FACTORS AFFECTING SOIL COLOR (PROGRESS REPORT)

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It is generally agreed among soil workers today that, outside of the parent material, the most potent factors of soil coloration are iron and organic matter. Further, it is commonly believed that the most influential forms of these substances, in this connection, are hematite and humic substances, respectively; hematite producing the "red"-colored soils and humic acid compounds, in connection with iron, producing the "dark"-colored soils. However, in view of the fact that a great many different shades of red soils, and fully as many shades of dark soils exist, it seems desirable to try to discover the mechanism which produces so many varieties of coloration from two pigmentary materials.

Hematite occurs in several color forms varying through different shades of red, pink, brown, purple, and gray to almost black; its streak color, however, is always reddish. Likewise, different types of organic matter vary through different shades of almost the same gamut of colors. Thus, mineral soil which consists otherwise of whitish, siliceous material could, if mixed with varying amounts of the two main pigmentary materials, be produced in an unending array of shades and hues of color.

In the present work it has been found that the reddish colors of the few existing truly red soils are not directly proportional to the amount of hematite present in them. Several instances have been observed in which two soils of indistinguishable red color had widely different iron contents. Conversely, still more instances have been observed where two soils of nearly identical iron content had widely different colors. Much more influential on color than amount of iron are particle size, density, and degree of agglomeration of the iron crystals present. If a small amount of nearly any red soil is placed in a mortar and pestled well the color becomes distinctly lighter. This is due to the greater scattering of light by the resulting finer particles and to the "diluted" effect or de-agglomeration of the iron produced by the grinding. It so happens that the density (felsitic quality) and agglomeration of hematite crystals are greatest in the reddest soils.

The explanation of this seems to be that these soils contain a very small amount of organic matter and that, at any time, there is never more than a trace of soluble organic matter present. This precludes the formation at one time of more than an infinitesimal amount of labile iron. This soluble iron comes almost entirely from amorphous or hydrated forms of iron and owing to the usual highly oxidative condition present in such soils, is fairly rapidly oxidized and built onto hematite crystals already present. Thus the inherent color becomes more apparent, light dispersion lessened and the red color of the iron is intensified.

It is somtimes found that, in certain areas of soil of pronounced reddish color, there are present small areas of seemingly otherwise similar soil which are only slightly reddish or perhaps not reddish-colored at all. Generally, if not always, it will be found that the nonreddish, or lighter-colored, soil contains considerably more calcium or other bases, particularly sodium, than the red soil. It is known in physical chemistry that bases tend to retard and often completely prevent agglomeration of the iron particles. Thus the iron effect is not allowed to become intensified and a lighter color of the soil is the result.

The brownish shades of color in soils are more complex than the reds since they are caused generally by both physical and chemical combinations of iron with organic matter. The lighter brown colors, tending toward yellowish, are mostly dominated by hydrated forms of iron oxide but always contain some water-soluble organic matter. As the brownish color becomes darker either or both of two changes occur; the degree of hydration of the iron lessens or the amount of organic matter in chemical combination with iron increases. In this connection, as will be brought out below, the reaction (acidic or basic) of the medium and the dominating degree of moisture have effects on the color. The chocolate brownish to maroon colors of certain soils in the south are not completely understood but it is believed that the comparatively low silica content of the parent material in connection with highly oxidized iron, plus soluble organic matter in a low acidic medium, is strongly influential. Titanium and manganese have been found to have little if any influence on color in this particular connection.

The color of some gray soils, low in organic matter, seems to be due to the presence of both ferric and ferrous iron and not to ferrous iron alone. The gray color due to iron was found to be best developed when the proportions of ferric to ferrous iron varied from 3:2 to 2:3. As the proportion of ferric iron exceeds these figures the colors of all soils studied become browner. Conversely, as the ferrous iron dominates more strongly, the color becomes lighter or more whitish.

The color of some other gray soils is influenced, in addition to the two iron forms, by highly dispersed, small particles of organic matter which are high in carbon content. Some of the carbon has been found to be highly graphitic and some to be humic in nature. The gray color of such soils may be said to be a highly diluted, blackish color.

Dark brown or blackish-colored soils are found mostly in depressed areas or in places where the organic matter has undergone decomposition under at least temporary excessive-moisture conditions. This has been found not to imply highly anaerobic conditions, except, possibly, temporarily. Instead, it has been found that considerable oxygen is necessary to develop a dark coloration. The mechanism that produces the dark coloration of the soil—both mineral and organic matter—demands an environment which is alternately strongly reducing and weakly oxidizing. The former condition is produced biologically with the aid of the excess moisture and easily decomposable organic matter while the latter is formed by a temporary significant decrease in moisture and available energy material. The particular component part of the organic matter which plays the most active role in coloration has been found to belong to the polyhydroxyphenols. It is formed primarily from tannic substances which occur in nearly all plant material and possesses actual indicator properties. When it combines with soluble iron, ferrous or ferric or both, it produces the well known dark "pigment," probably seen most commonly in soils occurring in depressed areas. This pigment, being an indicator, varies in color with the hydrogen-ion concentration of the soil medium. Normally it causes a grayish color at a pH of about 5.7 to 6.0. Below this concentration the color becomes lighter, gradually approaching the color of fresh ripe persimmon pulp, at strong acidities. Beginning at about pH 6 and with increasing alkalinity, the pigment gradually darkens in hue. Its maximum dark development is well evident in some black alkali soils.

Although it is true that the darker color is generally well developed under conditions where bases, such as sodium, calcium, etc., are excessively abundant, it is also developed under certain conditions where there may be only a minimum amount of bases present. Such an environment exists in ultramoist places where a modicum of oxygen and soluble organic matter exists. The oxygen may be supplied either by rains, by moving well-aerated ground water, or by aspiration by fluctuating water levels. Under this condition a medium strong to quite strong reducing environment is brought about and, as is the case with some indicators, the pigment is affected by oxidation-reduction potentials as well as by hydrogen-ion concentration. Thus it is that in depressed places this organic pigment is maintained in its dark form.

As yet, nothing has been mentioned about moisture. As is well known, the main effect that moisture has on color change is physical in nature. Its greatest development occurs in finely divided materials, such as soil, where the water merely fills up pore spaces, thereby stopping or greatly decreasing light dispersion. In this manner moisture gives the appearance of darkening soils.