

## FACTORS AFFECTING SOIL COLOR: PROGRESS REPORT No. 2

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In a previous report (Plice 1943) the mechanism of coloration of red, red-and-yellow, gray mineral, and dark organic soils was discussed. Truly red colors were described as being due to red-hematite crystals of sufficient size, translucency, and degree of agglomeration to produce the red color. Since hematite is known to exist in a gamut of colors—from black through grays and browns to scarlet and vermillion—the variety or type that causes redness in soils must be distinguished from other forms. The lighter reddish and yellowish colors in soils were explained as being due to lesser degrees of agglomeration and to decreases in crystal size of the hematite. Gray colors were ascribed to a rather short range in the ratio of ferric to ferrous iron. The dark colors in so-called "fertile" soils or in soils in poorly drained depressional areas were found to be due to complex mineral-organic pigments. These are of a polyhydroxyphenolic nature hooked up with ferric and ferrous iron; they act not only as acid-base indicators, but also as redox indicators.

Subsequent study of soil color phenomena has thrown additional light on the development of grays, browns, and purples, and on their oxygen-moisture-base relationships to the metallo-organic redox pigment colors. In the case of gray colors, where the preponderant color effect is caused by ferric-ferrous iron complexes, it is now found that the limits of proportions of ferric to ferrous iron can evidently be greater than the 3:2 to 2:3 ratio previously reported. Several samples of blue rocks (particularly limestone), shale, and lake-clay soil have shown such a wide diversity of proportions that it may be that there is no ferric-ferrous ratio or range of ratios necessary to produce those particular degrees of gray color. However, a correct determination of ferrous iron is extremely difficult to make, particularly if the least amount of soluble organic matter happens to be present. This is quite probably the explanation of widely varying determinations and other seeming discrepancies. No nuance has been found in the case of grays caused mainly by the presence of finely divided graphitic material in otherwise uncolored matrices, such as occur in certain carboniferous shales and soils of similar origin.

It is being agreed more and more that many of the so-called red soils are actually brown variants. The browns of otherwise uncolored, or light-colored, soils—mostly highly acidic or siliceous according to the geologist—are caused mainly by the presence of organic matter which is mostly in the form of "humates." These humates act as color indicators under certain conditions as will be emphasized below. Part of the brown may be due to iron oxide of the familiar iron-rust color. This color is due to the powdery form of the oxide present and the manner in which it scatters light. In some other soils, particularly of igneous origin and basaltic nature, iron coloration may be dominated by the presence of diamagnetite or the nonmagnetic form of magnetite. This material in the powder form, which is its most usual soil form, gives a characteristic dull brownish color. When red-hematite crystals are present, in addition to the magnetite, a suffused maroonish-color effect results. This color is especially evident when the soil is moist. It is quite closely reproduced in some soils of nonigneous origin, particularly in some local spots in the western prairie and Great Plains regions. These particular soils are of Permian red-beds origin and the maroonish and chestnut-color effects result from a dilution of the translucent red hematite with the peculiar pigment of the prairie-soil humic matter. These colors are strongly accentuated in many local areas of varying sizes in comparatively level grass country where wind-blown-clay aggregates have collected in even shallow deposits.

The aggregates have a size approximating that of medium-sized-to-coarse sand, sometimes being referred to as "pseudo-sand," and collect during very windy spells in dry cold winter seasons. The color accentuation is due mainly to the porous structure of the aggregates. This is readily observable when the small aggregates are crushed.

Brown colorations due to the presence of manganese or titanium oxides have been encountered in only a few small and very much localized spots. These exist under temporary seepy conditions where concretions of these elements were formed and have subsequently been weathered.

Occasionally brown and red soils differentiate into purplish-colored soils. However, in no case studied has the purplish color been real; it has been found to be due mostly to a mechanical mixture of red with either blackish or grayish material. In some instances a mixture of minute biotite flakes and/or hornblende with red soil produces a purplish effect. A more pronounced purple color results if the black admixed substance is black hematite, particularly specularite, with a crystal thickness such that a small amount of light is transmitted. Variations in purplish hue result from varying proportions of translucent and nontranslucent hematite crystals. A further purplish variant is to be seen in many places in the southwestern States where efflorescence of salts in soils is of common occurrence. Certain salts, particularly gypseous salts, when occurring in colloidal-crystal efflorescence, produce a Tyndall effect. When this occurs in red soils, particularly red-beds soils, a purplish effect results.

In the case of the previously reported organic pigment which functions both as an acid-and-base indicator and as a redox indicator, it was not certainly known whether its neutral or equivalence point occurred in an aerobic or anaerobic environment. Subsequent study has shown that this point, at which the darkest color results, is developed when the soil solution contains approximately three ppm of dissolved oxygen. When the oxygen supply drops below this amount the color becomes lighter, toward the brownish; when it exceeds it the color becomes lighter also, but towards an orange-yellowish shade.

A change either way from the equivalence point in oxygen content tends to raise acidity. Acidity influences the color effect. If sufficient reducing substances are present, with the proper amount of oxygen and moisture, a buffering or stabilizing effect seems to exist which tends to limit any change in color and acidity. On the other hand, if sufficient bases, such as calcium, magnesium, and sodium, are present changes in color and acidity are hindered even should the supply of oxygen and reducing substances become unfavorable. This may explain, partially at least, why some very dark-colored soils maintain their dark status even though they are scantily supplied with bases.

In the continuation of the present study a special effort will be made to get more light on the ferric-ferrous iron relationship in connection with the gray colorations supposedly caused by that hookup. One or two of the several recently discovered ferrous-ion indicators show some promise of giving an estimation of that ion more accurate than heretofore possible.

#### LITERATURE CITED

- Plice, M. J. 1943. Factors affecting soil color (progress report). Proc. Okla. Acad. Sc. 23: 49-51.