Munsell color value as related to organic carbon in Devonian shale of the Appalachian basin

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Abstract

Comparison of Munsell color value with organic-carbon content of 880 samples from 50 drill holes in the Appalachian basin shows that a power curve is the best fit for the data. A color value below 3 to 3.5 indicates the presence of organic carbon, but it is meaningless in determining the organic-carbon content because a large increase in the amount of organic carbon causes only a minor decrease in the color value. Above 4, the color value is one of the factors that could be used in calculating the organic content. For samples containing equal amounts of organic carbon, the calcareous shale containing more than 5 percent calcite is darker than the shale containing less than 5 percent calcite.

Introduction

We determined the color of more than 1900 samples from 80 drill holes throughout the Appalachian basin. To investigate the possibility of a relationship between color and organic-carbon content, comparisons were made for 880 samples from 50 drill holes. The Munsell soil color charts (Munsell Color Company, 1954) were visually compared with dry pressed-powder wafers prepared from our samples. Sample preparation and the method for making the wafers have been described by Hosterman and Loferski (1978). The Munsell color designation is composed of the hue (color), value (lightness), and chroma (saturation). A neutral (N) color has no hue or chroma but does have value. The value ranges from 0 (black) to 10 (white) for neutral colors and from 1 to 9 for colors having hue and chroma. Color values from the neutral and other colors were plotted against the organic-carbon content for the 880 samples.

All color determinations were made under similar lighting conditions. The chroma was estimated to the nearest 0.25, and the value was estimated to the nearest 0.1. A comparison of the wafer color with the color of the corresponding drill core showed that the value did not differ more than 0.1. Wetting the drill core lowered the value by approximately 2.0 but did not effectively change the hue or chroma.

Organic carbon refers to the disseminated carbonaceous material derived from both plants and animals. The organic-carbon content was determined by one of two methods. In the first method, the organic carbon is the difference between total carbon, measured by high-temperature combustion, and carbonate carbon, measured by titration (Leventhal, 1979). In the second method, the organic carbon is measured directly by a wet oxidation technique (Claypool and Stone, 1979; C. E. Claypool and C. N. Threlkeld, written communication, 1979; Claypool and others, 1980). The results of both methods are reported in percent by weight.

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Organic carbon related to color value

In the Appalachian basin, the Devonian shale can be divided into black-shale facies and gray-shale facies. The black-shale facies contains more organic carbon than does the gray-shale facies (J. S. Leventhal and J. W. Hosterman, unpublished data, 1980). More gas has been produced from the black-shale zones than from the gray-shale zones; therefore, the black zones are considered worth prospecting (Bagnall and Ryan, 1976; Patchen, 1977). The organic carbon is the source of the natural gas, and its volume is partly indicative of the total gas-generating capacity of the shale.

If a relationship existed between the color value and the organic-carbon content, then color value could be used to calculate the gas resources of the Devonian shale of the Appalachian basin. Schmoker (1980) regards black shale containing more than 2 percent by volume organic matter as a potential gas resource (equivalent to 0.8 percent by weight organic matter or about 0.6 percent by weight organic carbon). G. E. Claypool and C. N. Threlkeld (written communication, 1979) stated that, in five drill holes in the Appalachian basin, the gas content is slightly proportional to the organic-carbon content greater than 1 percent organic carbon; less than 1 percent, the gas and organic-carbon contents are not related.

We compared color value with organic carbon content for 880 samples from 50 drill holes throughout New York, Pennsylvania, Ohio, West Virginia, Kentucky, Tennessee, and Virginia. In all but two drill holes, where data are incomplete, a clear relationship represented by a power curve regression exists between the color value and the organic-carbon content. A color value below 3.0 to 3.5 does indicate that organic carbon is present in concentrations greater than 7 percent, but it is meaningless in determining organic-carbon content because a large change in the amount of organic carbon causes a minor increase or decrease in the color value. The correlation coefficients (r) for 48 drill holes ranged from 0.81 to 1.00. However, the spread color value between drill holes was greater than expected from the excellent individual correlations. This large spread in the color value indicated that something in addition to the organic-carbon content is also affecting the color.

The mineralogy of all 880 samples was carefully studied, and we determined that calcite was the only mineral to have any effect on the color value. Calcite content is greater than 5 percent in the black shale samples from New York, Pennsylvania, and one drill hole in northwestern Ohio.

The color value at 1.0 percent organic carbon ranges from 4.0 to 5.5 for the shale deposited in a high-calcium environment and from 4.8 to 6.1 for the shale deposited in a low- or no-calcium environment. Figure 1 shows the best power curve fit for 757 samples containing more than

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Figure 1 near here

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5 percent calcite (A) and for 123 samples that contain no more than a trace of calcite (B). The two curves indicate that black shale without calcite contains more than 1.0 percent organic carbon when the color value is 5.4 or less. Calcareous black shale containing more than 5 percent calcite contains more than 1.0 percent organic carbon when the color value is 4.7 or less.

Discussion

We assume that the influence of the calcium on the clay minerals during deposition causes the difference in color value between shale containing calcite and shale not containing calcite. All clay minerals have the property of sorbing and retaining anions and cations in an exchangeable state. In a calcium-rich environment, clay minerals adsorb the calcium ions easily, and clay minerals flocculate readily (Grim, 1968, p. 358). For the calcium ion to be replaced, more than the stoichiometric amount of organic matter is required (McAtee, 1959). However, flocculation of the clay minerals causes rapid deposition and prevents the organic matter from replacing the calcium ions. Thus, the organic material is free to settle as discrete grains. Conversely, in a calcium-free environment where no calcium ions are present to be adsorbed by the clay minerals and where the clay minerals have no tendency to flocculate, the organic material is adsorbed by the clay minerals. Where the organic material is adsorbed by the clay, its color is diluted by the clay, and where the organic material is free, the color of the rock is darker. In calculating potential gas resources by using color as an indicator of organic-carbon content, one must know whether the black-shale sequence was deposited in a calcium-rich environment.

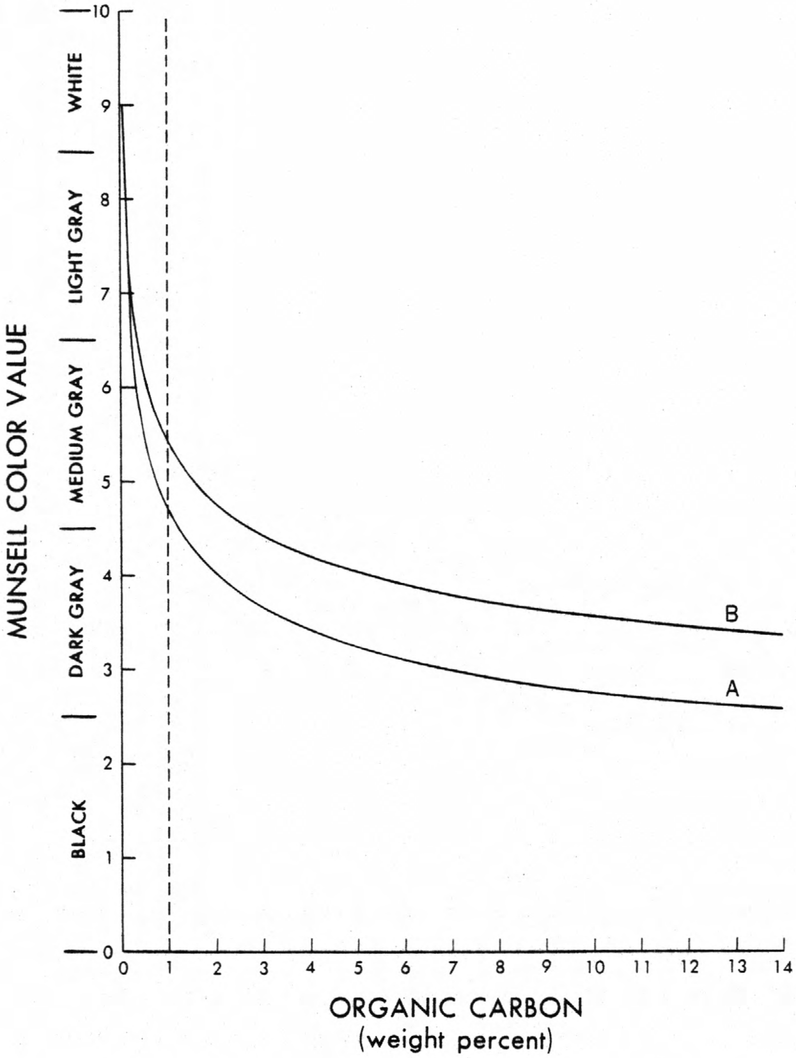

Figure 1.--Munsell color value and organic carbon in Devonian shale of the Appalachian basin. (A) Shale containing more than 5 percent calcite, (B) shale containing no more than a trace of calcite.

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