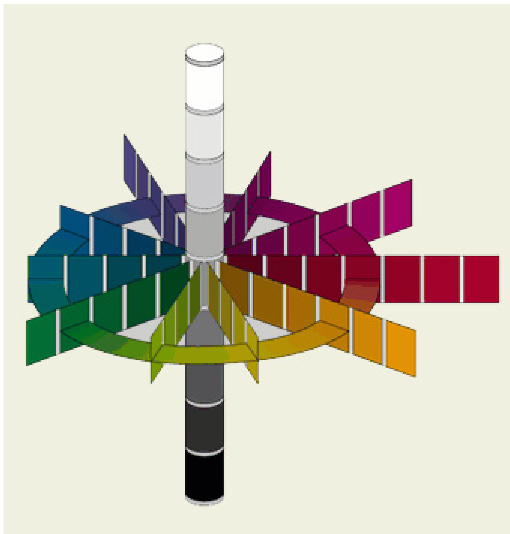
The Color of Soil



The first impression we have when looking at bare earth or soil is of color. Bright colors especially, catch our eye. Geographers are familiar with Red Desert soils in California, Arizona, and Nevada (Arizona State Soil); and Gray Desert soils in Idaho, Utah, and Nevada (Nevada State Soil). We have the White Sands in New Mexico, Green Sands along the Atlantic Coast, and Redbeds in Texas and Oklahoma (Oklahoma State Soil). The Red River between Oklahoma and Texas carries red sediment downstream, particularly in times of flood. The Yellow River (Hwang Ho) in China carries yellow sediment. Surface soils in the Great Plains and Corn Belt are darkened and enriched by organic matter.

Earth materials found in such locations as those mentioned above were used as coloring agents early in the development of most human cultures. As earth material was fashioned into utilitarian vessels, artistic colors inevitably were incorporated into them. Indigenous North American cultures used contrasting earth colors as body paints, and modern American culture uses colored earth in cosmetics and ceramics and as pigments for paints.

Munsell Color System

Red, brown, yellow, yellowish-red, grayish-brown, and pale red are all good descriptive colors of soil, but not very exact. Just as paint stores have pages of color chips, soil scientists use a book of color chips that follow the Munsell System of Color Notation (www.munsell.com). The Munsell System allows for direct comparison of soils anywhere in the world. The system has three components: hue (a specific color), value (lightness and darkness), and chroma (color intensity) that are arranged in books of color chips. Soil is held next to the chips to find a visual match and assigned the corresponding Munsell notation. For example, a brown soil may be noted as: hue value/chroma (10YR 5/3). With a soil color book with Munsell notations, a science student or teacher can visually connect soil colors with natural environments of the area, and students can learn to read and record the color, scientifically. Soil color by Munsell notation is one of many standard methods used to describe soils for soil survey. Munsell color notations can be used to define an archeological site or to make comparisons in a criminal investigation. Even carpet manufacturers use Munsell soil colors to match carpet colors to local soils so that the carpet will not show the dirt (soil) tracked into the house.

Soil Composition and Color

Soil color and other properties including texture, structure, and consistence are used to distinguish and identify soil horizons (layers) and to group soils according to the soil classification system called *Soil Taxonomy*. Color development and distribution of color within a soil profile are part of weathering. As rocks containing iron or manganese weather, the elements oxidize. Iron forms small crystals with a yellow or red color, organic matter decomposes into black humus, and manganese forms black mineral deposits. These pigments paint the soil (Michigan State Soil). Color is also affected by the environment: aerobic environments produce sweeping vistas of uniform or subtly changing color, and anaerobic (lacking oxygen), wet environments disrupt color flow with complex, often intriguing patterns and points of accent. With depth below the soil surface, colors usually become lighter, yellower, or redder.

Interpreting Soil Color

Color can be used as a clue to mineral content of a soil. Iron minerals, by far, provide the most and the greatest variety of pigments in earth and soil (see the following table).

Properties of Minerals

Mineral	Formula	Size	Munsell	Color
goethite	FeOOH	(1-2 m m)	10YR 8/6	yellow
goethite	FeOOH	(~0.2 m m)	7.5YR 5/6	strong brown
hematite	Fe_2O_3	(~0.4 m m)	5R 3/6	red
hematite	Fe_2O_3	(~0.1 m m)	10R 4/8	red
lepidocrocite	FeOOH	(~0.5 m m)	5YR 6/8	reddish-yellow
lepidocrocite	FeOOH	(~0.1 m m)	2.5YR 4/6	red
ferrihydrite	$Fe\ (OH)_3$		2.5YR 3/6	dark red
glauconite	$K(Si_xAl_{4-x})(Al,Fe,Mg)O_{10}(OH)_2$		5Y 5/1	dark gray
iron sulfide	FeS		10YR 2/1	black
pyrite	FeS_2		10YR 2/1	black (metallic)
jarosite	$K\ Fe_3\ (OH)_6\ (SO_4)_2$		5Y 6/4	pale yellow
todorokite	MnO_4		10YR 2/1	black
humus			10YR 2/1	black

calcite	$CaCO_3$		10YR 8/2	white
dolomite	$CaMg\ (CO_3)_2$		10YR 8/2	white
gypsum	$CaSO_4 \times 2H_2O$		10YR 8/3	very pale brown
quartz	SiO_2		10YR 6/1	light gray

Relatively large crystals of goethite give the ubiquitous yellow pigment of aerobic soils. Smaller goethite crystals produce shades of brown. Hematite (Greek for blood-like) adds rich red tints. Large hematite crystals give a purplish-red color to geologic sediments that, in a soil, may be inherited from the geologic parent material. In general, goethite soil colors occur more frequently in temperate climates, and hematite colors are more prevalent in hot deserts and tropical climates.

Color - or lack of color - can also tell us something about the environment. Anaerobic environments occur when a soil has a high water table or water settles above an impermeable layer. In many soils, the water table rises in the rainy season. When standing water covers soil, any oxygen in the water is used rapidly, and then the aerobic bacteria go dormant. Anaerobic bacteria use ferric iron (Fe^{3+}) in goethite and hematite as an electron acceptor in their metabolism. In the process, iron is reduced to colorless, water-soluble ferrous iron (Fe^{2+}), which is returned to the soil. Other anaerobic bacteria use Mn^{4+} as an electron acceptor, which is reduced to colorless, soluble Mn^{2+}. The loss of pigment leaves gray colors of the underlying mineral. If water stays high for long periods, the entire zone turns gray.

When the water table edges down in the dry season, oxygen reenters. Soluble iron oxidizes into characteristic orange colored mottles of lepidocrocite (same formula as goethite but different crystal structure) on cracks in the soil. If the soil aerates rapidly, bright red mottles of ferrihydrite form in pores and on cracks. Usually ferrihydrite is not stable and, in time, alters to lepidocrocite.

Along seacoasts, tide waters saturate soils twice daily, bringing soluble sulfate anions. Anaerobic bacteria use the sulfate as an electron acceptor and release sulfide (S^{2-}) which combines with ferrous iron to precipitate black iron sulfide. A little hydrochloric acid (HCl) dropped on this black pigment quickly produces a rotten egg odor of hydrogen sulfide (H_2S) gas. Soils that release H_2S gas are called sulfidic soils. With time, iron sulfide alters to pyrite (FeS_2) and imparts a metallic bluish color. If sulfidic soils are drained and aerated, they quickly become very acid (pH 2.5 to 3.5), and a distinctive pale yellow pigment of jarosite forms. This is the mark of an acid sulfate soil that is quite corrosive and grows few plants.

Galuconitic green sands form in shallow ocean water near a coast. They become part of soils that form after sea level drops. White colors of uncoated calcite, dolomite, and gypsum are common in geologic materials and soils in arid climates. A little carbonate dissolves in water, moves downward, and precipitates in soft white bodies or harder nodules. It also accumulates in root pores as lacy, dendritic (tree-branch) patterns.

Influence of Organic Matter on Soil Color

Soil has living organisms and dead organic matter, which decomposes into black humus. In grassland (prairie) soils the dark color permeates through the surface layers bringing with it nutrients and high fertility (Kansas State Soil). Deeper in the soil, the organic pigment coats surfaces of soil, making them darker than the color inside. Humus color decreases with depth and iron pigments become more apparent. In forested areas, organic matter (leaves, needles, pine cones, dead animals) accumulates on top of the soil. Water-soluble carbon moves down through the soil and scavenges bits of humus and iron that accumulate below in black, humic bands over reddish iron bands. Often, a white layer, mostly quartz occurs between organic matter on the surface where pigments were removed (Wisconsin State Soil).

Organic matter plays an indirect, but crucial role in the removal of iron and manganese pigments in wet soils. All bacteria, including those that reduce iron and manganese, must have a food source. Therefore, anaerobic bacteria thrive in concentrations of organic matter, particularly in dead roots. Here, concentrations of gray mottles develop.

Soil color is a study of various chemical processes acting on soil. These processes include the weathering of geologic material, the chemistry of oxidation-reduction actions upon the various minerals of soil, especially iron and manganese, and the biochemistry of the decomposition of organic matter. Other aspects of Earth science such as climate, physical geography, and geology all influence the rates and conditions under which these chemical reactions occur.

Soil adds beauty to our landscapes. These colors blend with vegetation, sky, and water. For art students and others who may be interested in creating a natural look to their artwork, try to incorporate finely ground colored soils as pigments into your work.

Adapted from: Lynn, W.C. and Pearson, M.J., The Color of Soil, The Science Teacher, May 2000.

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