Ohio Department of Transportation

VISUAL CLASSIFICATION COURSE FOR GEOTECHNICAL LOGGING OF SOIL AND ROCK STRATUM

SPRING 2015

Presented by:
Office of Geotechnical Engineering
Purpose:

- To inform and train all field persons who visually classify geotechnical samples (soil and rock).
- Developed to ensure high quality and consistency in the field classification of samples during subsurface explorations.
- Follows the Ohio Department of Transportation’s (ODOT) Specifications for Subsurface Explorations (SGE) - 2015.

http://www.dot.state.oh.us/Divisions/Engineering/Geotechnical/Pages/SGE.aspx

Sample Collection

ODOT Typically Collects Geotechnical Soil Samples through 3 methods:

1. Drill Rig
2. Test Pit
3. Hand Methods

Each Method Provides Samples requiring Visual Classification
Visual Classification Course for Geotechnical Logging of Soil and Rock Stratum

Drill Rig
Samples typically collected as disturbed or undisturbed

Disturbed Samples:
1. Split Spoon (SPT) – MOST COMMON
2. Auger sample
3. Sonic Drill

Undisturbed Samples
1. Shelby Tube (ST) – MOST COMMON
2. Piston Sampler (PS)

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Split Spoon Sampler
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N60 correction allows for consistent evaluation of blow counts independent of the drill system used.

\[ N_{60} = \frac{E_E C_B C_S C_R N}{0.60} \]

Where:
- \( N_{60} \) = SPT \( N \) value corrected for field procedures
- \( E_E \) = hammer efficiency (from Table 4.3)
- \( C_B \) = borehole diameter correction (from Table 4.4)
- \( C_S \) = sampler correction (from Table 4.4)
- \( C_R \) = rod length correction (from Table 4.4)
- \( N \) = measured SPT \( N \) value
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Auger Samples
Only Collects Samples

Sonic Drilling
Only Collects Sample
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Shelby Tube Sampler

Test Pits
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Hand Methods

Glacial Map of Ohio
ODNR Geologic Survey
Shaded Drift-Thickness Map of Ohio

ODNR Geologic Survey

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Common Soil Classifications

**AASHTO** American Association State Highway and Transportation Officials
- Standard for Several DOT Geotechnical Engineers
- Classification geared for the design and construction of roadways
- A-1-a is the best pavement subgrade

**USCS** Unified Soil Classification System
- Standard for non D.O.T. Geotechnical Engineers

**USDA** United States Department of Agriculture
- Standard for Agronomy (farming)
- Soil Taxonomy
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ODOT SOIL CLASSIFICATION

ODOT utilizes a modified AASHTO system

AASHTO system covered under M 145

Based on *gradation* and *plasticity index (PI)*

Percentages are based on:

* dry weight not volume

Break point between *non-cohesive* and *cohesive* soils is 36% passing #200 sieve.

![Classification of Soils Table]

Legend:

- **Non-Cohesive**
- **Silt**
- **Cohesive**
**MOST SOILS HAVE A MIXTURE OF DIFFERENT PARTICLE SIZES BEING GRAVEL, SAND, SILT AND/OR CLAY. THE PERCENTAGE OF EACH WILL DETERMINE THE CLASSIFICATION**

- **Non-cohesive Soils — vs. Cohesive Soils**

Determined based on Percentage of non-cohesive (gravel and sand) to cohesive (silt and clay).

**Classification of Soils is an Iterative Process Through the Collection of Additional Information**

- **Field Visual Classification** is based on the best judgment based on knowledge and time the field personnel posses — **Very Rudimentary**
- **Lab Visual Classification** should be more detailed that the field based on the lab personnel typically having more time to validate assumptions — **Preliminary**
- **Final Classification** is based on confirmation of assumption of the visual classification **validated by testing results** — **Precise**
**Visual Classification Course for Geotechnical Logging of Soil and Rock Stratum**

- **VISUALLY DESCRIBE AND DETERMINE WATER CONTENT OF EVERY SOIL SAMPLE (SGE 602)**

- **VISUALLY INSPECT SOIL SAMPLES AT PROPOSED SOIL SUBGRADE FOR THE PRESENCE OF GYPSUM CRYSTALS (SGE 602)**

- **VISUALLY CLASSIFY MISCELLANEOUS MATERIALS DUE TO DIFFICULT IN PERFORM LABORATORY TESTING (SGE 603.1)**

- **TEST REPRESENTATIVE SOIL SAMPLES TO UTILIZE THE ODOT SOIL CLASSIFICATION METHOD (SGE 603.2). TYPICALLY, A MINIMUM OF 1 TEST PER STRATA**

- **NEVER SOLELY VISUALLY CLASSIFY A-2-5, A-4b, A-5, A-7-5, A-8a OR A-8b SOILS WITHIN 3 FEET OF PROPOSED SUBGRADE ELEVATION (GB-1)**

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**Visual Classification Course for Geotechnical Logging of Soil and Rock Stratum**

- **GENERAL FIELD TESTS FOR VISUAL CLASSIFICATION**

- **NOT ALL TESTS ARE APPLICABLE FOR ALL SOIL TYPES**
**Visual Classification Course for Geotechnical Logging of Soil and Rock Stratum**

**Field Test - Dispersion Test**

- Dry out granular material if moist.
- Break/crumble material up as completely as possible.
- Place into closed jar with water.
- Shake jar vigorously mixing soils into suspension.
- Place jar on stable platform and allow suspension to settle.

- Gravel and coarse sand settle rapidly.
- Fine sand settles within about a minute.
- Silt and clay settle over as much as a couple of hours.

Add a deflocculating agent (dish detergent) to allow for separation of silt from clay particles.

**Field Test - Dilatancy Test**

- Remove particles >#40 sieve (coarse sand & gravel) and make a soil pat with the consistency of putty (moist condition).
- Pat size ½-in to ¾-in diameter and 1-in to 2-in length.
- Add water, if needed, to make soil moist and soft.
- Place pat in palm of one hand and shake vigorously against the other hand several times.

- Glossy wet surface appearance is a positive reaction.
- When pat is squeezed, the glossy disappears from surface.

- Fine sand and silt may have a positive dilatancy
Field Test - Dust Formation Test

- Dry out granular material if moist.
- Sift the dry granular material through fingers and let fall on a hard, clean surface.

➢ The more “DUSTY” the surface appears the larger the percentage of silt and clay particles present.

Field Ribbon Test (Soil Plasticity)

- Remove particles >#40 sieve (coarse sand & gravel) and make a soil pat with the consistency of putty (moist condition).
- Pat size ½ -in to ¾ -in diameter and 3-in to 5-in length.
- Press pat between thumb and index finger creating a ribbon ~1/8 –in thickness.
- The longer the ribbon before breaking under soil’s own weight, the higher the plasticity of the soil.

➢ ~4-in long ribbon, or longer than original pat; A-6b or A-7-6.
➢ No Ribbon, or delicate, softer and easily crumble; A-4b or A-4a.
➢ Somewhere in between; A-6a or lower A-6b.
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**Field Plastic Limit**

1. Select test soil at natural moisture
2. Remove any non-soil materials (i.e. rock, roots, etc.)
3. Roll sample between palms
4. Does it reach a uniform 1/8 inch diameter thread
5. Yes – above plastic limit
6. No – below plastic limit or non-plastic

- An 1/8 inch thread cannot be rolled = non-plastic
- When 1/8 inch thread becomes brittle = plastic limit.
- Tougher and stiffer thread the more clayey the soils
- Organic soils feel spongy near plastic limit

**Field Liquid Limit**

As a soil is wetted from either a dry or natural moisture content the stickiness will indicate it’s relative plasticity.

Stickiness estimates the soil’s capacity to adhere to other objects. Try to utilize a moisture content that displays the maximum adherence of the soil between the thumb and index finger after it is squeezed together.
Field Dry Strength (Soil Plasticity)

• Remove particles >#40 sieve (coarse sand & gravel) and make a soil pat with the consistency of putty (moist condition).
• Pat size ½ -in to ¾ -in diameter and 3-in to 5-in length.
• Allow pat to dry completely.
• Break and crumble pat between the fingers.

➤ Dry strength increases with increasing soil plasticity.

NON-COHESIVE SOILS

Photo from ODOT Photo Archives: Ashland County Circa 1918.
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Field Test for Non-cohesive Soils

- Soil particles can visually be seen and estimated
- Clean sand and gravel will not remain in a ball when squeezed
- Will not form a ribbon
- Wet, clean sand and gravel will not make your hands dirty
- Clean sand and gravel will make little to no cloud when placed in water.
- Will not stay on hands
- Sand feels gritty between fingers
- Dry, clean sand and gravel will have little dust when rubbed between your fingers

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Field Test - Dispersion Test

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- Place into closed jar with water.
- Shake jar vigorously mixing soils into suspension.
- Place jar on stable platform and allow suspension to settle.

- Gravel and coarse sand settle rapidly.
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- Silt and clay settle over as much as a couple of hours.

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- Pat size ½ -in to ¾ -in diameter and 1-in to 2-in length.
- Add water, if needed, to make soil moist and soft.
- Place pat in palm of one hand and shake vigorously against the other hand several times.

  o Glossy wet surface appearance is a positive reaction.
  o When pat is squeezed, the glossy disappears from surface.

➤ Fine sand may have a positive dilatancy

Field Test - Dust Formation Test

- Dry out granular material if moist.
- Sift the dry granular material through fingers and let fall on a hard, clean surface.

➤ The more “DUSTY” the surface appears the larger the percentage of silt and clay particles present.
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Description of Particle Size Determination

<table>
<thead>
<tr>
<th>Component</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boulders</td>
<td>Larger than 12 in. (300 mm)</td>
</tr>
<tr>
<td>Cobble</td>
<td>3 in. to 12 in. (75 mm to 300 mm)</td>
</tr>
<tr>
<td>Gravel Coarse</td>
<td>¾ in. to 3 in (19 mm to 75 mm)</td>
</tr>
<tr>
<td>Gravel Fine</td>
<td>#10 sieve to ¾ in. (2 mm to 19 mm)</td>
</tr>
<tr>
<td>Sand Coarse</td>
<td>#40 sieve to #10 sieve (0.42 mm to 2 mm)</td>
</tr>
<tr>
<td>Sand Fine</td>
<td>#200 sieve to #40 sieve (0.074 mm to 0.42 mm)</td>
</tr>
<tr>
<td>Silt</td>
<td>0.005 mm to #200</td>
</tr>
<tr>
<td>Clay</td>
<td>Smaller than 0.005 mm</td>
</tr>
</tbody>
</table>

Based on AASHTO

Visual Classification Course for Geotechnical Logging of Soil and Rock Stratum

• ODOT NON-COHESIVE SOILS

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>DESCRIPTION</th>
<th>Classification</th>
<th>LLu/LL</th>
<th>% Fines #10</th>
<th>% Fines #200</th>
<th>Liquid Limit (LL)</th>
<th>Plastic Index (PI)</th>
<th>Group Index (G)</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Gravel and/or Stone Fragments</td>
<td>A=1=c</td>
<td>30</td>
<td>15</td>
<td></td>
<td>6</td>
<td></td>
<td>0</td>
<td>Win. of 50% combined gravel, cobbles and boulder sizes</td>
</tr>
<tr>
<td></td>
<td>Gravel and/or Stone Fragments with Sand</td>
<td>A=1=b</td>
<td>50</td>
<td>25</td>
<td></td>
<td>6</td>
<td></td>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fine Sand</td>
<td>A=3</td>
<td>51</td>
<td>10</td>
<td></td>
<td>NON-PLASTIC</td>
<td></td>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Coarse and Fine Sand</td>
<td>--</td>
<td>35</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td>0</td>
<td>Win. of 50% combined coarse and fine sand sizes</td>
</tr>
<tr>
<td></td>
<td>Gravel and/or Stone Fragments with Sand and Silt</td>
<td>A=2-4</td>
<td>40</td>
<td>40</td>
<td>8</td>
<td>10</td>
<td></td>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gravel and/or Stone Fragments with Sand, Silt and Clay</td>
<td>A=2-5</td>
<td>35</td>
<td>40</td>
<td>41</td>
<td>11</td>
<td></td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gravel and/or Stone Fragments with Sand and Clay</td>
<td>A=2-6</td>
<td>35</td>
<td>40</td>
<td>41</td>
<td>11</td>
<td></td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>
### Visual Classification Course for Geotechnical Logging of Soil and Rock Stratum

**ODOT Non-Cohesive Soils**

- **A-1-a** Gravel and/or Stone Fragments
- **A-1-b** Gravel and/or Stone Fragments with Sand
- **A-3** Fine Sand
- **A-3a** Coarse and Fine Sand
- **A-2-4/5** Gravel and/or Stone Fragments with Sand and Silt
- **A-2-6/7** Gravel and/or Stone Fragments with Sand and Silt and Clay

> **Use Either “Gravel”; “Stone Fragments”;**
> **or “Gravel and Stone Fragments”**

> **For Man-made material use “Stone Fragments” with the type**
> **of man-made product as the secondary description**

- **Note:** A-2-5 and A-2-7 soils are not common in Ohio because of the elastic nature of the fines.

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**Gravel vs. Stone Fragment**

Material which is rounded and is not indigenous to the area will be gravel

From ASTM D 2488
Visual Classification Course for Geotechnical Logging of Soil and Rock Stratum

Boulders and Cobbles (pieces >3” in size)

Common Man-made Products

- **Coal By-Products:** Fly ash, Bottom ash, Boiler Slag
- **Steel By-Products:** Slag: wide variety of appearances and properties depending on mill generated from. Typically, has air bubbles (vesicular texture) present to identify it as slag. Common in east and northeastern Ohio. Older materials can be cemented together.
- **Recycled Portland Cement Concrete (RPCC):**
  Visually identifiable based on stone and cement fragments within the aggregate. Typically has a light gray to brownish gray color. Will react with HCL
Common Man-made Products

- **Crushed Asphalt Pavement (RACP):**
  Visually identifiable from its black aggregate with asphalt appearance. Typically found as a sub-base or mixed with soil as an embankment fill.

- **Haydite:** Manufactured burnt shale – light weight fill.

- **Foundary Sand:** By-product of metal processing. Sand is coated with bentonite clay or chemical resins. Foundry sand is darker in appearance from natural sands. May have unusual colors.

- **Limestone (CCS):** Crushed limestone (or dolostone) is the most common aggregate base used by ODOT.
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SILT SOILS

Photo from ODOT Photo Archives
Lake George, 1993A
Visual Classification Course for Geotechnical Logging of Soil and Rock Stratum

**SILT SOILS**

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>DESCRIPTION</th>
<th>Classification</th>
<th>LL/PL</th>
<th>% Pass 40</th>
<th>% Pass 200</th>
<th>Liquid Limit (LL)</th>
<th>Plastic Index (PI)</th>
<th>Group Index Max.</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandy Silt</td>
<td>A-4</td>
<td>A-4a</td>
<td>75 Min.</td>
<td>90 Min.</td>
<td>40 Min.</td>
<td>10 Min.</td>
<td>8</td>
<td>Less than 50% silt sizes</td>
<td></td>
</tr>
<tr>
<td>Silt</td>
<td>A-4</td>
<td>A-4b</td>
<td>75 Min.</td>
<td>50 Min.</td>
<td>40 Min.</td>
<td>10 Min.</td>
<td>8</td>
<td>50% or more silt sizes</td>
<td></td>
</tr>
</tbody>
</table>

* Only perform the oven-dried liquid limit test and this calculation if organic material is present in the sample.

A-4a and A-4b can be classified as either non-cohesive (if non-plastic) or cohesive (if it has PI)

Visual Classification Course for Geotechnical Logging of Soil and Rock Stratum

**Gravel and Sand** – Visible to the naked eye and can be visually estimated.

**Silt** - When subjected to shaking in the palm of the hand, a pat of saturated inorganic silt expels enough water to give a glossy appearance to the surface and, when bent or slightly squeezed between the fingers, the surface of the pat will become dull. The pat, upon working in the hand, loses moisture, becomes brittle, and breaks easily into very fine particles.

**Clay** - Clay is sticky at high water contents, plastic over a wide range of water contents, and can be rolled into a fine thread without breaking. Upon drying it becomes hard and will not break into fine particles.
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Characteristics of Silt Soils (A-4b, A-4a)
- Feels smooth when moist or wet
- Can only be molded at a small range of moisture contents
- Difficult to form a ribbon; when ribbon is formed it is delicate, softer and easily crumbles
- Washes off hands with running water
- Very weak strength when dried (crumbles)
- Clumps will disperse when worked under water
- Feels soft near the plastic limit and easily crumbles
- Dull appearance on surface when dry or damp
- Moist soil glisten when shaken

Silt Soils
- Can be either non-plastic or low plasticity relative to the percentage a sand, silt, and clay.
  - Silt (A-4b) typically non-plastic
  - Sandy Silt (A-4a) typically low plasticity if contains more clay particles than silt and sand
Dilatancy Test

- Remove particles >#40 sieve (coarse sand & gravel) and make a soil pat with the consistency of putty (moist condition).
- Pat size ½-in to ¾-in diameter and 1-in to 2-in length.
- Add water, if needed, to make soil moist and soft.
- Place pat in palm of one hand and shake vigorously against the other hand several times.
  - Glossy wet surface appearance is a positive reaction.
  - When pat is squeezed, the glossy disappears from surface.

➢ Silt and fine sand have a positive dilatancy

Field Ribbon Test (Soil Plasticity)

- Remove particles >#40 sieve (coarse sand & gravel) and make a soil pat with the consistency of putty (moist condition).
- Pat size ½-in to ¾-in diameter and 3-in to 5-in length.
- Press pat between thumb and index finger creating a ribbon ~1/8-in thickness.
- The longer the ribbon before breaking under soil’s own weight, the higher the plasticity of the soil.

➢ No Ribbon, or delicate, softer and easily crumble; A-4b or A-4a.
**Field Plastic Limit**

1. Select test soil at natural moisture
2. Remove any non-soil materials (i.e. rock, roots, etc.)
3. Roll sample between palms
4. Does it reach a uniform 1/8 inch diameter thread
5. Yes – above plastic limit
6. No – below plastic limit or non-plastic

<table>
<thead>
<tr>
<th>Description</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-plastic</td>
<td>A 1/8 in. thread cannot be rolled at any water content.</td>
</tr>
<tr>
<td>Low Plasticity</td>
<td>The thread can barely be rolled and the lump cannot be formed when drier than the plastic limit. (typically ~6 mm diameter @ 4 cm length)</td>
</tr>
</tbody>
</table>

**Visual Classification Course for Geotechnical Logging of Soil and Rock Stratum**

**COHESIVE SOILS**
Cohesive Materials

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>DESCRIPTION</th>
<th>Classification</th>
<th>LL/L/4</th>
<th>% Pass #40</th>
<th>% Pass #200</th>
<th>Plasticity Index (PI)</th>
<th>Group End Index</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>L Leaky Silt</td>
<td>A-4</td>
<td>75 Min.</td>
<td>36 Min.</td>
<td>40 Min.</td>
<td>10 Min.</td>
<td>8</td>
<td>Less than 50% silt sizes</td>
<td></td>
</tr>
<tr>
<td>L Leaky Silt</td>
<td>A-6</td>
<td>75 Min.</td>
<td>50 Min.</td>
<td>40 Min.</td>
<td>10 Min.</td>
<td>8</td>
<td>50% or more silt sizes</td>
<td></td>
</tr>
<tr>
<td>L Leaky Silt and Clay</td>
<td>A-5</td>
<td>75 Min.</td>
<td>36 Min.</td>
<td>41 Min.</td>
<td>10 Min.</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L Leaky Silt and Clay</td>
<td>A-6</td>
<td>75 Min.</td>
<td>36 Min.</td>
<td>40 Min.</td>
<td>10 Min.</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S Silt and Clay</td>
<td>A-6</td>
<td>75 Min.</td>
<td>36 Min.</td>
<td>40 Min.</td>
<td>10 Min.</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S Silt and Clay</td>
<td>A-8</td>
<td>75 Min.</td>
<td>36 Min.</td>
<td>40 Min.</td>
<td>10 Min.</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>G2 Gritty Clay</td>
<td>A-6</td>
<td>75 Min.</td>
<td>36 Min.</td>
<td>40 Min.</td>
<td>10 Min.</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E Elastic Clay</td>
<td>A-7-6</td>
<td>75 Min.</td>
<td>36 Min.</td>
<td>41 Min.</td>
<td>10 Min.</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C Clay</td>
<td>A-7-6</td>
<td>75 Min.</td>
<td>36 Min.</td>
<td>41 Min.</td>
<td>10 Min.</td>
<td>8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Only perform the oven-dried liquid limit test and this calculation if organic material is present in the sample.

Characteristics of Clayey Soils (A-6, A-7-6)

- Feels sticky when wet
- Can be molded at a wide range of moisture contents
- Can form long ribbon when moist
- Will not wash off hands easily
- Very high strength when dried
- Can have a waxy feel (highly plastic)
- Shiny smooth surface when moist
- Does not easily disperse when worked under water
- Feels tough and stiff near the plastic limit
- Moist soil does not glisten when shaken
- Higher the plasticity the slower to dry
Field Ribbon Test (Soil Plasticity)

- Remove particles >#40 sieve (coarse sand & gravel) and make a soil pat with the consistency of putty (moist condition).
- Pat size ½-in to ¾-in diameter and 3-in to 5-in length.
- Press pat between thumb and index finger creating a ribbon ~1/8-in thickness.
- The longer the ribbon before breaking under soil’s own weight, the higher the plasticity of the soil.

- ~4-in long ribbon, or longer than original pat; A-6b or A-7-6.
- No Ribbon, or delicate, softer and easily crumble; A-4b or A-4a.
- Somewhere in between; A-6a or lower A-6b.

Field Plastic Limit

1. Select test soil at natural moisture
2. Remove any non-soil materials (i.e. rock, roots, etc.)
3. Roll sample between palms
4. Does it reach a uniform 1/8 inch diameter thread
5. Yes – above plastic limit
6. No – below plastic limit or non-plastic

- When 1/8 inch thread becomes brittle = plastic limit.
- Tougher and stiffer thread the more clayey the soils
- Organic soils feel spongy near plastic limit
Lab Plastic Limit

Moisture content (%) at which the soil can be rolled into 1/8 in diameter thread, or the boundary between semi-solid and plastic state.

<table>
<thead>
<tr>
<th>Description</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-plastic</td>
<td>A 1/8 in. thread cannot be rolled at any water content.</td>
</tr>
<tr>
<td>Low Plasticity</td>
<td>The thread can barely be rolled and the lump cannot be formed when drier than the plastic limit. (typically ~6 mm diameter @ 4 cm length)</td>
</tr>
<tr>
<td>Medium Plasticity</td>
<td>The thread is easy to roll and not much time is required to reach the plastic limit. The thread cannot be re-rolled after reaching the plastic limit. The lump crumbles when drier than the plastic limit. (typically ~4 mm diameter @ 4 cm length)</td>
</tr>
<tr>
<td>High Plasticity</td>
<td>It takes considerable time rolling and kneading to reach the plastic limit. The thread can be re-rolled several times after reaching the plastic limit. The lump can be formed without crumbling when drier than the plastic limit. (typically ~2 mm diameter @ 4 cm length)</td>
</tr>
</tbody>
</table>

Plasticity determined through Atterberg Limits:

- Liquid Limit Test (LL)
- Plastic Limit Test (PL)
Field Liquid Limit

As a soil is wetted from either a dry or natural moisture content the stickiness will indicate its relative plasticity.

Stickiness estimates the soil’s capacity to adhere to other objects. Try to utilize a moisture content that displays the maximum adherence of the soil between the thumb and index finger after it is squeezed together.

<table>
<thead>
<tr>
<th>Stickiness</th>
<th>Description</th>
<th>Relative Plasticity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-Sticky</td>
<td>Little or no Soil adheres to fingers after release of pressure. Soil adheres to both fingers after release of pressure with little stretching on separate of fingers.</td>
<td>Non-plastic</td>
</tr>
<tr>
<td>Slightly Sticky</td>
<td>Soil adheres to both fingers after release of pressure with some stretching on separation of fingers.</td>
<td>Low Plasticity</td>
</tr>
<tr>
<td>Moderately Sticky</td>
<td>Soil adheres firmly to both fingers after release of pressure with stretches greatly on separation of fingers.</td>
<td>Medium Plasticity</td>
</tr>
<tr>
<td>Very Sticky</td>
<td></td>
<td>High plasticity</td>
</tr>
</tbody>
</table>
Visual Classification Course for Geotechnical Logging of Soil and Rock Stratum

Non-Sticky (non-plastic)

Slightly Sticky (low plasticity)

Very Sticky (high plasticity)

Lab Liquid Limit

Moisture content (%) at which the soil crosses the boundary from a plastic state to a liquid state.
Plasticity Index \( (PI) = LL - PL \)

PI is the basic measure of the nature of a fine-grained soil.

Four (4) states of fine-grained soil relative to PI and moisture content:

1. Solid
2. Semi-solid
3. Plastic
4. Liquid

Field Dry Strength (Soil Plasticity)

- Remove particles >#40 sieve (coarse sand & gravel) and make a soil pat with the consistency of putty (moist condition).
- Pat size ½ -in to ¾ -in diameter and 3-in to 5-in length.
- Allow pat to dry completely.
- Break and crumble pat between the fingers.

➤ Dry strength increases with increasing soil plasticity.
ORGANICS IN SOILS EXCEPT PEAT: Describe organics by characteristics such as smell, texture, staining, color, or presence of organic material.

PEAT SOILS: Describe soils composed primarily of plant tissue in various stages of decomposition and having a fibrous to amorphous texture, a dark brown to black color, and an organic odor as a peat. Distinguish among various peat soils according to its composition, for example, woody peat, fibrous peat, sedimentary peat, fine textured peat, loamy peat, marly peat, marls, or various combinations thereof.
Characteristics of Organic Soils

- “Earthy Smell”
- Light to very light weight
- Can have unique colors (Black and dark colors common)
- May change color when fresh surface is exposed to air
- Contains plant and/or animal fragments
- Very poor strength
Primary description would be PEAT, with a secondary description (sedimentary, fibrous, woody, etc.) afterward.

<table>
<thead>
<tr>
<th>Peat Formation and Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sedimentary Peat</strong>: Open water vegetation deposited in base of pond. Typically, soft, oozy, structureless peat. Fine texture which is gelatinous when wet, hard when dry.</td>
</tr>
<tr>
<td><strong>Loamy Peat</strong>: Typically, predominately silt with varying amounts of fine sand and clay. Dry densities range between 50 and 70 pcf. Moistures between 50 and 70% and organic contents between 4 and 10%</td>
</tr>
<tr>
<td><strong>Fibrous Peat</strong>: Lattice of firm, coarse to felt fiberous and porous peat layer of plant material, stems and roots.</td>
</tr>
<tr>
<td><strong>Woody Peat</strong>: Buildup of roots, leaf litter, branches and logs in various degrees of decomposition.</td>
</tr>
</tbody>
</table>

Source: Michigan DOT; Field Manual for Soil Engineering

---

**ORGANIC CONTENT OF SOILS**

<table>
<thead>
<tr>
<th>Percentage of Organic Matter (By Weight)*</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 to 4</td>
<td>Slightly Organic</td>
</tr>
<tr>
<td>4 to 10</td>
<td>Moderately Organic</td>
</tr>
<tr>
<td>&gt;10</td>
<td>Highly Organic</td>
</tr>
</tbody>
</table>

* As Determined by LOI

➢ When Field Visual Description uses term “Moderately or Highly Organic”; verified with laboratory testing
• Organic Classification of Soil
  • Can only be classified based on Laboratory Testing
    • Air dried LL vs. Oven Dried LL

  ➢ NOT COMMON IN OHIO
      May be Classified as Peat

  ➢ A-8a if material would classify as an A-4 a or b
  ➢ A-8b if material would classify as an A-6 a or b or A-7-6

Field Estimate of Moisture Content
  “Squeeze Test” and “Ball Test”

Used to estimate the samples moisture content. Typically utilized when hand sample or auger samples are being collected due to “bulk” nature of sample amount required for test.

➢ Typically used by construction inspectors
Above Optimum (Clay)

- Stays together
- Excess moisture in hands

Above Optimum (Clay)

- Breaks apart in two pieces
- With effort
At Optimum (Sand)

- Stays together
- No excess moisture

Above Optimum (Sand)

- Stays together
- Excess moisture on hands
Ball Method

- Roll the material into a 1-inch ball
- Squeeze the ball between the thumb and forefinger

Ball Method

- Ball cannot be formed
  – Below optimum
- Breaks apart into uniform pieces
  – At optimum
  – Clays will have larger pieces than silts
Ball Method

• The ball becomes oval
• Above optimum

Visual Classification Course for Geotechnical Logging of Soil and Rock Stratum

Ball Method

• Ball cannot be formed
  – Below optimum
• Breaks apart into uniform pieces
  – At optimum
  – Clays will have larger pieces than silts

➢ DOES NOT Replace a moisture content test.
Visual Classification Course for Geotechnical Logging of Soil and Rock Stratum

**BUILDING “THE” DESCRIPTION**

Visual Classification Course for Geotechnical Logging of Soil and Rock Stratum

**ODOT SOIL SAMPLE DESCRIPTION**

1. Consistency or Compactness
2. Color
3. Primary Component (Classification)
4. Modifiers of Components
5. Supplementary Descriptive Terms
6. Water Content

**REMINDER:** CLASSIFICATION OF SOILS IS AN ITERATIVE PROCESS THROUGH THE COLLECTION OF ADDITIONAL INFORMATION!
**CONSISTENCY OR COMPACTNESS**

- **Non-cohesive Soils** are described by **Compactness**
- **Cohesive Soils** are described by **Consistency**
- **Intermediate Soils** are described based on whether they are non-cohesive or cohesive

**Relative Compactness of Non-cohesive Soils**

<table>
<thead>
<tr>
<th>Description</th>
<th>Standard Penetration; Blows per Foot, ( N_{60} )*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Loose</td>
<td>Less than 5</td>
</tr>
<tr>
<td>Loose</td>
<td>5 – 10</td>
</tr>
<tr>
<td>Medium Dense</td>
<td>11 – 30</td>
</tr>
<tr>
<td>Dense</td>
<td>30 – 50</td>
</tr>
<tr>
<td>Very Dense</td>
<td>Greater than 50</td>
</tr>
</tbody>
</table>

*Correct \( N \) value for hammer energy ratio (ER.)

\[
N_{60} = N_{\text{measured}} \times (\text{ER}/60)
\]

\( \text{ER} \) = Hammer energy ratio
Relative Consistency of Cohesive Soils

<table>
<thead>
<tr>
<th>Description</th>
<th>Unconfined Compressive Strength*; TSF</th>
<th>Standard Penetration; Blows per Foot, $N_{60}$</th>
<th>Hand Manipulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Soft</td>
<td>Less than 0.25</td>
<td>Less than 2</td>
<td>Easily penetrated 2 in. by first</td>
</tr>
<tr>
<td>Soft</td>
<td>0.25 – 0.5</td>
<td>2 – 4</td>
<td>Easily penetrated 2 in. by thumb</td>
</tr>
<tr>
<td>Medium Stiff</td>
<td>0.5 – 1.0</td>
<td>5 – 8</td>
<td>Penetrated by thumb with moderate effort</td>
</tr>
<tr>
<td>Stiff</td>
<td>1.0 – 2.0</td>
<td>9 – 15</td>
<td>Readily indented by thumb but not penetrated</td>
</tr>
<tr>
<td>Very Stiff</td>
<td>2.0 – 4.0</td>
<td>16 – 30</td>
<td>Readily indented by thumbnail</td>
</tr>
<tr>
<td>Hard</td>
<td>Greater than 4.0</td>
<td>Greater than 30</td>
<td>Indented with difficulty by thumbnail</td>
</tr>
</tbody>
</table>

* As determined by hand penetrometer or torvane test
COLOR

• Important property in identifying organic soils, and it may also be useful in identifying materials of similar geologic origin within a given locality.
• Soil Color will change with moisture conditions.
• Primary Color should be used (brown, gray, black, red...).
• Soils with different shades or tints of basic colors are described using two basic colors (grayish brown, brownish gray, etc...).
• Non-organic soil colors are associated with the presence, absence, or oxygenation of iron minerals.
• Gray soil indicate that the surface particles have not reacted with oxygen.
• Yellow and brown soils will become gray over time in anaerobic conditions.

The soil color of the upper aerated profile will typically be brown to yellowish brown.
The soil color below the groundwater table will be typically more gray.
A profile of clay soils typically goes from brown near the surface and fade to gray with depth due to the lack of oxygen.
Sand colors are not typically affect by moisture.

Example of Munsell Soil Color Chart
(Over 1600 color options)
Required for USDA: Chroma, Value, Hue
NOT REQUIRED by AASHTO
Standard set contain 322 colors
Visual Classification Course for Geotechnical Logging of Soil and Rock Stratum

Example of Mottled Soil

By: Peter Flecher
US Dept. of Agriculture
Soil Conservation Services

Visual Classification Course for Geotechnical Logging of Soil and Rock Stratum

**PRIMARY COMPONENT**

- Primary material encountered.
- Determined by the ODOT Soil Classification Chart
- Given a letter-number code designation
  example: Gravel (A-1-a)
  Silt (A-4b)
  Clay (A-7-6)
### USCS Comparison to AASHTO

<table>
<thead>
<tr>
<th>Fines</th>
<th>Grain</th>
<th>Type of Grains</th>
<th>Group Symbol</th>
<th>Sand/Gravel</th>
<th>Group Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 5%</td>
<td>Clay</td>
<td>P.O. Sand</td>
<td>GW</td>
<td>&lt; 15% sand</td>
<td>WELL-COMPAKED SAND</td>
</tr>
<tr>
<td></td>
<td>Clay</td>
<td>P.O. Sand</td>
<td>GP</td>
<td>&lt; 15% sand</td>
<td>POORLY GRADED SAND</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Silt</td>
<td>GW-SP</td>
<td>&lt; 15% silt</td>
<td>WELL-GRADED SAND WITH SILT</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Silt</td>
<td>GP-SP</td>
<td>&lt; 15% silt</td>
<td>POORLY GRADED SAND WITH SILT</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Silty</td>
<td>GW-SI</td>
<td>&lt; 15% silty</td>
<td>WELL-GRADED SAND WITH SILTY</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Silty</td>
<td>GP-SI</td>
<td>&lt; 15% silty</td>
<td>POORLY GRADED SAND WITH SILTY</td>
</tr>
<tr>
<td>&lt; 5%</td>
<td>Clay</td>
<td>P.O. Sand</td>
<td>GW-NW</td>
<td>&lt; 15% sand</td>
<td>WELL-COMPAKED SAND</td>
</tr>
<tr>
<td></td>
<td>Clay</td>
<td>P.O. Sand</td>
<td>GP-NW</td>
<td>&lt; 15% sand</td>
<td>POORLY GRADED SAND</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Silt</td>
<td>GW-SPN</td>
<td>&lt; 15% silt</td>
<td>WELL-GRADED SAND WITH SILT</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Silt</td>
<td>GP-SPN</td>
<td>&lt; 15% silt</td>
<td>POORLY GRADED SAND WITH SILT</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Silty</td>
<td>GW-SIP</td>
<td>&lt; 15% silty</td>
<td>WELL-GRADED SAND WITH SILTY</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Silty</td>
<td>GP-SIP</td>
<td>&lt; 15% silty</td>
<td>POORLY GRADED SAND WITH SILTY</td>
</tr>
</tbody>
</table>

**USCS Granular Soils**

*USCS Granular Soils* are defined as having less than 50% passing 200 sieve. Only the granular soils are used in this comparison. **NO**
### USCS Comparison to AASHTO

<table>
<thead>
<tr>
<th>Group Symbol</th>
<th>clay</th>
<th>cohesiveness</th>
<th>sand or gravel</th>
<th>Group Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>CL ≤25% plus No.200</td>
<td>&lt;15% clay to 200</td>
<td>% sand + % gravel</td>
<td>Silt or gravel</td>
<td>CLY CLAY</td>
</tr>
<tr>
<td>≥25% plus No.200</td>
<td>% sand + % gravel</td>
<td>3 to 15% clay</td>
<td>CLY SANDY CLAY</td>
<td></td>
</tr>
<tr>
<td>CL ≥15% plus No.200</td>
<td>% sand + % gravel</td>
<td>&gt;30% sand to 200</td>
<td>CLY GRAVELY CLAY</td>
<td></td>
</tr>
<tr>
<td>&gt;25% plus No.200</td>
<td>% sand + % gravel</td>
<td>&gt;30% sand to 200</td>
<td>CLY SANDY CLAY</td>
<td></td>
</tr>
</tbody>
</table>

### Organic Content of Soils

#### Visual Classification Course for Geotechnical Logging of Soil and Rock Stratum

<table>
<thead>
<tr>
<th>Organic Matter (By Weight)*</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 to 4</td>
<td>Slightly Organic</td>
</tr>
<tr>
<td>4 to 10</td>
<td>Moderately Organic</td>
</tr>
<tr>
<td>&gt;10</td>
<td>Highly Organic</td>
</tr>
</tbody>
</table>

* As Determined by LOI
Supplementary Descriptive Terms: Use supplemental descriptive terms for additional information when appropriate, such as: glacial till, alluvial, residual.

DO NOT use: well-graded, uniform, gap-graded (USCS descriptions which not correspond within the ODOT Classification system.

Use secondary descriptive terms such as: a description of foreign material, organic odor, fissures, voids or cavities, staining, or lenses.

Denote isolated areas (such as lenses) with @ and depths!
Gypsum: Visually inspect for the presence of gypsum crystals within the soil matrix or within natural soil fractures.

Moisture Content Description of Soil

<table>
<thead>
<tr>
<th>Term</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry</td>
<td>• Soil leaves no moisture when pressed between fingers.</td>
</tr>
<tr>
<td></td>
<td>• For cohesive soils, is brittle to powdery.</td>
</tr>
<tr>
<td></td>
<td>• Water content well below the plastic limit</td>
</tr>
<tr>
<td>Damp</td>
<td>• Soil leaves very little moisture when pressed between fingers.</td>
</tr>
<tr>
<td></td>
<td>• Soil contains a small amount of moisture.</td>
</tr>
<tr>
<td></td>
<td>• Water content below the plastic limit.</td>
</tr>
<tr>
<td>Moist</td>
<td>• Soil leaves small amount of moisture when pressed between fingers.</td>
</tr>
<tr>
<td></td>
<td>• Water content above the plastic limit to -3% of the liquid limit.</td>
</tr>
<tr>
<td>Wet</td>
<td>• For cohesive soils, the water content is near or above the liquid limit.</td>
</tr>
<tr>
<td></td>
<td>• For granular soils, the pore space is filled with water and water can be poured from sample with ease.</td>
</tr>
</tbody>
</table>
EXAMPLES

FIELD PROPERTIES

<table>
<thead>
<tr>
<th>Field Property</th>
<th>Example #1</th>
<th>Example #2</th>
</tr>
</thead>
<tbody>
<tr>
<td>N60 Value</td>
<td>25</td>
<td>15</td>
</tr>
<tr>
<td>Color</td>
<td>Brown</td>
<td>Mottled brown and yellow</td>
</tr>
<tr>
<td>Gradation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Passing #10</td>
<td>~80-85% est. - rounded</td>
<td>~85% est. – angular</td>
</tr>
<tr>
<td>Passing #40</td>
<td>Most (~65% est.)</td>
<td>~75% est.</td>
</tr>
<tr>
<td>Passing #200</td>
<td>Very little (&lt;10% est)</td>
<td>Majority (~70% est)</td>
</tr>
<tr>
<td>Hand Penetrometer</td>
<td>NA (non-cohesive)</td>
<td>2.25</td>
</tr>
<tr>
<td>Field Plasticity and Liquidity Tests</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Does not ribbon</td>
<td>• Very Sticky</td>
<td></td>
</tr>
<tr>
<td>• Gritty feel</td>
<td>• Somewhat waxy feel</td>
<td></td>
</tr>
<tr>
<td>• Small Grains visible</td>
<td>• ~ 4” Ribbons</td>
<td></td>
</tr>
<tr>
<td>Moisture Content</td>
<td>free water in spoon</td>
<td>Leaves moisture on hand when squeezed</td>
</tr>
</tbody>
</table>
**Field or Laboratory Visual Classification**

**Example #1:**
- Medium dense, brown SAND, little to some gravel, trace silt and clay, wet.

**LABORATORY TESTING DATA**

<table>
<thead>
<tr>
<th></th>
<th>Example #1</th>
<th>Example #2</th>
</tr>
</thead>
<tbody>
<tr>
<td>N60 Value</td>
<td>25</td>
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</tr>
<tr>
<td>Gradation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Passing #10</td>
<td>81</td>
<td>87</td>
</tr>
<tr>
<td>Passing #40</td>
<td>68</td>
<td>78</td>
</tr>
<tr>
<td>Passing #200</td>
<td>9</td>
<td>68</td>
</tr>
<tr>
<td>Hand Penetrometer</td>
<td>NA</td>
<td>2.25</td>
</tr>
<tr>
<td>LL/PI</td>
<td>Non Plastic</td>
<td>38/20</td>
</tr>
<tr>
<td>Moisture Content</td>
<td>25 (free water in spoon)</td>
<td>30</td>
</tr>
</tbody>
</table>
Example #1 Visual Classification:
➢ Medium dense, brown SAND, little to some gravel, trace silt and clay, wet.

Example #1 Classification:
➢ Medium dense, brown FINE SAND (A-3a), some gravel, trace silt and clay, wet.

<table>
<thead>
<tr>
<th>FIELD PROPERTIES</th>
<th>Example #1</th>
<th>Example #2</th>
</tr>
</thead>
<tbody>
<tr>
<td>N60 Value</td>
<td>25</td>
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<td>Brown</td>
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<td>Gradation</td>
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</tr>
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<td>~80-85% est. – rounded</td>
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</tr>
<tr>
<td>Moisture Content</td>
<td>free water in spoon</td>
<td>Leaves moisture on hand when squeezed</td>
</tr>
</tbody>
</table>
Field or Laboratory Visual Classification

Example #2:
- Very stiff, mottled brown and yellow, CLAY, some sand, little to some stone fragments, moist.

<table>
<thead>
<tr>
<th></th>
<th>Example #1</th>
<th>Example #2</th>
</tr>
</thead>
<tbody>
<tr>
<td>N60 Value</td>
<td>25</td>
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<tr>
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<td>Brown</td>
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<td></td>
</tr>
<tr>
<td>Passing #10</td>
<td>81</td>
<td>87</td>
</tr>
<tr>
<td>Passing #40</td>
<td>68</td>
<td>78</td>
</tr>
<tr>
<td>Passing #200</td>
<td>8</td>
<td>68</td>
</tr>
<tr>
<td>Hand Penetrometer</td>
<td>NA</td>
<td>2.25</td>
</tr>
<tr>
<td>LL/PI</td>
<td>Non Plastic</td>
<td>38/20</td>
</tr>
<tr>
<td>Moisture Content</td>
<td>25</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>(free water in spoon)</td>
<td></td>
</tr>
</tbody>
</table>
Example #2 Visual Classification:
 Very stiff, mottled brown and yellow, CLAY, some sand, little to some stone fragments, moist.

Example #2 Classification:
 Very stiff, mottled brown and yellow SILTY CLAY (A-6b), some sand, little stone fragments, moist.

UNSUITABLE MATERIALS:

SUBGRADE (WITHIN 3 FEET)
 A-2-5
 A-2-7
 A-4b
 A-5
 A-8 a or b
 LL >65
 RACP
 BEDROCK (INCLUDING SHALE AND COAL)

EMBANKMENT – SEE CMS 203.03 FOR RESTRICTIONS
Visual classification course for geotechnical logging of soil and rock stratum

?QUESTIONS?

Photo from ODNR Geological Survey
Visual Classification Course for Geotechnical Logging of Soil and Rock Stratum

ROCK MASS CLASSIFICATION HAS BEEN ATTEMPTED FOR OVER 100 YEARS

- Ritter (1879) – Tunnel Design
- Terzaghi (1946) – Tunnel Design
- Lauffer (1958) – Tunnel Design
  (modified into New Austrian Tunnelling Method)
- Deere et al (1967) – Rock Quality Designation Index (RQD)
- Wickham et al (1972) – Rock Structure Rating (RSR)
- Bieniawski (1976) – Geomechanics Classification
  - or Rock Mass Rating (RMR)
- Cummings et al (1982) – Modified Basic RMR (MBR)
- Hoek (1995) – Geologic Strength Index (GSI)

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➢ ODOT Utilizes a modified RMR/GSI system for rock classification

ODOT looks at Rock Classification as a Tiered process with the level of detail within the description relative to the type of project for which the boring is being drilled.

➢ Why is the boring being drilled?
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Sample Collection

**ODOT Typically Collects Geotechnical Rock Samples through 3 methods:**

1. Drill Rig
2. Test Pit
3. Hand Methods

**Each Method Provides Samples requiring Visual Classification**

- Additionally, Visual Classification of bedrock is also necessary when rock outcrops are involved in a project.

---

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**Rock Core can be obtained in various size which are designated by a letter code:**

<table>
<thead>
<tr>
<th>Core Designation</th>
<th>Core Size*</th>
<th>Inches</th>
<th>mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1</td>
<td>27</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>1.5</td>
<td>36.5</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>2</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>H</td>
<td>2.5</td>
<td>63.5</td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>3.25</td>
<td>85</td>
<td></td>
</tr>
</tbody>
</table>

* Core size will vary on the drilling method (ie standard, double tube wireline, triple tube wireline)

---

**Most geotechnical explorations into bedrock are completed utilizing N-series core equipment.**
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LITHOLOGY: Determine the type of in-place bedrock based upon its physical characteristics. Try to determine a Bedrock Unit versus possibly individual lithological units.

The primary bedrock types encountered in Ohio are:

- Claystone (Mudstone),
- Coal,
- Underclay
- Dolomite,
- Limestone,
- Sandstone,
- Shale,
- Siltstone,
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**CLAYSTONE**
A fine-grained rock formed of at least 75% clay sized particles. Claystone is comprised of lithified clay having the texture and composition of shale, but lacking the laminations and fissility of a shale. Generally has a blocky, thick to massive appearance. Claystone may range in color from red, gray, olive, yellow, or brown with multiple colors typical. Slickensides are commonly found within claystone.

**COAL**
A combustible substance containing more than 50%, by weight, and more than 70%, by volume, of carbonaceous material; formed from the compaction and lithification of plant remains. Colors of coals range from brown to black. It is generally light weight with a shiny appearance on fresh surfaces.

**UNDERCLAY**
A layer of clay lying immediately beneath a coal bed or carbonaceous shale. This layer may be bioturbated and indurated or lithified. It is chiefly comprised of siliceous or aluminous clay capable of withstanding high temperatures without deformation, and may have a high shrink/swell potential.
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DOLOMITE
A sedimentary rock of which more than 50% consists of the mineral dolomite (calcium magnesium carbonate – CaMg(CO3)2) and less than 10% is comprised of the mineral calcite. It is commonly interbedded with limestone, and the magnesium can be replaced with ferrous iron. Dolomite typically has a hardness of 3.5 to 4, colors ranging from white to light gray and will weakly react with cold dilute HCl on fresh or powdered surfaces.

LIMESTONE
A sedimentary rock consisting of the mineral calcite (calcium carbonate – CaCO3). Impurities may include chert, clay and minor mineral crystals. It may be crystalline (hard, pure, fine to coarse texture) with very fine grains not visible to the naked eye and/or fossiliferous (contains remains of organisms). Limestone is typically white to dark gray in color with a hardness of 3.5 to 4.0 and reacts vigorously with cold dilute HCl.
SANDSTONE
A sedimentary rock comprised of grains of angular or rounded sand in a matrix of silt and/or clay cemented together by silica, iron oxides, or calcium carbonate. Sandstones may be composed of up to 25% of particles of gravel, cobbles, and/or boulders sizes. Color depends on the cementing agent with white, gray, yellow, orange, brown, and red colors common.

SHALE
A fine-grained sedimentary rock formed by the lithification of clay, silt or mud (predominate particle size is less than 0.002 mm). Shale has a laminated structure, which gives it fissility along which the rock splits readily. Shale is commonly interbedded with sandstone or limestone. Carbonaceous shale often grades into coal. Typical colors may be red, brown, black, green or gray.
**SILTSTONE**

A fine-grained sedimentary rock formed from particles finer than sand, but coarser than clay. Siltstone is comprised of lithified silt and lacks lamination or fissility. Typical colors may be gray, olive, or brown. Generally, siltstone has a fine grit feeling when rubbed against teeth.

If repeating lithologies in thin units use the term “Interbedded” and describe each lithologic unit.

- **Interbedded Shale** (70%) and **Limestone** (30%), Unit RQD 50%, Unit Recovery 10%;
- **Shale**, gray, moderately weathered, weak, laminated, calcareous; ranges in thickness from 3” to 26”;
- **Limestone**, light gray, slightly weathered, moderately hard, thin bedded, fossiliferous; ranges in thickness from 2” to 8”.
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**NOTE:** REMEMBER THIS IS FOR AN ENGINEERING DESIGN NOT A GEOLOGICAL RESEARCH PROJECT.

**COLOR:** IMPORTANT PROPERTY IN IDENTIFYING ORGANIC MATERIALS, AND IT MAY ALSO BE USEFUL IN IDENTIFYING MATERIALS OF SIMILAR GEOLOGIC ORIGIN WITHIN A GIVEN LOCALITY

Variegated: Contains two distinct colors intermingled or "swirled" together.
Visual Classification Course for Geotechnical Logging of Soil and Rock Stratum

<table>
<thead>
<tr>
<th>Description</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unweathered</td>
<td>No evidence of any chemical or mechanical alternation of the rock mass. Mineral crystals have a bright appearance with no discoloration. Fractures show little or no staining on surfaces.</td>
</tr>
<tr>
<td>Slightly Weathered</td>
<td>Slight discoloration of the rock surface with minor alterations along discontinuities. Less than 10 percent of the rock volume presents alteration.</td>
</tr>
<tr>
<td>Moderately Weathered</td>
<td>Portions of the rock mass are discolored as evident by a dull appearance. Surfaces may have a pitted appearance with weathering “halos” evident. Isolated zones of varying rock strengths due to alteration may be present. 10 to 15 percent of the rock volume presents alterations.</td>
</tr>
<tr>
<td>Highly Weathered</td>
<td>Entire rock mass appears discolored and dull. Some pockets of slightly to moderately weathered rock may be present and some areas of severely weathered materials may be present.</td>
</tr>
<tr>
<td>Severely Weathered</td>
<td>Majority of the rock mass reduced to a soil-like state with relic rock structure discernable. Zones of more resistant rock may be present, but the material can generally be molded and crumbled by hand pressures.</td>
</tr>
</tbody>
</table>

**Strength of Bedrock**

<table>
<thead>
<tr>
<th>Description</th>
<th>Field Parameters</th>
<th>Unconfined Compressive Strength psi (ksf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Weak</td>
<td>Can be carved with a knife. Can be excavated readily with a point of a pick. Pieces 1 inch (25 mm) or more in thickness can be broken by finger pressure. Can be scratched by fingernail.</td>
<td>40 to 750 (6 to 108)</td>
</tr>
<tr>
<td>Weak</td>
<td>Can be grooved or gouged readily by a knife or pick. Can be excavated in small fragments by moderate blows of a pick point. Small, thin pieces can be broken by finger pressure.</td>
<td>750 to 1500 (108 to 215)</td>
</tr>
<tr>
<td>Slightly Strong</td>
<td>Can be grooved or gouged 0.05 inch (2 mm) deep by firm pressure of a knife or pick point. Can be excavated in small chips to pieces about 1-inch (25 mm) maximum size by hard blows of the point of a geologist’s pick.</td>
<td>1500 to 3600 (215 to 520)</td>
</tr>
<tr>
<td>Moderately Strong</td>
<td>Can be scratched with a knife or pick. Grooves or gouges to ¼ (6mm) deep can be excavated by hand blows of a geologist’s pick. Requires moderate hammer blows to detach hand specimen.</td>
<td>3600 to 7500 (520 to 1080)</td>
</tr>
<tr>
<td>Strong</td>
<td>Can be scratched with a knife or pick only with difficulty. Requires hard hammer blows to detach hand specimen. Sharp and resistant edges are present on hand specimen.</td>
<td>7500 to 15,000 (1080 to 2160)</td>
</tr>
<tr>
<td>Very Strong</td>
<td>Cannot be scratched by a knife or sharp pick. Breaking of hand specimens requires hard repeated blows of the geologist hammer.</td>
<td>15,000 to 30,000 (2160 to 4320)</td>
</tr>
<tr>
<td>Extremely Strong</td>
<td>Cannot be scratched by a knife or sharp pick. Chipping of hand specimens requires hard repeated blows of the geologist hammer.</td>
<td>Greater than 30,000 (&gt; 4320)</td>
</tr>
</tbody>
</table>
### Visual Classification Course for Geotechnical Logging of Soil and Rock Stratum

<table>
<thead>
<tr>
<th>COMPONENT</th>
<th>PARTICLE SIZE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boulder</td>
<td>Larger than 12 in.</td>
</tr>
<tr>
<td>Cobble</td>
<td>3 in. to 12 in.</td>
</tr>
<tr>
<td>Gravel</td>
<td>0.08 in. to 3 in.</td>
</tr>
<tr>
<td>Coarse</td>
<td>0.02 in. to 0.08 in.</td>
</tr>
<tr>
<td></td>
<td>(#35 to #10 sieve)</td>
</tr>
<tr>
<td>Medium</td>
<td>0.01 in. to 0.02 in.</td>
</tr>
<tr>
<td></td>
<td>(#60 to #35 sieve)</td>
</tr>
<tr>
<td>Fine</td>
<td>0.005 in. to 0.01 in.</td>
</tr>
<tr>
<td></td>
<td>(#120 to #60 sieve)</td>
</tr>
<tr>
<td>Very Fine</td>
<td>0.003 in. to 0.003 in.</td>
</tr>
<tr>
<td></td>
<td>(#200 to #120 sieve)</td>
</tr>
</tbody>
</table>
### Bedding Thickness of Bedrock

<table>
<thead>
<tr>
<th>Description</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Thick</td>
<td>Greater than 36 in. (&gt; 1000 mm)</td>
</tr>
<tr>
<td>Thick</td>
<td>18 in. to 36 in. (500 mm to 1000 mm)</td>
</tr>
<tr>
<td>Medium</td>
<td>10 in. to 18 in. (250 mm to 500 mm)</td>
</tr>
<tr>
<td>Thin</td>
<td>2 in. to 10 in. (50 mm to 250 mm)</td>
</tr>
<tr>
<td>Very Thin</td>
<td>0.4 in. to 2 in. (10 mm to 50 mm)</td>
</tr>
<tr>
<td>Laminated</td>
<td>0.1 in. to 0.4 in. (2.5 mm to 10 mm)</td>
</tr>
<tr>
<td>Thinly Laminated</td>
<td>Less than 0.1 in. (&lt; 2.5 mm)</td>
</tr>
</tbody>
</table>

**Descriptors:** Use terms to describe secondary characteristics of bedrock as necessary. Use no more than three characteristics in the description.

- Arenaceous
- Argillaceous
- Brecciated
- Calcareous
- Carbonaceous
- Cherty
- Clay Seams
- Conglomeritic
- Crystalline
- Dolomitic
- Ferriferous
- Fissile
- Fossiliferous
- Friable
- Iron Stained
- Lithic
- Micaceous
- Pyritic
- Siliceous
- Stylolitic
- Vuggy

See SGE Appendix A for additional terms.
Modified RMR Description of Discontinuities

- Spread footing foundations on bedrock
- Cut Slopes partially or fully in bedrock

**DISCONTINUITIES IN BEDROCK**

<table>
<thead>
<tr>
<th>Description</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fault</td>
<td>Fracture which expresses displacement parallel to the surface that does not result in a polished surface.</td>
</tr>
<tr>
<td>Joint</td>
<td>Planar fracture that does not express displacement. Generally occurs at regularly spaced intervals.</td>
</tr>
<tr>
<td>Shear</td>
<td>Fracture which expresses displacement parallel to the surface that results in polished surfaces or slickensides.</td>
</tr>
<tr>
<td>Bedding</td>
<td>A surface produced along a bedding plane.</td>
</tr>
<tr>
<td>Contact</td>
<td>A surface produced along a metamorphic contact plane. (generally not seen in)</td>
</tr>
</tbody>
</table>
**Visual Classification Course for Geotechnical Logging of Soil and Rock Stratum**

<table>
<thead>
<tr>
<th>Description</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Joint (JT)</td>
<td>A relatively planar fracture along which there has been little or no shearing displacement.</td>
</tr>
<tr>
<td>Foliation Joint (FJ) or Bedding Joint (BJ)</td>
<td>A relatively planar fracture that is parallel to foliation or bedding along which there has been little or no shearing displacement.</td>
</tr>
</tbody>
</table>

**Visual Classification Course for Geotechnical Logging of Soil and Rock Stratum**

<table>
<thead>
<tr>
<th>Description</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Random Fracture (RF)</td>
<td>A natural break (fracture) with a generally rough, very irregular, non-planar surface which does not belong to a joint set.</td>
</tr>
<tr>
<td>Mechanical Break (MB)</td>
<td>A break due to drilling, blasting, or handling. Mechanical breaks parallel to bedding or foliation are called <em>Bedding Breaks</em> (BB) or <em>Foliation Breaks</em> (FB), respectively. Recognizing mechanical breaks may be difficult. The absence of oxidation, staining, or mineral fillings, and often a hackly or irregular surface are clues for recognition.</td>
</tr>
</tbody>
</table>
Discontinuities in Bedrock – Degree of Fracturing

<table>
<thead>
<tr>
<th>Description</th>
<th>Spacing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unfractured</td>
<td>Greater than 10 ft.</td>
</tr>
<tr>
<td>Intact</td>
<td>3 ft. to 10 ft.</td>
</tr>
<tr>
<td>Slightly Fractured</td>
<td>1 ft. to 3 ft.</td>
</tr>
<tr>
<td>Moderately Fractured</td>
<td>4 in. to 12 in.</td>
</tr>
<tr>
<td>Fractured</td>
<td>2 in. to 4 in.</td>
</tr>
<tr>
<td>Highly Fractured</td>
<td>Less than 2 in.</td>
</tr>
</tbody>
</table>

Note: to describe the bedrock as Unfractured more than one core run is necessary.

CONDITION OF FRACTURES IN BEDROCK

<table>
<thead>
<tr>
<th>Description</th>
<th>Aperture Width</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open</td>
<td>Greater than 0.2 in.</td>
</tr>
<tr>
<td>Narrow</td>
<td>0.05 in. to 0.2 in.</td>
</tr>
<tr>
<td>Tight</td>
<td>Less than 0.05 in.</td>
</tr>
</tbody>
</table>

SURFACE ROUGHNESS

<table>
<thead>
<tr>
<th>Description</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Rough</td>
<td>Near vertical steps and ridges occur on the discontinuity surface</td>
</tr>
<tr>
<td>Slightly Rough</td>
<td>Asperities on the discontinuity surface are distinguishable and can be felt.</td>
</tr>
<tr>
<td>Slickensided</td>
<td>Surface has a smooth, glassy finish with visual evidence of striations.</td>
</tr>
</tbody>
</table>
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- **APERTURE/OPENNESS**
  - **PERPENDICULAR DISTANCE SEPARATING ADJACENT ROCK WALLS OF AN OPEN DISCONTINUITY**
  - **IT IS UNLIKELY THAT AN ACTUAL APERTURE CAN BE OBSERVED AND MEASURED IN CORE**

- **_FILLING THICKNESS**
  - **PERPENDICULAR DISTANCE SEPARATING ADJACENT ROCK WALLS OF A FILLED DISCONTINUITY**

**TERMINOLOGY:**

- **SLICKENSIDED (POLISHED):** EXTREMELY SMOOTH AND SHINY
- **SLIGHTLY ROUGH:** SMALL ASPERITIES ARE VISIBLE AND CAN BE FELT, MOST EXTEND < 0.5 MM
- **VERY ROUGH:** LARGE, ANGULAR ASPERITIES CAN BE SEEN, MOST EXTEND > 2 MM
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**GSI DESCRIPTION OF DISCONTINUITIES**

- Drilled Shaft Foundations in Bedrock
- Cut Slopes Partially or Fully in Bedrock

**GEOLOGIC STRENGTH INDEX (GSI)**

INTRODUCED JULY 2014
### GSI Description: Structure

<table>
<thead>
<tr>
<th>Description</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intact or Massive</td>
<td>Intact rock with few widely spaced discontinuities</td>
</tr>
<tr>
<td>Blocky</td>
<td>Well interlocked undisturbed rock mass consisting of cubical blocks</td>
</tr>
<tr>
<td></td>
<td>formed by three interesting discontinuity sets</td>
</tr>
<tr>
<td>Very Blocky</td>
<td>Interlocked, partially disturbed mass with multi-faceted angular blocks</td>
</tr>
<tr>
<td></td>
<td>formed by 4 or more joint sets</td>
</tr>
<tr>
<td>Blocky/Disturbed/Seamy</td>
<td>Angular blocks formed by many intersecting discontinuity sets,</td>
</tr>
<tr>
<td></td>
<td>Persistence of bedding planes</td>
</tr>
<tr>
<td>Disintegrated</td>
<td>Poorly interlocked, heavily broken rock mass with mixture of angular</td>
</tr>
<tr>
<td></td>
<td>and rounded rock pieces</td>
</tr>
<tr>
<td>Laminated/Sheared</td>
<td>Lack of blockiness due to close spacing of weak shear planes</td>
</tr>
</tbody>
</table>

### GSI Description: Structure

<table>
<thead>
<tr>
<th>Description</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Good</td>
<td>Very rough, fresh unweathered surfaces</td>
</tr>
<tr>
<td>Good</td>
<td>Rough, slightly weathered, iron stained surface</td>
</tr>
<tr>
<td>Fair</td>
<td>Smooth, moderately weathered and altered surfaces</td>
</tr>
<tr>
<td>Poor</td>
<td>Slickensided, highly weathered surface with compact coatings or fillings or angular fragments</td>
</tr>
<tr>
<td>Very Poor</td>
<td>Slickensided, highly weathered surfaces with soft clay coating or fillings</td>
</tr>
</tbody>
</table>
ROCK QUALITY DESIGNATION (RQD): The Rock Quality Designation, RQD, is an index of fracture frequency. Determine the RQD value for each core run (Run RQD) and for the total length of each bedrock unit encountered by a boring (Unit RQD).

The RQD value is calculated by adding up the total length of each rock core piece which is 4 inches (100 millimeters), or longer, and dividing by the total length of the core run or total rock unit thickness. The value is expressed as a percentage. Take measurements along the centerline axis of the core. Consider only natural fractures for the RQD determination, discounting mechanical breaks resulting from the drilling operations or transport of the core. Consider fractures that cannot be determined to be either mechanical or natural to be natural.

Applies to NQ, NX and PQ holes (1.87”, 2.16”, and 3.35”)

\[ RQD = \left( \frac{\sum \text{Length of Pieces > 4 inches}}{\text{Total Length of Core}} \right) \times 100 \]

\[ RQD = \left( \frac{25 + 33 + 20 + 12}{120} \right) \times 100 = 75\% \]
MECHANICAL BREAKAGE:

- Fresh, rough, unweathered surface
- Very good fit between core pieces
- No staining
- "Spin" marks where the core was staying stationary while barrel was still rotating
- "Hackel Plum" fracturing
- If you break it to fit in the core box it is mechanical
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- Measure RQD during the drilling operations as soon as possible after core run.

- RQD can change over time due to:
  - Poor curatorial handling
  - Slaking
  - Dessication
  - Stress Relief
  - Swelling

\[
\text{RQD} = \left( \frac{97}{120} \right) \times 100 = 81\%
\]
Core Recovery: Calculate recovery within each core run (Run Recovery) and for each rock unit (Unit Recovery). Calculate the recovery, expressed as a percentage, by the following equations:

\[
\text{Unit Recovery} = \left( \frac{R_U}{L_U} \right) \times 100
\]

\[
\text{Run Recovery} = \left( \frac{R_R}{L_R} \right) \times 100
\]

Where:

- \( L_U \) = Length (thickness) of bedrock unit
- \( L_R \) = Length of core run
- \( R_U \) = Length of recovered core from bedrock unit
- \( R_R \) = Length of recovered core from core run

Rock Core Photographs

Obtain a digital photograph of each core run after placing in the box, looking directly down onto the core. Take a sufficient number of photographs of each box of core to depict the pertinent characteristics of the rock, including any necessary close-up photographs. Wet the rock to enhance the color contrast of the core. Include the project, boring, and rock core run information and a legible scale in each photograph.
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Rock Core Photographs
Core Preservation and Handling

- Preservation based on anticipated testing requirements
  - Follow ASTM D 5079, Paragraph 7.5.2 (no wax)
  - Block voids in box (wood block, foam spacers, etc.)
- Attempt to minimize shock or vibration while transporting (bumps and sharp turns resulting in the core banging around)

Core Preservation and Handling

- Follow ASTM D 5079, Paragraph 7.5.2 (Special Care)
  1. Wrap core tightly with plastic wrap (e.g. Saran Wrap)
  2. Make sure no air bubbles are trapped in wrapping
  3. Tightly place a layer of aluminum foil over the plastic wrap
  4. Make sure no air bubbles are trapped in wrapping
  5. Do not place microcrystalline wax over the aluminum foil, unless the samples are very moisture critical.

Can use polyethylene plastic tubing instead of aluminum foil
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Visual Classification Course for Geotechnical Logging of Soil and Rock Stratum

**QUESTIONS?**

Visual Classification Course for Geotechnical Logging of Soil and Rock Stratum

**LOGGING OF GEOTECHNICAL BORINGS:**

- FIELD OPERATIONS
- FINAL LOGS
FIELD OPERATIONS

✓ Field Logger must collect and record data that can only be obtained during the field operations ….. If you do not record the information then it will be lost! This information can be referred to as Fugitive Data.

❖ Fugitive: fleeting; transitory; elusive.

EXAMPLES OF FUGITIVE DATA:

✓ Water levels
  • When was water first encountered
  • Heaving sand/elevated head pressures
  • Water level prior to introduction of drill water
  • Water level at completion
✓ Loss/gain of drilling fluid
  • Depth of loss/gain and full recovery
  • If partial loss, estimate percentage of loss
✓ Rod/tool drops
  • Depth drop occurred and length of drop
✓ Drilling fluid color
  • Clear, cloudy, milky, gray, brown
✓ Water pressure or down pressure
EXAMPLES OF FUGITIVE DATA (CONT):

- Cuttings
  - No cutting returns
  - Poor cutting return
  - Unusual cuttings
- Changes in drilling rates
  - Augers or core steel advancing faster or slower
  - Rig motor bogging down
- Bit/rig chatter
- Issues with core handling
  - Difficulty in removing core from barrel
  - Accidents while placing in box
  - Accidents with core boxes
  - Core breaks for box placement

- Obstacles encountered
  - Boulder or cobbles
  - Buried structure
  - Caving materials
  - Squeezing ground
- Surface material & thickness
  - Pavement (asphalt or concrete)
  - Aggregate
  - Topsoil
- Drillers comments
- Other
WHAT DO YOU MEAN THERE WAS **NO REPORTED** WATER DURING DRILLING?!

BORING BACKFILL/ABANDONMENT

- How was the boring completed?
  - Abandoned and/or grouted;
  - Instrumentation installed;
    - Piezometer/Monitoring Well
    - Inclinometer
    - TDR Cable
    - Other
  - Instrumentation grout

- Material and quantities need recorded on field log or on appropriate recording keeping forms.
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Typical Pavement Design/Buildup

- Asphalt Wearing Course
- Asphalt Intermediate Course
- Asphalt Base Course
- Aggregate Base
- Subbase

Asphalt
Aggregate
ODOT Soil Class
Common Man-made Products

- **Coal By-Products:** Fly ash, Bottom ash, Boiler Slag
- **Steel By-Products:** Slag: wide variety of appearances and properties depending on mill generated from. Typically, has air bubbles (vesicular texture) present to identify it as slag. Common in east and northeastern Ohio. Older materials can be cemented together.
- **Recycled Portland Cement Concrete (RPCC):** Visually identifiable based on stone and cement fragments within the aggregate. Typically has a light gray to brownish gray color. Will react with HCL

- **Crushed Asphalt Pavement (RACP):** Visually identifiable from its black aggregate with asphalt appearance. Typically found as a subbase or mixed with soil as an embankment fill.
- **Haydite:** Manufactured burnt shale – light weight fill.
- **Foundry Sand:** By-product of metal processing. Sand is coated with bentonite clay or chemical resins. Foundry sand is darker in appearance from natural sands. May have unusual colors.
- **Limestone (CCS):** Crushed limestone (or dolostone) is the most common aggregate base used by ODOT.
### Visual Classification Course for Geotechnical Logging of Soil and Rock Stratum

<table>
<thead>
<tr>
<th>No.</th>
<th>Sampled</th>
<th>Material Description and Notes</th>
<th>Color</th>
<th>Texture</th>
<th>Compaction/Consistency</th>
<th>Color</th>
<th>Texture</th>
<th>Compaction/Consistency</th>
<th>Notes</th>
<th>Wangdang</th>
<th>Others' Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>Soft gray clay (1-10), some silt, wet</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>2</td>
<td>1</td>
<td>Dull gray sand (8-3), some silt, wet</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>5</td>
<td>1</td>
<td>Black, some silt, clay (4), some silt, wet</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>Black, some silt, clay (5), some silt, wet</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes:
- Soft gray clay: Soft and easily compressed, wet.
- Dull gray sand: Gray, fine-grained, slightly to moderately compacted, wet.
- Yellow, some silt, clay: Yellowish, contains silt and clay, moderately compacted, wet.
- Black, some silt, clay: Black, contains silt and clay, moderately to densely compacted, wet.

### Visual Classification Course for Geotechnical Logging of Soil and Rock Stratum

<table>
<thead>
<tr>
<th>No.</th>
<th>Sampled</th>
<th>Material Description and Notes</th>
<th>Color</th>
<th>Texture</th>
<th>Compaction/Consistency</th>
<th>Color</th>
<th>Texture</th>
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<th>Notes</th>
<th>Wangdang</th>
<th>Others' Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>Soft gray clay (1-10), some silt, wet</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>2</td>
<td>1</td>
<td>Dull gray sand (8-3), some silt, wet</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>Yellow, some silt, clay (2), some silt, wet</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>Black, some silt, clay (3), some silt, wet</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>Black, some silt, clay (4), some silt, wet</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>Black, some silt, clay (5), some silt, wet</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes:
- Soft gray clay: Soft and easily compressed, wet.
- Dull gray sand: Gray, fine-grained, slightly to moderately compacted, wet.
- Yellow, some silt, clay: Yellowish, contains silt and clay, moderately compacted, wet.
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Visual Classification Course for Geotechnical Logging of Soil and Rock Stratum
### Visual Classification Course for Geotechnical Logging of Soil and Rock Stratum

**Table:**

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Depth</th>
<th>Materials</th>
<th>Quantities</th>
<th>Units</th>
<th>Method</th>
<th>Instrumentation</th>
<th>Additional Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/24/15</td>
<td>1:50</td>
<td>3.4</td>
<td>Sandstone</td>
<td>2</td>
<td>Yd</td>
<td>Yd</td>
<td>GPS Fix.</td>
<td>Crew Chief Signature</td>
</tr>
<tr>
<td>3/24/15</td>
<td>1:45</td>
<td>6.5</td>
<td>Shale</td>
<td>2</td>
<td>Yd</td>
<td>Yd</td>
<td>GPS Fix.</td>
<td>Crew Chief Signature</td>
</tr>
</tbody>
</table>

**Description:**

<table>
<thead>
<tr>
<th>Depth</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.4</td>
<td>Sandstone, brown sand, clayey silt, medium hardness</td>
</tr>
<tr>
<td>6.5</td>
<td>Shale, light gray, fine sand, clayey silt, medium hardness</td>
</tr>
</tbody>
</table>

---

**Table:**

<table>
<thead>
<tr>
<th>Depth</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.4</td>
<td>Sandstone, brown sand, clayey silt, medium hardness</td>
</tr>
<tr>
<td>6.5</td>
<td>Shale, light gray, fine sand, clayey silt, medium hardness</td>
</tr>
</tbody>
</table>

---

**Diagram:**

Visual Classification Course for Geotechnical Logging of Soil and Rock Stratum
**Visual Classification Course for Geotechnical Logging of Soil and Rock Stratum**

<table>
<thead>
<tr>
<th>Material Description</th>
<th>Elevation</th>
<th>Depths</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandstone, brown and gray, moderately weathered, slightly strong. (Drillers description)</td>
<td>0.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Interbedded sandstone (top and shale) (DP1)</td>
<td>0.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Sandstone, yellowish-gray and yellowish-brown, moderately weathered, slightly strong. (DP1)</td>
<td>6.0</td>
<td>10.0</td>
</tr>
<tr>
<td>Sandstone, yellowish-gray and yellowish-brown, moderately weathered, slightly strong. (DP1)</td>
<td>11.0</td>
<td>14.0</td>
</tr>
<tr>
<td>Sandstone, yellowish-gray and yellowish-brown, moderately weathered, slightly strong. (DP1)</td>
<td>15.0</td>
<td>19.0</td>
</tr>
<tr>
<td>Sandstone, yellowish-gray and yellowish-brown, moderately weathered, slightly strong. (DP1)</td>
<td>20.0</td>
<td>24.0</td>
</tr>
<tr>
<td>Sandstone, yellowish-gray and yellowish-brown, moderately weathered, slightly strong. (DP1)</td>
<td>25.0</td>
<td>29.0</td>
</tr>
<tr>
<td>Sandstone, yellowish-gray and yellowish-brown, moderately weathered, slightly strong. (DP1)</td>
<td>30.0</td>
<td>34.0</td>
</tr>
</tbody>
</table>

---

**Exploration Log (Sheet 1 of 3)**

- **Top Soil to Brown Clay:**
  - Drilling Method: A-110
  - Hammer: 500

- **Rock:**
  - Safety Hammer: 500
  - Energy Ratio (%): 100

- **Core:**
  - Sample Size: 100
  - Sample ID: N0-1

- **Shale:**
  - Sample Size: 100
  - Sample ID: N0-2

- **Limestone, Fossuliferous:**
  - Sample Size: 38
  - Sample ID: N0-3

---

3/26/2015
Visual Classification Course for Geotechnical Logging of Soil and Rock Stratum

<table>
<thead>
<tr>
<th>Depth</th>
<th>Material Description and Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>0 100 SS-3</td>
</tr>
<tr>
<td>1.0</td>
<td>0 1 33 SS-4</td>
</tr>
<tr>
<td>2.0</td>
<td>0 1 33 SS-4</td>
</tr>
<tr>
<td>3.0</td>
<td>0 1 33 SS-4</td>
</tr>
<tr>
<td>4.0</td>
<td>0 1 33 SS-4</td>
</tr>
<tr>
<td>5.0</td>
<td>0 1 33 SS-4</td>
</tr>
<tr>
<td>6.0</td>
<td>0 1 33 SS-4</td>
</tr>
<tr>
<td>7.0</td>
<td>0 1 33 SS-4</td>
</tr>
<tr>
<td>8.0</td>
<td>0 1 33 SS-4</td>
</tr>
<tr>
<td>9.0</td>
<td>0 1 33 SS-4</td>
</tr>
</tbody>
</table>

**Notes:** Slightly Organic.
Visual Classification Course for Geotechnical Logging of Soil and Rock Stratum

?QUESTIONS?

Visual Classification Course for Geotechnical Logging of Soil and Rock Stratum

- ODOT Specifications for Geotechnical Explorations (SGE)
  
  http://www.dot.state.oh.us/Divisions/Engineering/Geotechnical/Pages/SGE.aspx

- Geotechnical Bulletins
  
  http://www.dot.state.oh.us/Divisions/Engineering/Geotechnical/Pages/Manuals.aspx#Bulletins

- ODOT GEOMS
  
  http://odotgeoms.org/
APPENDIX A.3 - ODOT Rock Type

**GENERAL AND GLOSSARY:**
The following terms are use in describing the rock types found within Ohio. The following listing is presented in alphabetical order.

**Amorphous:** Does not contain crystalline structure with shapeless appearance.

**Anhydrous:** Does not contain water within the crystalline structure.

**Bioturbated:** Evidence of past organisms, such as filled burrows, within the rock mass.

**Conchoidal Fracture:** A curved fracture plane with a rock mass.

**Concretion:** A solidified mass of concentrated material, usually of a single or multiple mineral composition.

**Dilute HCl:** A liquid composed of a 10% Hydrochloric Acid solution.

**Hydrous:** Contains water within the crystalline structure.

**Hardness:** When describing rock and minerals, the hardness of the material is commonly referred to. The hardness is the ability of the material to resist scratching. The easier the material is scratched, the lower the hardness, and the more resistant the material is to scratching, the higher the hardness. The following table list hardness of common items to aid in field determinations:

<table>
<thead>
<tr>
<th>Object</th>
<th>Hardness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fingernail</td>
<td>2.5</td>
</tr>
<tr>
<td>Copper Penny (pre 1982)</td>
<td>3.5</td>
</tr>
<tr>
<td>Knife Blade/Nail</td>
<td>5.5</td>
</tr>
<tr>
<td>Window Glass</td>
<td>5.5</td>
</tr>
<tr>
<td>Hardened Steel (File)</td>
<td>6.5</td>
</tr>
</tbody>
</table>

**Indurated:** Partially lithified (hardened) sediment.

**Lithified:** Process during which unconsolidated sediments are formed into sedimentary rock.

**Luster:** The ability of the material to reflect light resulting in a surface appearance.

**Vitreous:** Description referring to a glassy luster.
**ROCK TYPES:**
The following are descriptions of the basic rock types found within Ohio. It should be noted that when referencing a percentage of composition the percentage is based on volume not weight.

<table>
<thead>
<tr>
<th>ROCK TYPE</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ANHYDRITE</strong></td>
<td>A rock or mineral consisting of anhydrous calcium sulfate (CaSO₄) which is common to massive evaporite beds and readily alters to gypsum. Anhydrite is white, has a vitreous or pearly luster, and a hardness of 3.5.</td>
</tr>
<tr>
<td><strong>BRECCIA</strong></td>
<td>A coarse-grained sedimentary rock comprised of more than 25% subangular to angular gravel, cobbles and/or boulders. These grains are supported by either inter-grain contact or a matrix of sands, silt and/or clay and cemented by calcite, dolomite, hematite, silica or hardened clay. Color depends on the cementing agent with white, gray, yellow, orange, brown, and red colors common.</td>
</tr>
<tr>
<td><strong>CHERT</strong></td>
<td>A hard dense sedimentary rock consisting of very fine quartz crystals and may contain amorphous silica or silica replaced fossils. Chert varieties in color, but commonly is white or ranges from brown to black, has a semi-vitreous to dull luster, and a hardness of 7. When broken it commonly produces conchoidal fractures. These fractures are smooth with sharp edges. Chert forms as oval or irregular nodular or concretionary segregations, or as layered deposits in limestone and dolomite. Also referred to as flint.</td>
</tr>
<tr>
<td><strong>CLAYSTONE</strong></td>
<td>A fine-grained rock formed of at least 75% clay sized particles. Claystone is comprised of lithified clay having the texture and composition of shale, but lacking the laminations and fissility of a shale. Generally has a blocky, thick to massive appearance. Claystone may range in color from red, gray, olive, yellow, or brown with multiple colors typical. Slickensides are commonly found within claystone.</td>
</tr>
<tr>
<td><strong>COAL</strong></td>
<td>A combustible substance containing more than 50%, by weight, and more than 70%, by volume, of carbonaceous material; formed from the compaction and lithification of plant remains. Colors of coals range from brown to black. It is generally light weight with a shiny appearance on fresh surfaces.</td>
</tr>
<tr>
<td><strong>CONGLOMERATE</strong></td>
<td>A coarse-grained sedimentary rock comprised of more than 25% rounded to subrounded gravel, cobbles, and/or boulders. These grains are supported by either inter-grain contact or a matrix of sands, silt and/or clay and cemented by calcite, hematite, silica or hardened clay. Color depends on the matrix and cementing agent with white, gray, yellow, orange, brown, and red colors common.</td>
</tr>
<tr>
<td><strong>DOLOMITE</strong></td>
<td>A sedimentary rock of which more than 50% consists of the mineral dolomite (calcium magnesium carbonate – CaMg(CO₃)₂) and less than 10% is comprised of the mineral calcite. It is commonly interbedded with limestone, and the magnesium can be replaced with ferrous iron. Dolomite typically has a hardness of 3.5 to 4, colors ranging from white to light gray and will weakly react with cold dilute HCl on fresh or powdered surfaces.</td>
</tr>
<tr>
<td><strong>FIRECLAY</strong></td>
<td>See Underclay for description. The preferred use is Underclay.</td>
</tr>
<tr>
<td>ROCK TYPE</td>
<td>DESCRIPTION</td>
</tr>
<tr>
<td>-----------</td>
<td>-------------</td>
</tr>
<tr>
<td><strong>FLINT</strong></td>
<td>A common name for chert, generally used by archaeologists. See Chert for a description.</td>
</tr>
<tr>
<td><strong>GYPSUM</strong></td>
<td>A rock or mineral consisting of hydrous calcium sulfate (CaSO₄·2H₂O). It forms thick extensive beds in Silurian aged rock commonly associated with halite and anhydrite in evaporative deposits. Gypsum may be white, translucent or transparent with a vitreous to pearly luster and a hardness of 2.0. Does not react with dilute HCl.</td>
</tr>
<tr>
<td><strong>HALITE</strong></td>
<td>A rock or mineral occurring in massive, granular compact or cubic-crystalline forms associated with evaporite beds. It is comprised of sodium chloride (NaCl) and is commonly known as salt. Halite is colorless to white with a hardness of 2.0 to 2.5. Fresh samples will have a salty flavor.</td>
</tr>
<tr>
<td><strong>IRONSTONE</strong></td>
<td>A sedimentary rock that is heavy and compact, containing primary components of iron oxides, carbonates, clay, and/or sand. Fresh surfaces generally are gray which weathers (oxidizes) to yellowish brown (limonite) to deep red (hematite) depending on the type and amount of oxide/hydroxide formed. It is very distinct in that its density is greater than a typical sedimentary rock. Purer forms of ironstone occur as concretionary forms within shale, sandstone and limestone or dolomite layers, or at bedding contacts. Generally these concretionary forms are composed of goethite (Fe(OH), hardness 5.0-5.5), limonite (FeX(OH), hardness 4.0-5.5), or siderite (FeCO₃, hardness 3.5-4.5) and can be called “kidney ores” for their kidney shapes. Colors of these concretions vary between gray, yellowish brown, brown, brownish red or black depending upon the composition and degree of weathering.</td>
</tr>
<tr>
<td><strong>LIMESTONE</strong></td>
<td>A sedimentary rock consisting of the mineral calcite (calcium carbonate – CaCO₃). Impurities may include chert, clay and minor mineral crystals. It may be crystalline (hard, pure, fine to coarse texture) with very fine grains not visible to the naked eye and/or fossiliferous (contains remains of organisms). Limestone is typically white to dark gray in color with a hardness of 3.5 to 4.0 and reacts vigorously with cold dilute HCl. Descriptions based on Folk or Dunham Carbonate Classification systems are not needed.</td>
</tr>
<tr>
<td><strong>MUDSTONE</strong></td>
<td>A fine grained sedimentary rock comprised of mud (silt and clay) sized particles. Mudstone can be used as a generic term incorporating the rock classes of siltstone, claystone, and shale with Ohio. Although this term was widely used on pasts projects, the three previous descriptions are preferred for current projects. For a detailed description see Claystone.</td>
</tr>
<tr>
<td><strong>SANDSTONE</strong></td>
<td>A sedimentary rock comprised of grains of angular or rounded sand in a matrix of silt and/or clay cemented together by silica, iron oxides, or calcium carbonate. Sandstones may be composed of up to 25% of particles of gravel, cobbles, and/or boulders sizes. Color depends on the cementing agent with white, gray, yellow, orange, brown, and red colors common.</td>
</tr>
</tbody>
</table>
**Rock Types**

<table>
<thead>
<tr>
<th>ROCK TYPE</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SHALE</strong></td>
<td>A fine-grained sedimentary rock formed by the lithification of clay, silt or mud (predominate particle size is less than 0.002 mm). Shale has a laminated structure, which gives it fissility along which the rock splits readily. Shale is commonly interbedded with sandstone or limestone. Carbonaceous shale often grades into coal. Typical colors may be red, brown, black, green or gray.</td>
</tr>
<tr>
<td><strong>SILTSTONE</strong></td>
<td>A fine-grained sedimentary rock formed from particles finer than sand, but coarser than clay. Siltstone is comprised of lithified silt and lacks lamination or fissility. Typical colors may be gray, olive, or brown. Generally, siltstone has a fine grit feeling when rubbed against teeth.</td>
</tr>
<tr>
<td><strong>UNDERCLAY</strong></td>
<td>A layer of clay lying immediately beneath a coal bed or carbonaceous shale. This layer may be bioturbated and indurated or lithified. It is chiefly comprised of siliceous or aluminous clay capable of withstanding high temperatures without deformation, and may have a high shrink/swell potential.</td>
</tr>
</tbody>
</table>

**Rock Descriptors:**

The following listing of descriptors is for rock types found within Ohio. The following descriptors should be applied when the condition comprises 10% or more of the observed sample by volume. If the condition comprises less than 10% use “contains ---”. For example if the core contains more than 10% mica then the rock is “micaceous”, but if the rock is composed of 5% mica then the rock is “contains mica.” The following listing is presented in alphabetical order.

<table>
<thead>
<tr>
<th>Percentage Composition</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;10%</td>
<td>Contains sand sized particles. Should not be used to describe sandstone, conglomerate, or breccia.</td>
</tr>
<tr>
<td>&lt;10%</td>
<td>Contains clay and/or silt sized particles that result in the appearance having a slightly clayey texture. Should not be used to describe shale, claystone, or mudstone.</td>
</tr>
<tr>
<td>NA</td>
<td>Contains less than 25% angular to subangular gravel, cobbles and boulders. Typically used to describe sandstone, limestone or dolomite.</td>
</tr>
<tr>
<td>NA</td>
<td>Contains calcium carbonate indicated by reaction with HCl. Should not be used for describing limestone or dolomite.</td>
</tr>
<tr>
<td>NA</td>
<td>Contains a significant amount of carbon, but is not combustible. Should not be used to describe coal.</td>
</tr>
<tr>
<td>Contains chert fragments</td>
<td>Contains chert fragments.</td>
</tr>
<tr>
<td>NA</td>
<td>Contains less than 25% rounded to subrounded gravel, cobbles and boulders. Typically used to describe sandstone, limestone or dolomite</td>
</tr>
<tr>
<td>NA</td>
<td>Contains crystalline structure visible with the unaided eye or a 10 power hand lens. Generally referred to by the crystal size based upon texture chart, i.e. fine grained.</td>
</tr>
<tr>
<td>Percentage Composition</td>
<td>Description</td>
</tr>
<tr>
<td>------------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>&gt;10%</td>
<td>&lt;10%</td>
</tr>
<tr>
<td>Dolomitic</td>
<td>NA</td>
</tr>
<tr>
<td>Ferriferous/Ferric</td>
<td>Slightly ferric</td>
</tr>
<tr>
<td>Fissile</td>
<td>NA</td>
</tr>
<tr>
<td>Fossiliferous</td>
<td>Contains fossils</td>
</tr>
<tr>
<td>Friable</td>
<td>NA</td>
</tr>
<tr>
<td>Lithic</td>
<td>Contains lithic fragments</td>
</tr>
<tr>
<td>Marine</td>
<td>NA</td>
</tr>
<tr>
<td>Micaceous</td>
<td>Contains Mica</td>
</tr>
<tr>
<td>Non-marine</td>
<td>NA</td>
</tr>
<tr>
<td>Petroliferous</td>
<td>NA</td>
</tr>
<tr>
<td>Pyritic</td>
<td>Contains pyrite</td>
</tr>
<tr>
<td>Siliceous</td>
<td>Contains silica</td>
</tr>
<tr>
<td>Stylolitic</td>
<td>NA</td>
</tr>
<tr>
<td>Vuggy</td>
<td>NA</td>
</tr>
</tbody>
</table>

- **Dolomitic**: NA
- **Ferriferous/Ferric**: Slightly ferric
- **Fissile**: NA
- **Fossiliferous**: Contains fossils
- **Friable**: NA
- **Lithic**: Contains lithic fragments
- **Marine**: NA
- **Micaceous**: Contains Mica
- **Non-marine**: NA
- **Petroliferous**: NA
- **Pyritic**: Contains pyrite
- **Siliceous**: Contains silica
- **Stylolitic**: NA
- **Vuggy**: NA

Contains calcium/magnesium carbonate. Reacts slightly with dilute HCl on a fresh surface, and slightly to moderately on a powdered surface. Should only be used with limestone.

Contains iron based minerals that are either visible, or results in an increase density.

Partings along closely spaced planes parallel or nearly parallel to bedding.

Contains remains of plant and animals including carbonized fossils, silica, pyrite or other mineral replaced organisms and sand, silt, and/or clay filled cast or burrows of organisms in most sedimentary rocks.

Can be easily broken down with hand pressure.

Contains less than 25% rounded to angular rock fragments. Typically used to describe claystone.

Reference made to limestone and dolomites which were deposited in a salt water marine environment.

Rock mass contains mica fragments.

Reference made to limestone and dolomites which were deposited in a fresh water environment. Commonly also referred to as “impure”.

Contains free petroleum or petroleum staining, including natural asphalt.

Rock mass contains pyrite crystals or nodules.

Rock mass contains very fine to fine silica material.

Contain stylotites (cranial suture like structure) within the rock mass.

Contains solution cavities which may or may not contain mineral crystals. Typically used to describe carbonate rocks.
GLACIAL DEPOSITS OF OHIO

Although difficult to imagine, Ohio has at various times in the recent geologic past (within the last 1.6 million years) had three-quarters of its surface covered by vast sheets of ice perhaps as much as 1 mile thick. This period of geologic history is referred to as the Pleistocene Epoch or, more commonly, the Ice Age, although there is abundant evidence that Earth has experienced numerous other “ice ages” throughout its 4.6 billion years of existence.

Ice Age glaciers invading Ohio formed in central Canada in response to climatic conditions that allowed massive buildups of ice. Because of their great thickness, these ice masses flowed under their own weight and ultimately moved south as far as northern Kentucky. Oxygen-isotope analysis of deep-sea sediments indicates that more than a dozen glaciations occurred during the Pleistocene. Portions of Ohio were covered by the last two glaciations, known as the Wisconsinan (the most recent) and the Illinoian (older), and by an undetermined number of pre-Illinoian glaciations.

Because each major advance covered deposits left by the previous ice sheets, pre-Illinoian deposits are exposed only in extreme southwestern Ohio in the vicinity of Cincinnati. Although the Illinoian ice sheet covered the largest area of Ohio, its deposits are at the surface only in a narrow band from Cincinnati northeast to the Ohio-Pennsylvania border. Most features shown on the map of glacial deposits of Ohio are the result of the most recent or Wisconsinan-age glaciers.

The material left by the ice sheets consists of mixtures of clay, sand, gravel, and boulders in various types of deposits of different modes of origin. Rock debris carried along by the glacier was deposited in two principal fashions, either directly by the ice or by meltwater from the glacier. Some material reaching the ice front was carried away by streams of meltwater to form outwash deposits. Material deposited by water on and under the surface of the glacier itself formed features called kames and eskers, which are recognized by characteristic shapes and composition. A distinctive characteristic of glacial sediments that have been deposited by water is that the material was sorted by the water that carried it. Thus, outwash, kame, and esker deposits normally consist of sand and gravel. The large boulder-size particles were left behind and the smaller clay-size particles were carried far away, leaving the intermediate gravel- and sand-size material along the stream courses.

Material deposited directly from the ice was not sorted and ranges from clay to boulders. Some of the debris was deposited as ridges parallel to the edge of the glacier, forming terminal or end moraines, which mark the position of the ice when it paused for a period of time, possibly a few hundred years. When the entire ice sheet receded because of melting, much of the ground-up rock material still held in the ice was deposited on the surface as ground moraine. The oldest morainic deposits in Ohio are of Illinoian and pre-Illinoian age. Erosion has significantly reduced these deposits along the glacial boundary, leaving only isolated remnants that have been mapped as dissected ground moraine and hummocky moraine.

Many glacial lakes were formed in Ohio during the Ice Age. Lake deposits are primarily fine-grained clay- and silt-size sediments. The most extensive area of lake deposits is in northern Ohio bordering Lake Erie. These deposits, and adjacent areas of wave-planed ground moraine, are the result of sedimentation and erosion by large lakes that occupied the Erie basin as Wisconsinan-age ice retreated into Canada. Other lake deposits accumulated in stream valleys whose outlets were temporarily dammed by ice or outwash. Many outwash-dammed lake deposits are present in southeastern Ohio far beyond the glacial boundary. Peat deposits are associated with many lake deposits and formed through the accumulation of partially decayed aquatic vegetation in oxygen-depleted, stagnant water.

The term glacial drift commonly is used to refer to any material deposited directly (e.g., ground moraine) or indirectly (e.g., outwash) by a glacier. Because the ice that invaded Ohio came from Canada, it carried in many rock types not found in Ohio. Pebbles, cobbles, and boulders of these foreign rock types are called erratics. Rock collecting in areas of glacial drift may yield granite, gneiss, trace quantities of gold, and very rarely, diamonds. Most rocks found in glacial deposits, however, are types native to Ohio.

Certain deposits left behind by the ice are of economic importance, particularly sand and gravel, clay, and peat. Sand and gravel that have been sorted by meltwater generally occur as kames or eskers or as outwash along major drainageways. Sand and gravel are vital to Ohio's construction industry. Furthermore, outwash deposits are among the state's most productive sources of ground water.

Glacial clay is used in cement and for common clay products (particularly brick). The minor quantities of peat produced in the state are used mainly for mulch and soil conditioning.
EXPLANATION

Thickness (in feet) of drift in glaciated areas and some non-glaciated areas along glacial boundary, and of outwash and glaciolacustrine deposits in sediment-filled valleys beyond the glacial boundary.

Available as 1:500,000-scale (poster-size) print and in digital (GIS) format. To order, contact Geologic Records Center at 614-265-6576.

SHAPED DRIFT-THICKNESS MAP OF OHIO

INTRODUCTION

The drift-thickness map of Ohio depicts the thickness and distribution of glacially derived sediments (called drift) and post-glacial stream sediments overlain the buried bedrock surface. This map was produced by subtracting bedrock-surface elevations from land-surface elevations to produce a residual map of drift thickness. Colors portray thickness intervals of glacial and modern sediments, which can range up to several hundred feet.

Prior to the onset of continental glaciation in the Early Pleistocene Epoch, approximately 1.8 million years before present, the Ohio landscape was dominated by rolling hills and deeply incised, mature rivers and streams. A reduced version of the Division of Geological Survey’s Shaded-Bedrock Topography map of Ohio (fig. 1) reveals some aspects of this old land surface. Erosion and deposition by Ice-Age continental glaciers advancing into northern and western Ohio produced a low-relief land surface compared to the unglaciated, high-relief land surface of southeastern Ohio (fig. 2). Comparing the shaded elevation map (fig. 2) with the shaded bedrock-topography map (fig. 1) reveals the dramatic impact of glaciation on the state’s current landscape.

Drift thickness in western and northern Ohio (fig. 3) is highly variable, a consequence of numerous geologic factors acting in combination or alone. In some areas, drift has been deposited on a relatively flat bedrock surface and changes in drift thickness are primarily the result of variations in the amount of glacial material deposited. In other areas, drift has filled in a deeply incised buried-bedrock surface, and changes in drift thickness are primarily the result of variations in bedrock-surface elevation. In still other instances, the drift surface parallels the underlying bedrock surface to produce areas of relatively uniform drift thickness.

Distinct, narrow linear patterns of thick drift in western and central Ohio are the result of deep incisions in the underlying limestone and dolomite bedrock by a large, northwest flowing drainage system, the Teays Valley system, that existed prior to and during early glaciations (fig. 1). The main Teays Valley entered the state at Wheelersburg (Scioto County), where remnants of the Teays Valley are still evident on the modern land surface. At Chillicothe (Ross County), the valley disappears under glacial sediments which cover western Ohio. However, the valley continues north, below the surface, to Circleville (Pickaway County) and then northwest to Mercer County where the valley exits the state into Indiana. Early southward-advancing glaciers blocked the north-flowing river system of the Teays and created immense lakes in southeastern Ohio.

In northeastern Ohio, narrow thick-drift areas south of Lake Erie were also preglacial bedrock valleys. These valleys were partially filled with thick deposits of till and glaciolacustrine (glacial lake) sediment and then re-excavated by later northward-flowing rivers such as the Cuyahoga River and the East Branch of Rocky River.

In northwestern Ohio, repeated scouring of the relatively soft bedrock surface by glacial ice flowing southwestward from the Lake Erie Basin destroyed most pre-existing drainage systems. In this part of Ohio, the bedrock surface is smooth and the upper surface of the drift has been planed off by wave action and deposition by a post-glacial, high-level ancestral Lake Erie. In the extreme northwest corner of Ohio, in Williams County and portions of Defiance County, drift thickens considerably because of numerous moraines that formed along the northwestern edge of the Erie Lobe.

In western Ohio, draping linear features of thick drift, called ridge moraines, formed along the temporarily stationary ice-front as glacial sediment was released from the ice. These ribbons of thick drift define the lateral dimensions of glacial ice lobes, particularly those of the last Wisconsinan ice sheet (fig. 4). Many ridge moraines in western and northeastern Ohio have a draped appearance because south-flowing ice, impeded by bedrock highlands, moved more easily along major lowlands. The numerous resistant bedrock highlands in northeastern Ohio caused ridge moraines to be especially arcuate and closely stacked.

Southeastern Ohio is unglaciated and devoid of ice-deposited sediment (glacial till). Many southeast Ohio valleys, however, carried

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**FIGURE 1.**—Shaded bedrock-topography map of Ohio showing the sculpted bedrock surface that lies beneath glacial drift in northern and western Ohio and the land surface in unglaciated southeastern Ohio. Note the surface expression of the Teays Valley System south of the glacial boundary (arrow), the location of the main Teays Valley (between yellow dashed lines), the area of smooth bedrock topography, and the area of re-excavated preglacial bedrock valleys in northeastern Ohio. (W = Wheelersburg, C = Circleville, CH = Chillicothe) (modified from Ohio Division of Geological Survey, 2005).

**FIGURE 2.**—Shaded elevation map of the land surface of Ohio with glacial boundary. Note the smooth landscape of glaciated northern and western Ohio compared to the high-relief landscape of unglaciated southeastern Ohio (modified from Powers, Laine, and Pavely, 2002).
huge volumes of glacial meltwater away from the ice front and toward the Ohio River. In the process, many of these valleys were at times made deeper by the erosive force of fast-flowing meltwater streams, and at other times were partially filled with sediment. Some valleys in unglaciated Ohio contain thick deposits of clay and silt that accumulated on the bottoms of lakes that formed when glacial ice blocked the flow of rivers or when rapidly accumulating meltwater sediments blocked the mouths of smaller tributaries.

METHODS

Two digital data layers are required to generate the drift-thickness map: the surface-elevation layer and the bedrock-topography layer. Drift thickness is calculated by subtracting the bedrock-topography elevation from the land surface elevation. The bedrock-topography component is one of the products resulting from a multi-year effort by the ODNR, Division of Geological Survey to map the bedrock geology of Ohio. Bedrock-topography maps are required to determine the relief on the bedrock surface beneath thick layers of glacial drift. Bedrock-topography maps were created by the Division of Geological Survey for all 788 7/8-minute topographic quadrangles in the state as part of a project to produce accurate bedrock-geology maps for glaciated portions of Ohio and for those areas beyond the glacial boundary where valleys are infilled with sediment. Data accuracy and quality assurance are those of the original, hand-drawn bedrock-topography maps vary widely across the state in response to changing geologic and topographic conditions. These data contain mostly of water-well logs on file at the ODNR, Division of Water, supplemented by outcrop data, Ohio Department of Transportation bridge-boring data, and oil-and-gas-well data. During the course of mapping, over 162,000 data points were interpreted for bedrock-surface elevation and in some cases drift thickness. These points were plotted on maps and used as control for the bedrock-topography lines. Individual 24,000-scale bedrock-topography maps are available from the Division of Geologic Records Center.

Elevation contours and data points from the 788 bedrock-topography maps were digitized and compiled for the glaciated portions of the state and for the valleys beyond the glacial boundary containing significant accumulations of sediment deposited during and after glacial retreat. The digitized bedrock-topography contours were digitally converted in an ArcGIS environment to create a continuous grid model (60 meter grid spacing). A statewide compilation map and digital dataset of the bedrock topography of Ohio (modified from Ohio Division of Geological Survey, 2003) are available from the Division of Geological Survey.

Uncolored areas of southeastern Ohio represent extensive portions of unglaciated Ohio where the land surface and the bedrock surface are essentially the same. On the original maps in these areas, bedrock-topography lines were restricted to the buried-valley portions of the map and were not drawn in upland portions.

The second component needed to create the drift-thickness map, the land-surface topography, is based largely on data derived from the U.S. Geological Survey’s National Elevation Dataset (30 meter grid spacing). These data have been modified extensively by the Ohio Division of Geological Survey to replace some anomalous errors that are inherent in portions of the National Elevation Dataset. A statewide compilation map and digital dataset of the shaded elevation of Ohio (modified from Powers, Laine, and Pavey, 2002) are available from the Division of Geological Survey.

A grid of the digitized bedrock-topography contours was subtracted from a grid of the land-surface Digital Elevation Model to derive a third grid (60 meter grid spacing) representing the thickness of the drift. This grid surface was shaded from the northwest, slightly above the horizon, to produce the appearance of a three-dimensional surface.

REFERENCES


This map is a generalization of the Bedrock Geologic Map of Ohio (Slucher and others, 2006)—the first statewide 1:500,000-scale bedrock-geology map compiled by the Ohio Division of Geological Survey since 1920 and the first to properly portray the bedrock geology that exists beneath the extensive deposits of Quaternary sediments that cover much of the bedrock in the state. Overall, the bedrock geology of Ohio consists of flat lying to gently dipping carbonate, siliciclastic, evaporite, and organoclastic strata of sedimentary origin that range in age from Upper Ordovician to Upper Carboniferous-Lower Permian. At depth, as illustrated in the cross section, older sedimentary, igneous, and metamorphic rocks that range from Lower Ordovician to Mesoproterozoic in age occur. At the surface, an irregular veneer of mainly unconsolidated Quaternary sediments conceal most bedrock units occurring northward and westward of the glacial margin.

Strata of the Orдовiscopal System are the oldest exposed rocks in Ohio and consist mainly of alternating shale and limestone sequences. Silurian System strata are mostly dolomites with lesser amounts of shale. Rocks of the Devonian System consist of two contrasting types. Lower and Middle Devonian-age strata are mainly carbonate rocks whereas Upper Devonian-age rocks consist mostly of clastic rocks. In Champaign and Logan Counties, Devonian rocks occur on a small erosional remnant referred to as the Bellefontaine Outlier by geologists. Coincidentally, the highest topographic point in Ohio (Campbell Hill—1,549 feet above sea level) occurs also in this area.

The Carboniferous System is divided into two Subsystems, the Mississippian and Pennsylvanian. Mississippian strata are mostly shales and sandstones that occur locally in various proportions. Pennsylvanian strata consist mainly of a diverse array of alternating sandstones, siltstones, shales, mudstones, limestones, and sandstones; economic coal beds occur also in portions of this sequence. The youngest interval of sedimentary rocks in Ohio, the Dunkard Group, occurs only in southeastern Ohio and consists of strata similar in composition to the underlying Upper Pennsylvanian-age rocks; however, the age of the Dunkard Group has been debated since the late 1800s. Dunkard strata contain a well-studied late Pennsylvanian-age assemblage of plant fossils with infrquent early Permian-age forms. Yet, fossil plant spores found in coal beds in the interval only support a late, but not latest Pennsylvania age. Thus, until more definitive fossils are found, geologist are unable to determine the exact age of the Dunkard Group beyond a combined Permian-Pennsylvanian age assignment.

In western-central Ohio, the ancient Teays River system extended across much of Ohio during the late Neogene to early Quaternary Periods and sculptured an extensive network of deeply dissected valleys into the bedrock surface. The spatial configuration of many geologic units on this map clearly reflects the major channel networks of these former drainage systems. Also, four major regional structural geology elements affect the spatial distribution of rocks in Ohio: the Appalachian and Michigan basins, and the Cincinnati and Findlay arches which occur between the two basins. Locally, several high-angle normal faults displace rocks in the state.

The Serpent Mound Impact Structure in southern Ohio is a circular area of deformed and broken rocks that is approximately four and one-half miles in diameter. Recent investigations indicate the feature is the result of a meteorite impact believed to have occurred between 256 and 330 million years ago.

Cross section A-A' traverses Ohio from the northwest to the southeast and intersects the southern portion of the Michigan Basin, the area between the Cincinnati and Findlay arches, and the western Appalachian Basin, respectively. The stratigraphic units shown in this profile illustrate the broad, arching geometric distortion to the bedrock in Ohio created mainly by periods of tectonic subsidence within these regional structural basins. For specific details on the various rock units, economic commodities, and geologic hazards within Ohio, see either the printed or digital version of the Bedrock Geologic Map of Ohio (Slucher and others, 2006). Both products are available for purchase by contacting the ODNR Geologic Records Center by calling 614-265-6576 or emailing: geo.survey@dnr.state.oh.us.
OHIO KARST AREAS

Kast is a landform that develops on or in limestone, dolomite, or gypsum by dissolution and that is characterized by the presence of characteristic features such as sinkholes, underground (or internal) drainage through solution-enlarged fractures (joints), and caves. While kast landforms and features are commonly striking in appearance and host to some of Ohio's rarest fauna, they also can be a significant geologic hazard. Sudden collapse of an underground cavern or opening of a sinkhole can cause surface subsidence that can severely damage or destroy any overlaying structure such as a building, bridge, or highway. Improperly backfilled sinkholes are prone to both gradual and sudden subsidence, and similarly threaten overlaying structures. Sewage, animal wastes, and agricultural, industrial, and ice-control chemicals entering sinkholes as surface drainage are conducted directly and quickly into the ground water system, thereby posing a severe threat to potable water supplies. Because of such risks, many of the nation's state geological surveys, and the U.S. Geological Survey, are actively mapping and characterizing the nation's karst regions.

The five most significant Ohio karst regions are described below.

BELLEVUE-CASTALIA KARST PLAIN

The Bellevue-Castalia Karst Plain occupies portions of northeastern Seneca County, northwestern Huron County, southeastern Sandusky County, and northeastern Ottawa County, including the Marblehead Peninsula, Catawba Island, and the Bass Islands, is related in geologic origin to the Bellevue-Castalia Karst Plain. The area is underlain by up to 175 feet of Devonian carbonates (Delaware Limestone, Columbus Limestone, Lucas Dolomite, and Amherstburg Dolomite) overlying Silurian dolomite, anhydrite, and gypsum of the Bass Islands Dolomite and Salina Group.

The Bellevue-Castalia Karst Plain is believed to contain more sinkholes than any of Ohio's other karst regions. Huge, irregularly shaped, closed depressions up to 270 acres in size and commonly enclosing smaller, circular-closed depressions 5 to 80 feet in diameter pockmark the land between the village of Flat Rock in northeastern Seneca County and Castalia in western Erie County. Surface drainage on the plain is very limited, and many of the streams which are present disappear into sinkholes called swallow holes.

Kast in the Bellevue-Castalia and Lake Erie island regions is due to collapse of overlying carbonate rocks into voids created by the dissolution and removal of underlying gypsum beds. According to Verber and Stansbery (1953, Ohio Journal of Science), ground water is introduced into Salina Group anhydrite (CaSO₄) through pores and fractures in the overlying carbonates. The anhydrite chemically reacts with the water to form gypsum (CaSO₄ 2H₂O), undergoing a 33 to 62 percent increase in volume in the process. This swelling lifts overlying strata, thereby opening fractures and creating extensive passages for ground-water projects.

Dissected Niagra Escarpment

The dissected Niagara Escarpment of southwestern Ohio includes the largest single area of karst terrain in the state and the greatest number of surveyed caves. It also is estimated to include the second-largest number of sinkholes in the state. The area is underlain by Silurian rocks of the Pebbles Dolomite, Lilley Formation, Bisher Formation, Estill Shale, and Noland Formation in Adams, Highland, and Jackson Counties and the Cedarville Dolomite, Springfield Dolomite, Euphemia Dolomite, Massie Shale, Laurel Dolomite, Osgood Shale, and Dayton Formation in Greene, Clark, Miami, Montgomery, and Preble Counties. The Pebble-Lolley-Bisher sequence and the Cedarville-Springfield-Euphemia sequence constitute the Lockport Group.

Most karst features along the Niagara Escarpment in southwestern Ohio are developed in Lockport Group strata. More than 100 sinkholes and caves developed in the Lockport have been documented in the field, and more than 1,000 prehistoric sinkhole bedrock features have been identified on aerial photographs, soils maps, and topographic maps. As with most karst terrain, sinkholes developed on the Niagara Escarpment commonly show linear orientations aligned with prevailing joint trends in the area. The greatest concentration of sinkholes on the escarpment is south of the Wisconsinan glacial border in southern Highland and Adams Counties, where highly dissected ridges capped by Silurian carbonate rocks rise 150 to 200 feet above surrounding drainage. Illinois till in these areas is thin to absent, and soils are completely leached with respect to calcium and calcium-magnesium carbonate. Such geologic settings are ideal for active karst processes, as downward-percolating, naturally acidic rain water is not buffered until it has dissolved some of the underlying carbonate bedrock. Other significant karst features of the Niagara Escarpment include small caves in escarpment re-entrants created by the valleys of the Great Miami and Stillwater Rivers in Miami County.

BELLEFONTAINE OUTLIER

The Bellefontaine Outlier in Logan and northern Champaign Counties is an eroded, resistant "island" of Devonian carbonates capped by Ohio Shale and surrounded by a "sea" of Silurian strata. Though completely glaciated, the outlier was such an impediment to Ice Age glaciers that it repeatedly separated advancing ice sheets into two glacial lobes—the Miami Lobe on the west and the Scioto Lobe on the east. Most Ohioans recognize the outlier as the location of Campbell Hill—the highest point in the state at an elevation of 1,849 feet above mean sea level.

Although it is not known for having an especially well-developed karst terrain, the outlier is the location of Ohio's largest known cave, Ohio Caverns. The greatest sinkhole concentrations are present in McArthur and Rushcreek Townships of Logan County, where the density of sinkholes in some areas approaches 30 per square mile. Sinkholes here typically occur in upland areas of Devonian Lucas Dolomite or Columbus Limestone that are 30 to 50 feet or more above surrounding drainage and are covered by less than 20 feet of glacial drift and/or Ohio Shale.

SCIOTO AND OLENTANGY RIVER GORGES

The uplands adjacent to the gorges of the Scioto and Olentangy Rivers in northern Franklin and southern Delaware Counties include areas of well-developed, active karst terrain. These uplands also are among the most rapidly developing areas of the state, which means karst should be a consideration in site assessments for commercial and residential construction projects.

The Scioto River in this area has been incised to a depth of 50 to 100 feet into underlying bedrock, creating a shallow gorge. The floor, walls, and adjacent uplands of the gorge consist of Devonian Delaware and Columbus Limestones mantled by up to 20 feet of Wisconsinan till. Sinkhole concentrations up to 1 sinkhole per acre are not uncommon in Concord, Scioto, and Radnor Townships of Delaware County. The sinkholes range in diameter from about 10 to 100 feet and commonly are aligned linearly along major joint systems.

The Olentangy River is approximately 5 miles east of the Scioto River in southern Delaware County and occupies a gorge that is narrower and up to 50 feet deeper than the Scioto River gorge. The floor and the lower half of the walls along the Olentangy gorge are composed of Delaware and Columbus Limestones, the upper half of the walls is composed of Devonian Ohio and Ostracod Shale, and is scoured by a thin veneer of glacial drift. Karst terrain has developed along portions of the gorge in a manner similar to karst terrain along the Scioto River.

ORDOVICIAN UPLANDS

The Ordovician uplands of southwestern Ohio are the location of surprisingly well-developed karst terrain despite the large component of shale in local bedrock. Numerous sinkholes are present in Ordovician rocks of Adams, Brown, Clermont, and Hamilton Counties.

The carbonate-rich members of the Grant Lake Formation (Bellevue and Mount Auburn), Grant Lake Limestone (Bellevue and Straight Creek), and the upper portion of the Arnhem formation are the Ordovician units most prone to karstification; however, the shale-rich (70 percent shale, 30 percent limestone) Wayneville Formation also has been subjected to a surprising amount of karst development in southeastern Brown and southwestern Adams Counties, just north of the Ohio River.

ACKNOWLEDGMENT

The Division of Geological Survey gratefully acknowledges the Ohio Low-Level Radioactive-Waste Facility Development Authority for its financial support for mapping Ohio karst terrain.