LAB 1
IDENTIFYING MATERIALS FOR MAKING SOILS: MINERALS

Learning outcomes

Students are able to:

1. understand and identify minerals.
2. discuss elements and their relationship to minerals and plant nutrition
3. discuss minerals and their relationship to soil (earth materials)

Introduction

Soil formation is greatly the result of the interaction of five soil forming factors: parent material, climate, biological activity, topography and time. The ability to identify the geologic material from which soils are formed and the possession of knowledge of the chemical composition of that geologic material is extremely important in describing soil and its properties.

The skeleton of the soil is inorganic material that comes from weathered fragments of rocks. The rocks from which these fragments are formed are composed of minerals and the minerals are composed of elements, some of which the plant uses in its metabolism.

Element

An element is a substance that cannot be broken down to simpler forms. Elements may exist in a single atom state (monatomic), or bond together into molecules that contain two or more of the same atoms. Example: N₂, O₂, and H₂. There are over one hundred elements, each of which has a unique set of characteristics.
Together, the elements oxygen and silicon make up 75% of the elemental composition of the earth's crust. Aluminum, iron, calcium, sodium, and potassium, together with oxygen and silicon make up 97% of the earth's crust.

There are 17 essential plant nutrients that are elements known to be necessary for the growth of all plants. Macronutrients are required in large amounts while micronutrients are required in small to trace amounts.

Macronutrients: C, H, O, P, N, S, Ca, K, Mg
Micronutrients: B, Cl, Cu, Fe, Mn, Mo, Ni, Zn

Silicon and aluminum (and sometimes sodium) are present in soils in extremely large quantities, but are not essential for plant growth. Table 1.1 presents the elemental composition of some minerals.

Table 1.1: Elemental composition of some common minerals

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Elemental composition</th>
<th>Plant essential elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quartz</td>
<td>Si, O</td>
<td>-</td>
</tr>
<tr>
<td>Orthoclase</td>
<td>K, Al, Si, O</td>
<td>K</td>
</tr>
<tr>
<td>Muscovite</td>
<td>K, Al, Si, O</td>
<td>K</td>
</tr>
<tr>
<td>Amphibole</td>
<td>Fe, Mg, Ca, Si, O</td>
<td>Fe, Mg, Ca</td>
</tr>
</tbody>
</table>

Mineral

A mineral is a naturally occurring inorganic solid substance having a characteristic chemical composition and a distinctive set of physical properties. Examples include quartz, gold and ice. Non-minerals include coal, asphalt, glass, and water.

Minerals are crystalline, i.e. each species has its own geometric internal arrangement of ions governed by electric charge and ionic size. This crystalline structure accounts for the characteristic physical properties of each mineral species. Minerals are formed by the crystallization under igneous and metamorphic conditions, by weathering at the earth's surface and by precipitation from solution, as in seawater.
Materials

Mineral samples
Moh’s Hardness Scale
Porcelain Streak Plate
Mineral Physical Properties (Appendix)

Activities

1. With the display of the common minerals, make note on their observable properties.

2. From each mineral in the display, postulate the probable richness of plant nutrients derived from them. The plant nutrients are 17 in number.
Appendix

Mineral Identification

Practical identification of the common minerals is based on sight recognition of diagnostic physical properties, plus simple tests for hardness and acid reaction. For minerals in rocks and soils, the most important physical properties and the methods used for identifying them are as follows:

Cleavage and Fracture - Most minerals tend to break along smooth, plane surfaces in one or more directions governed by their internal atomic arrangement. Such surfaces are termed cleavages. Their number and angular relationships are very useful for identification. For instance, micas cleave perfectly in one direction, feldspars in two directions not at right angles, etc. Irregular breaks not along cleavages are termed fractures. Fracture is most useful for minerals with no cleavage; for instance, quartz has a fairly smooth, curved type of fracture (conchoidal fracture) such as seen on broken glass.

Hardness - The hardness of an unknown mineral is determined by scratch tests or by known minerals. The numerical basis for hardness is the MOH's scale, which from softest to hardness consists of:

1) talc
2) gypsum
3) calcite
4) fluorite
5) apatite
6) orthoclase
7) quartz
8) topaz
9) corundum
10) diamond

Crude MOH's scale test values that can easily be used in the field include:

<table>
<thead>
<tr>
<th>Object</th>
<th>Hardness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fingernail</td>
<td>2.5</td>
</tr>
<tr>
<td>Penny (Coin)</td>
<td>3</td>
</tr>
<tr>
<td>Knife or glass</td>
<td>5.5</td>
</tr>
</tbody>
</table>

Luster - Luster is the appearance of a mineral in reflected light. Most minerals in rocks and soils have glassy or earthy luster. Micas have a brilliant luster.

Color - Mineral color is often quite variable for a given mineral species, due to impurities. For this reason color should be used with caution, and never by itself, for mineral identification. For minerals, color usually allows the accurate separation of light and dark minerals and the recognition of orthoclase (pink).

Streak - Streak is the color of a mineral's powder, generally obtained by scratching the mineral on an unglazed porcelain streak plate. Streak is reliable, but because most rock forming minerals have whitish streaks, this characteristic is not particularly useful, except for the iron oxides.
Specific Gravity - This property is the ratio of the weight of water of a mineral sample divided by the weight of the same volume of water. The specific gravity of the common light-colored rock forming minerals is about 2.7 (quartz, feldspar, calcite). Specific gravity is most useful for the identification of abnormally dense minerals such as barite (4.5) and galena (PbS, 7.5).

Crystal Form - Crystal form is the shape of minerals which have developed crystal faces, such as on quartz crystals which grow in a hollow space.

Acid Test - Carbonate rocks react with acid to give off CO$_2$ (effervescence).

\[ \text{CO}_3^{2-} + 2\text{H}^+ \rightarrow \text{H}_2\text{O} + \text{CO}_2 \]

Some Key Minerals: Chemical Composition and Diagnostic Properties

Quartz (SiO$_2$) - generally glassy looking (colorless) in rocks; white in veins; very hard (7); conchoidal fracture.

Feldspar - a family of light-colored minerals with two good cleavages at about 90°; hardness 6.
- Orthoclase (KAlSi$_3$O$_8$) - pinkish, reddish, or flesh color, no striations.
- Plagioclase (varies from NaAlSi$_3$O$_8$ to CaAl$_2$Si$_2$O$_8$) - generally whitish, sometimes colorless; commonly shows fine parallel striations on one of the two cleavages.

A-P Minerals - Amphibole and Pyroxene families - generally dark green to black (Fe, Mg, Ca silicates; amphiboles contain some Al and H$_2$O); two cleavage planes at either 124° = amphibole or 95° = Pyroxene.

Micas - One perfect cleavage yielding thin, elastic flakes.
- Muscovite (white mica) - (a K-Al silicate) white.
- Biotite (dark mica) - (as above plus Fe & Mg) brownish to black.

Iron Oxides - Metallic luster in rocks, earthy luster in soils.
- Hematite (Fe$_2$O$_3$) - dark red; leaves a red streak when rubbed on unglazed porcelain.
- Limonite (hydrated ferric oxide - 2Fe$_2$O$_3$ *3H$_2$O) rust color; leaves a yellow streak when rubbed on unglazed porcelain.

Clay Minerals - (mainly Al silicates containing water) a group of minerals characterized by an earthy odor and plasticity when moist.

Carbonates - The most important of the several carbonates is calcite (CaCO$_3$) clear to white; soft (3); rhombohedral cleavage - 3 directions not at 90°; effervescences violently in cold acids.