Areas with high water tables sometimes have blue or blue-gray soils. In some cases, the blue soil is mottled with streaks of reddish-brown material. These conditions are caused by iron in soils that either are continuously saturated (blue or blue-gray soils) or are frequently saturated (mottled soils).

In an aerated soil, the iron is said to be oxidized. The iron, a ferric compound, is relatively insoluble in water, and under these conditions, helps promote good soil structure.

In saturated soil, however, a change in the state of iron can occur under certain conditions (which must be met simultaneously) in the soil environment: the presence of organic material; lack of oxygen; and occurrence of anaerobic microorganisms in an environment that promotes their growth (proper temperature and pH). If these conditions are present, then ferric iron is reduced to ferrous iron. The reduction process is accompanied by oxidation of the organic material by the microorganisms. The chemical reaction is described by:

$$\text{CH}_2\text{O} + 2 \text{Fe}_2\text{O}_3 + 7\text{CO}_2 + 3\text{H}_2\text{O} \rightarrow 4\text{Fe}^{2+} + 8\text{HCO}_3^-$$

where CH2O represents organic material. The result is a soil with a blue or blue-gray color or mottled appearance.

The reduced or ferrous iron compounds are much more soluble in water than ferric compounds. Experiments have shown that increasing the organic matter content of the soil hastens the reduction process, and increasing the time of saturation increases the amount of soluble iron.

For agricultural purposes, it may be necessary to drain these soils to provide a root zone environment conducive to plant growth. This is commonly done by installing subsurface drainage systems, which may consist of interceptor drains or of laterals spaced throughout a field, depending on the source of drainage water.

A key factor in the performance of a drainage system is the hydraulic conductivity of the soil. The hydraulic conductivity, a measure of the ability of water to flow through the soil, is described by:

$$K = \frac{Cd^2\rho g}{\mu}$$

where

- $K$ = hydraulic conductivity
- $d$ = some mean diameter of the pore space of the soil
- $\rho$ = density of water
- $g$ = gravity constant
- $\mu$ = viscosity of water
- $C$ = dimensionless constant, which includes the effect of factors such as pore space shape and tortuosity.

Although the hydraulic conductivity is affected by several factors, it can be seen that the pore space diameter is particularly significant. Hydraulic conductivity is directly proportional to the square of the mean diameter of the pore space. Thus, changes in the pore space diameter can severely affect the hydraulic conductivity of a soil.

Some recent drainage investigations of fields where reduced soil conditions occurred revealed extremely low hydraulic conductivity in the reduced material. However, the soil texture indicated that water movement through the soil should be adequate for drainage.

The first site was a field in a river floodplain. Throughout most of the problem area, the blue soil was overlain by a brown top soil, and both had a similar texture. In one part of the field, the blue soil extended up to the surface and was more sandy.

The second site was a field on a hillside. Near the bottom of the field was a seepage area, upslope from which sand underlay the

**TABLE 1. Particle Size Analysis of Soils at Two Sites**

<table>
<thead>
<tr>
<th>Location</th>
<th>Clay</th>
<th>Silt</th>
<th>Sand</th>
</tr>
</thead>
<tbody>
<tr>
<td>River flood-plain site</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Top soil</td>
<td>15</td>
<td>71</td>
<td>14</td>
</tr>
<tr>
<td>Underlying blue soil</td>
<td>15</td>
<td>77</td>
<td>8</td>
</tr>
<tr>
<td>Sandy soil</td>
<td>11</td>
<td>36</td>
<td>53</td>
</tr>
<tr>
<td>Hillside site</td>
<td>18</td>
<td>12</td>
<td>70</td>
</tr>
</tbody>
</table>

**TABLE 2. Iron Content and Organic Matter Content of Soils in Drainage Problem Areas**

<table>
<thead>
<tr>
<th>Location</th>
<th>pH</th>
<th>Organic matter content</th>
<th>Total iron*</th>
<th>Soluble iron†</th>
</tr>
</thead>
<tbody>
<tr>
<td>River flood-plain site</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Top soil</td>
<td>7.9</td>
<td>3.5</td>
<td>2.6</td>
<td>20</td>
</tr>
<tr>
<td>Underlying blue soil</td>
<td>5.7</td>
<td>6.4</td>
<td>2.3</td>
<td>248</td>
</tr>
<tr>
<td>Sandy soil</td>
<td>7.4</td>
<td>†</td>
<td>1.4</td>
<td>140</td>
</tr>
<tr>
<td>Hillside site</td>
<td>5.3</td>
<td>1.3</td>
<td>2.6</td>
<td>210</td>
</tr>
</tbody>
</table>

*Approximation by perchloric acid digestion.
†Diethylenetriamine pentaacidic acid (DTPA) extraction.
‡Not measured.
top soil, and below which the underlying soil was a sandy loam. This texture change was the cause of the seepage area.

At both sites, holes were augered into the soil so that rate of water movement into the holes could be observed and soil hydraulic conductivity measured. After at least five hours of observation, no appreciable volume of water had flowed into the auger holes, even though the water table of the surrounding soil was at or near the surface. Hydraulic conductivity measurements were not possible because of the slow water movement.

It is believed that the low hydraulic conductivity of these soils is due to presence of reduced iron and high organic matter content. Under these conditions, ferrous hydroxide is formed and precipitates out of the water. The reaction is described by:

\[ \text{Fe}^{2+} + 2\text{HCO}_3^- \rightarrow \text{Fe(OH)}_2 + 2\text{CO}_2 \]

In laboratory experiments relating to reclamation of salt-affected soils conducted at U. C., Davis, by M. A. El-Nahal, the formation of gelatinous substances under reducing conditions similar to those at the sites was observed in many cases. The gelatinous substance in those experiments, accompanied by reduction of ferric iron to the ferrous state and presumed to be \( \text{Fe(OH)}_2 \), markedly reduced percolation through soil columns. The conditions at these sites indicate that this precipitate probably was forming and was a major contributing cause of the poor soil hydraulic conductivity.

A second factor also believed to be caused by the precipitate is compaction of the reduced soil. This compaction was evident while jetting observation wells into the soil. It is believed that the precipitate may have a lubrication effect, allowing soil particles to compact more readily than they would normally. This compaction would also reduce pore dimensions, thus lowering the hydraulic conductivity.

To correct this problem, it is necessary to drain the soil and oxidize the reduced iron. However, drainage is not possible because of the poor drainage characteristics and the periodic wetting by irrigation and rainfall. Thus, if a problem soil underlies a good top soil, a shallow drainage system installed only in the top soil, coupled with good irrigation management, may be the only feasible means of providing a suitable root environment.

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