample. Air dry test samples are placed in water for one hour. They are then tested in the same manner as dry and moist consistence are done. The codes for degree of cementation are found in Table 3-20.

Table 3-20: Degree of cementation codes

CEMENTATION DEGREE CODES		
Cod	Class	Description
W	Weakly Cemented	Wet sample can be crushed between the thumb and forefinger.
M	Moderat-ely Cemented	Wet sample is brittle and hard and cannot be crushed between the thumb and forefinger but can be broken in the hands.
S	Strongly Cemented	The wet sample cannot be broken in the hands, but is easily broken with a hammer.
I	Indurated	Wet sample is so strongly cemented that a very sharp hammer blow is required to break it.

3.15.3 EXTENT

Cementation continuity is classified using two categories based on horizon extent **(**Table 3-21**).**

Table 3-21: Cementation extent codes

CEMENTATION EXTENT CODES	
Code	Cementation Extent
C	Continuous over distance of 1 meter.
D	Discontinuous over a distance of 1 meter; this includes horizons where only cemented fragments occur.

3.15.4 CEMENTED HORIZON (Lower case "c")

To determine if the lower case "c" (cemented) is to be used place a piece of the horizon into a bowl of water. The specimen is not cemented if it slakes (crumbles) in water. If it does not slake the horizon is cemented and the lower case "c" is used. For example: BCc.

3.16 VON POST SCALE OF DECOMPOSITION FOR ORGANIC MATERIALS

Organic material includes the nonliving organic materials and the microscopic living organisms associated with it. This section is applied to the Om, Of, and Oh horizons. Organic material is described using the von Post scale of decomposition.

In this field test squeeze a sample of the organic material within the closed hand. Observe the color of the solution that is expressed between the fingers, the nature of the fibers, and the proportion of the original sample that remains in the hand..

Table 3-22: Von Post Decomposition Scale

Code	Horiz	Description
1	Of	Undecomposed; plant structure unaltered; yields only clear water coloured light yellow-brown
2	Of	Almost undecomposed; plant structure distinct; yields only clear water coloured light yellow-brown.
3	Of	Very weakly decomposed: plant structure distinct; yields distinctly turbid brown water; no peat substance passes be- tween the fingers; residue not mushy.
4	Of	Weakly decomposed; plant structure distinct; yields strongly turbid water, no peat substance passes between the fingers, residue rather mushy.
5	Om	Moderately decomposed; plant structure clear but becoming indistinct; yields much turbid brown water; some peat escapes between the fingers; residue very mushy.
6	Om	Strongly decomposed: plant structure somewhat indistinct but clearer in the squeezed residue than in the undisturbed peat; about one third of the peat escapes between the fingers; residue strongly mushy.
7	Oh	Strongly decomposed: plant structure indistinct but recognizable; about half the peat escapes between the fingers.
8	Oh	Very strongly decomposed: plant structure very indistinct; about two-thirds of the peat escapes between the fingers; residue almost entirely resistant remnants such as root fibers and wood.
9	Oh	Almost completely decomposed: plant structure almost unrecognizable; nearly all the peat escapes between the fingers.
10	Oh	Completely decomposed: plant structure unrecognizable; all the peat escapes between the fingers.

3.17 AREA-COVERED CHARTS

Figure 3-22: 2% Area-covered chart.

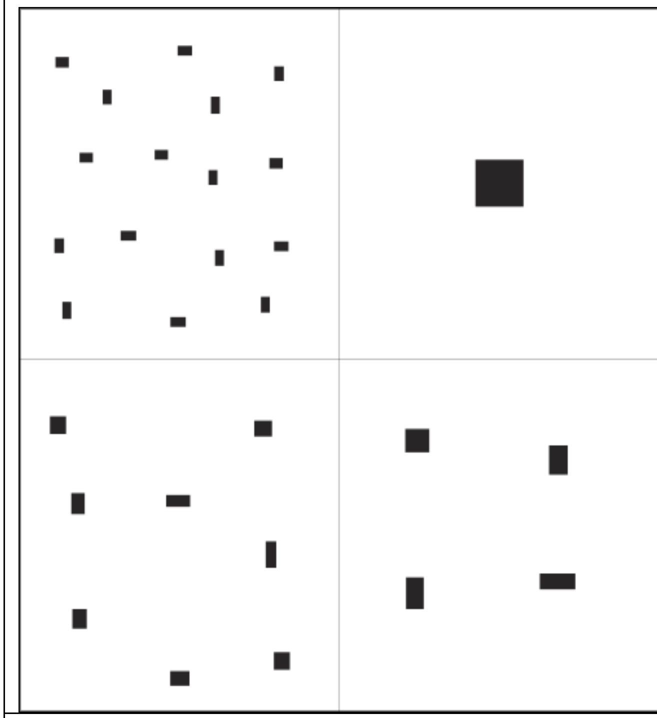


Figure 3-23: 20% area-covered chart

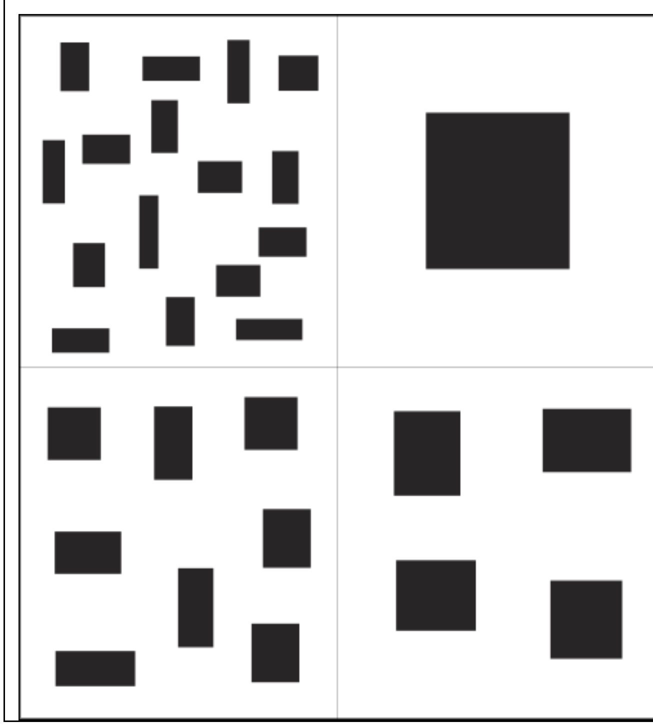


Figure 3-24: 50% area-covered chart

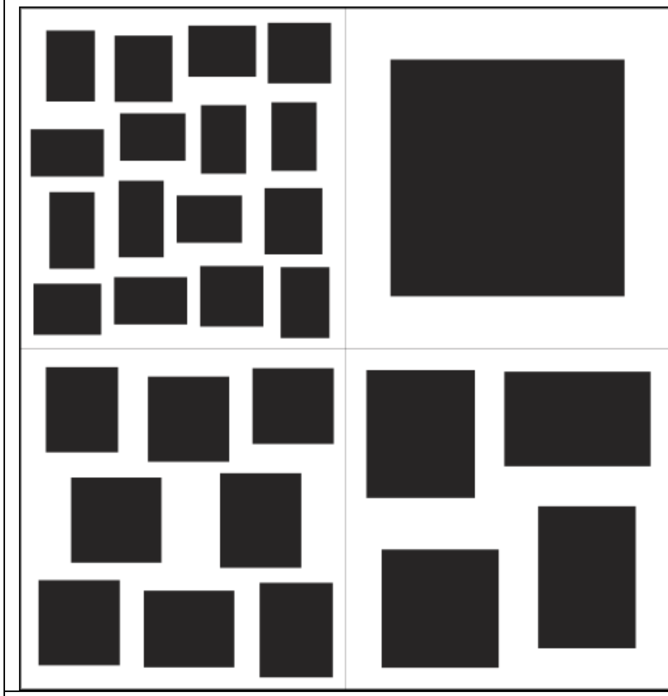


Figure 3-25: 80% area-covered chart.