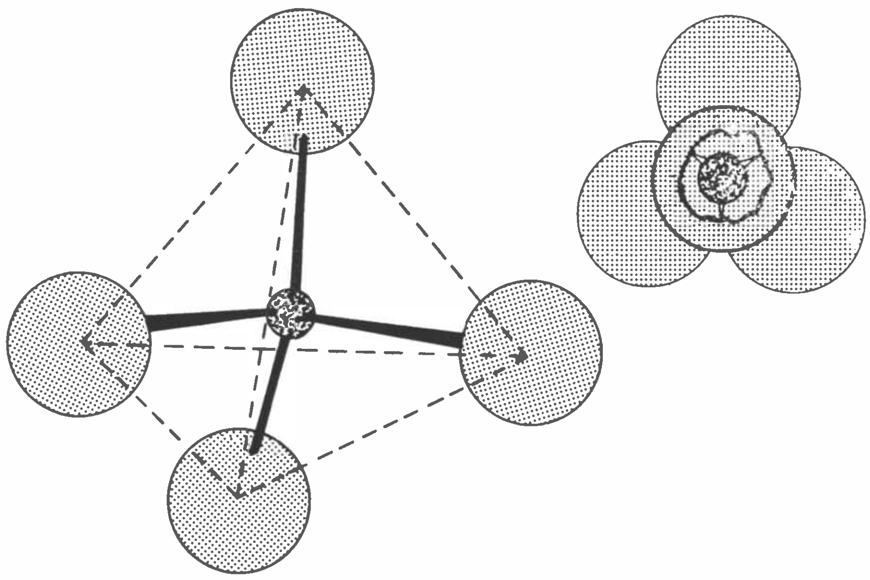
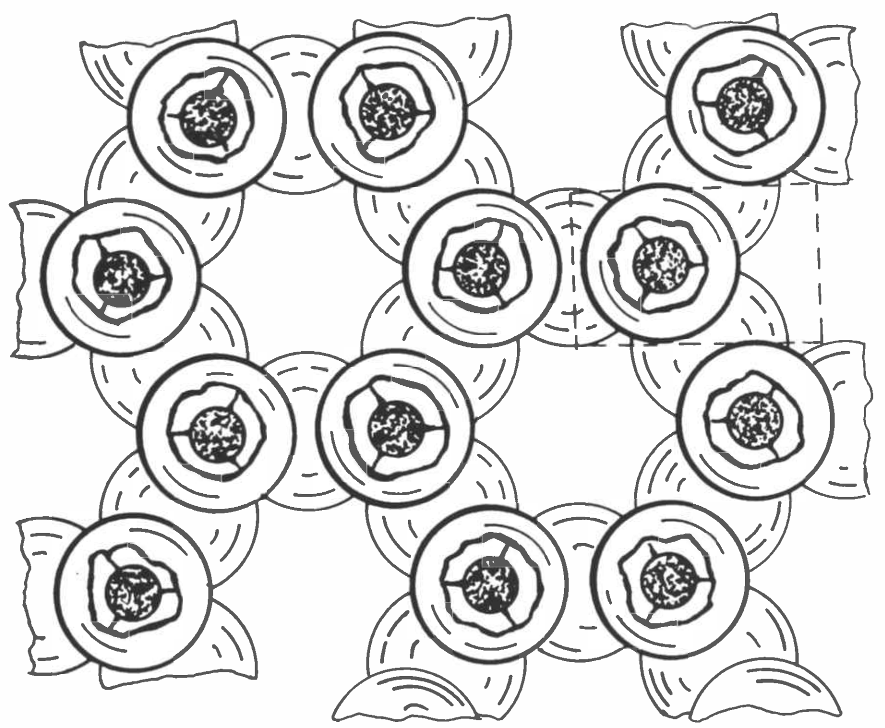


1. Model of a single silicon-oxygen tetrahedron. The perspective, expanded view, left, and cutaway view, right. Three of the oxygen atoms lie in a single plane while the fourth extends above this plane.



2. Twelve silicon-oxygen tetrahedrons joined together to illustrate the sheet-like structure of mica. This model illustrates the way in which the silicon atoms (darkened spheres) share the oxygen atoms (larger spheres) lying in the horizontal plane.

The Making of Soils

by Donald E. Post[*]

Understanding the nature, evolution, and development of soils, and changes which take place with time, are necessary to explain certain soil-plant-water reactions. This ultimately helps in the development of optimum methods of soil treatment and productive use of soils for the cultivation of crops.

Trained soil scientists working in the United States currently recognize over 8000 different kinds of soils. These are called *soil series* and are usually named after a geographical landmark where they were first discovered and mapped. Three examples of soils found in Arizona are the Gila soil, named after the Gila River, and the Casa Grande and Springerville soils named after their respective Arizona towns.

About 200 soil series are found in Arizona. Each of these soils have significantly different characteristics, important enough to affect their management and productivity.

What makes these soils different?

A soil as it exists today any place on the face of the earth is the result of five factors of soil formation: climate, living organisms, parent material, topography, and time. If any two soils have different characteristics, it was because one or more of these five factors varied. Let's begin at the beginning.

Soils are formed from the rock surface of the earth by the process of weathering. This weathering of rock takes two principal forms, *physical* and *chemical.*

Physical weathering includes such processes as the action of water, as it freezes and melts, in cracking and chipping rock and breaking it into finer particles, thermal fracturing due to temperature changes, and the action of growing plants as their roots exert pressure and cause splits and breaks in the rocks of the earth's surface.

Chemical weathering encompasses all those changes of the rocks which result from chemical activity, principally in the presence of water and the various components of the atmosphere. One example of chemical weathering is the chemical modification of potassium feldspar minerals to clay and silica. Atmospheric carbon dioxide unites with water to form carbonic acid. The dilute solution of

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carbonic acid to which these feldspars are exposed in rain and soil water causes a chemical reaction which removes the potassium from the rock to form potassium carbonate, while the dissolved aluminum reacts with some of the dissolved silica to form clay minerals.

Physical weathering also plays a significant role in chemical weathering of this sort, since the finer the particles into which the feldspar is broken by various mechanical means, the greater the surface area available for chemical weathering processes and the more rapid the chemical reaction. For various types of rock, of course, the kind and the rate of weathering undergone varies greatly. Some rocks decompose with relative rapidity while others are most resistant to weathering. It is in the process of weathering, however, along with the accumulation of organic debris, which is responsible for the genesis and growth of the coating of soil on the land surfaces of our earth.

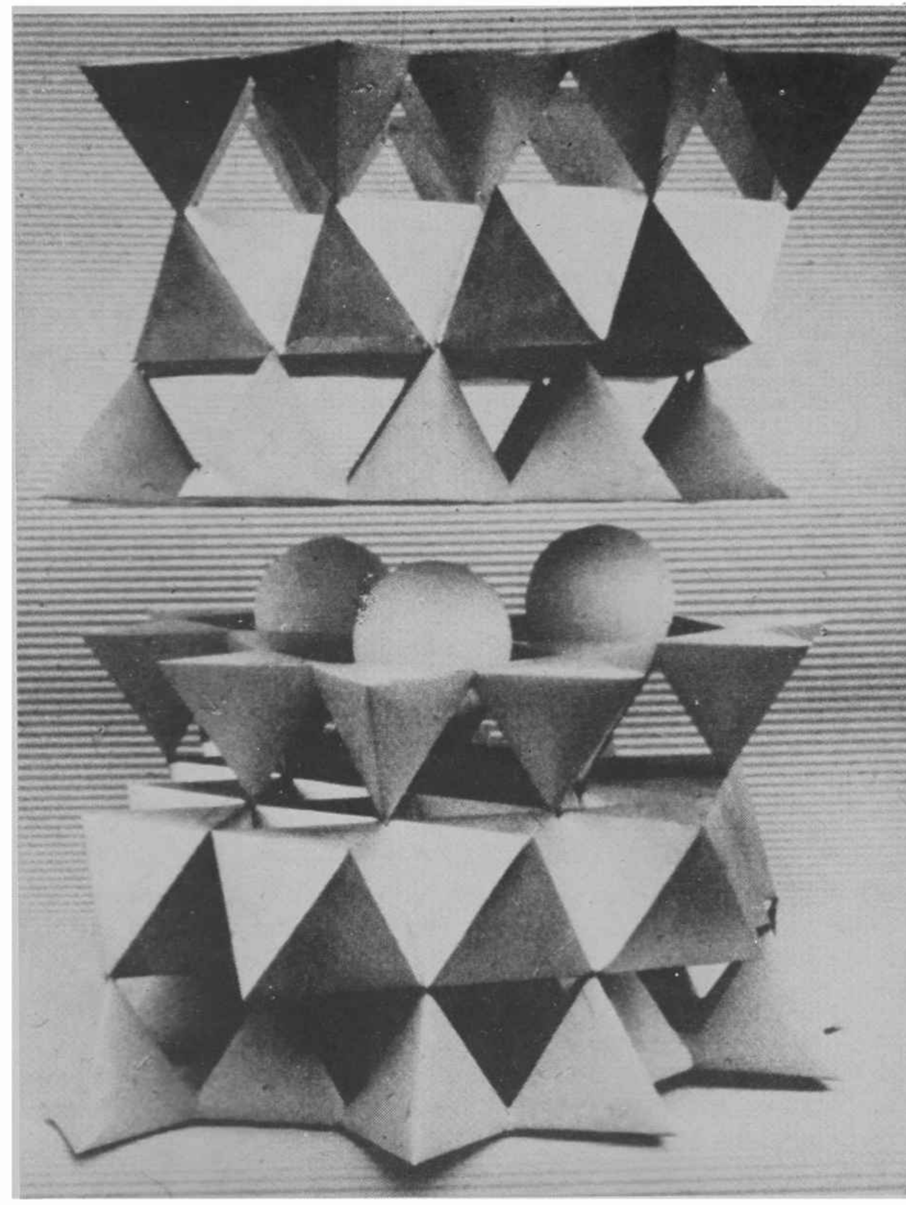
In referring again to the five factors of soil formation, *climate* and *living organisms* are referred to as the active factors of soil formation. They supply the energy to the "weathering" system. Parent material, topography, and time are passive factors. Although the three passive factors do exert a great influence on the type of soil, it is a matter of chance how these factors combine in nature.

Weathering of rocks is important because ions are released and subsequently may be utilized by plants, but variable weathering conditions produce different types of minerals. These different minerals have characteristics which greatly affect future fertility, management, and engineering properties of soils where they are found. This is especially true for the very small colloidal particles in soils.

Common minerals found in igneous rocks are the feldspars and micas. When subjected to chemical weathering, they produce minerals belonging to the clay mineral group. There are a great number of specific clay minerals, but most of them fall into one of three principal classes, kaolinite, montmorillonite, and illite or mica. These clays are one or another form of oxides of silica. In addition, montmorillonite and mica and related minerals contain various amounts of magnesium, aluminum, iron and bound water.

The word "illite" is a term to describe clay-size mica which had been weathered appreciably and could not be readily characterized.

The feldspars and mica (illite) are common mineral constituents of the igneous rocks found in Arizona and are very important parent minerals in Arizona soil clay formation. The micas are so called because of their peculiar glistening quality (in Latin this means "to shine"). The micas, in general, tend to be constructed in a sheet-like pattern, so that thin layers may easily be peeled off. The sheets of the various micas are joined in different fashion, but they all share this layering characteristic. The molecular basis for the layered structure of mica is the relationship between the silica atom and the oxygen atoms of the compound. Silicon has a valence of four, and so can be surrounded by four oxygen atoms. Three of the four oxygen atoms of this structure, called a tetrahedron, can lie in a single plane while the fourth extends above or below this plane. (See Figure 1) The three oxygens in the common plane are shared by other silicon atoms while the silicon atom has to itself the single oxygen which



3. Structural model of mica showing the tetrahedron-octahedron arrangement. The white balls show the position of potassium ions in openings in the surface of the silicate.

extends above or below this plane. (See Figure 2) This planar arrangment of the tetrahedra accounts for the sheet-like structure of the micas. The single free oxygen atom of each tetrahedron is bonded with one or another metallic ion in an octahedron arrangement (six oxygens surrounding the metallic cation), the role of which is to hold the sheets of mica together. In some micas this metal may be aluminum, in others, iron or magnesium. The double sheets bonded to each other by metallic ions are, in turn, bonded to other double sheets by potassium ions. Since the potassium bonds are the weakest, the cleavage of mica sheets normally takes place along the potassium bond layer. The third figure represents a mica particle.

The structure of micas might be likened to a Chinese checker board — the marbles representing the potassium ions. The surface of a mica flake 2 x 1 micron in size (a micron equals .000039 inches) contains as many potassium ions as a Chinese checker board the size of a football field. The thickness of a single mica sheet is such that 25,000,000 of these would be required to make a stack 1 inch in height.

An understanding of the basic crystal structure of the clay minerals is necessary to fully understand why the Springerville soil shrinks and swells, why the Gila soil has an abundance of potassium available for plants, or perhaps "fixes" ammonia when applied as a fertilizer on cotton, and what type of management is best to use on the saline Casa Grande soil. What basically causes these phenomena will be considered in later articles.