SAMPLE

Earth's Dynamic Systems: Soil Formation

The Living Ground

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Conclusion

This free sample contains the Introduction and Chapter 1. The complete book contains the full contents above.

Introduction

Soil formation, also known as pedogenesis, is the process of soil genesis as regulated by the effects of place, environment, and history. Biogeochemical processes act to both create and destroy order (anisotropy) within soils. These alterations lead to the development of layers, termed soil horizons, distinguished by differences in color, structure, texture, and chemistry. These features occur in patterns of soil type distribution, forming in response to differences in soil forming factors.

Pedogenesis is studied as a branch of pedology, the study of soil in its natural environment. Other branches of pedology are the study of soil morphology and soil classification. The study of pedogenesis is important to understanding soil distribution patterns in current (soil geography) and past (paleopedology) geologic periods. Soil develops through a series of changes. The starting point is weathering of freshly accumulated parent material.

A variety of soil microbes (bacteria, archaea, fungi) feed on simple compounds (nutrients) released by weathering and produce organic acids and specialized proteins which contribute in turn to mineral weathering. They also leave behind organic residues which contribute to humus formation. Plant roots with their symbiotic mycorrhizal fungi are also able to extract nutrients from rocks. New soils increase in depth by a combination of weathering and further deposition.

In Sicily under Mediterranean climate the soil production rate due to weathering is approximately 1/10 mm per year. New soils can also deepen from dust deposition. Gradually soil is able to support higher forms of plants and animals, starting with pioneer species and proceeding along ecological succession to more complex plant and animal communities. Topsoils deepen with the accumulation of humus originating from dead remains of higher plants and soil microbes.

They also deepen through mixing of organic matter with weathered minerals.

As soils mature, they develop soil horizons as organic matter accumulates and mineral weathering and leaching take place. Soil formation is influenced by at least five classic factors that are intertwined in the evolution of a soil. They are: parent material, climate, topography (relief), soil organisms, and time. When reordered to climate, organisms, relief, parent material, and time, they form the acronym CLORPT. The mineral material from which a soil forms is called parent material.

Typical parent materials are the common rock-forming minerals, and they are

sorted by the manner in which they were deposited. Climate acts on the process directly, governing the pace of weathering and leaching: among its visible influences are a shallow accumulation of lime as caliche in low rainfall areas, the formation of acid soils in humid areas, erosion of soils on steep hillsides, and very intense chemical weathering, leaching and erosion in warm, humid regions where the ground does not freeze.

Chapter 1: The Discovery of Soil Formation

Rock, whether its origin is igneous, sedimentary, or metamorphic, is the source of all soil mineral materials and the origin of all plant nutrients with the exceptions of nitrogen, hydrogen and carbon. As the parent rock is chemically and physically weathered, transported, deposited and precipitated, it is transformed into a soil.

Quartz: SiO_2

Calcite: $CaCO_3$

Feldspar: $KAlSi_3O_8$

Mica (biotite): $K(Mg,Fe)_3(AlSi_3O_{10})(F,OH)_2$

Parent materials are classified according to how they came to be deposited. Residual materials are mineral materials that have weathered in place from primary bedrock. Transported materials are those that have been deposited by water, wind, ice or gravity. Cumulose material is organic matter that has grown and accumulates in place. Residual soils are soils that develop from their underlying parent rocks and have the same general chemistry as those rocks.

Residual soils can be found on mesas and volcanoes.

In the United States as little as three percent of the soils are residual. Most soils derive from transported materials that have been moved many miles by wind, water, ice and gravity: Aeolian processes (movement by wind) are capable of moving silt and fine sand many hundreds of miles, forming loess soils (60-90 percent silt), common in the Midwestern United States and Canada, north-western Europe, Argentina and Central Asia. Clay is seldom moved by wind as it forms stable aggregates.

Water-transported materials are classed as either alluvial, lacustrine, or marine. Alluvial materials are those moved and deposited by flowing water. Sedimentary deposits settled in lakes are called lacustrine. Lake Bonneville and many soils around the Great Lakes are examples. Marine deposits, such as soils along the Gulf Coast and in the Imperial Valley of California are the beds of ancient seas that have been revealed as the land uplifted.

Ice moves parent material and makes deposits in the form of terminal and lateral moraines in the case of stationary glaciers. Retreating glaciers leave smoother ground moraines, and in all cases outwash plains are left as alluvial deposits are moved downstream from the glacier. Parent material moved by gravity is obvious at the base of steep slopes as talus cones and is called

colluvial material. Cumulose parent material is not moved but originates from deposited organic material.

This includes peat and muck soils and results from preservation of plant residues by the low oxygen content of a high water table. While peat may form sterile soils, muck soils may be very fertile. The weathering of parent material takes the form of physical weathering (disintegration), chemical weathering

(decomposition) and chemical transformation. Weathering is usually confined to the top few meters of geologic material, because physical, chemical, and biological stresses and fluctuations generally decrease with depth.

Physical disintegration begins as rocks that have solidified deep in the Earth are exposed to lower pressure near the surface and swell and become mechanically unstable. Chemical decomposition is a function of mineral solubility, the rate of which doubles with each 10 °C rise in temperature but is strongly dependent on water to effect chemical changes. Rocks that will decompose in a few years in tropical climates will remain unaltered for millennia in deserts.

Structural changes are the result of hydration, oxidation, and reduction.

Chemical weathering mainly results from the excretion of organic acids and chelating compounds by bacteria and fungi, and is thought to increase under greenhouse effect. Physical disintegration is the first stage in the transformation of parent material into soil. Temperature fluctuations cause expansion and contraction of the rock, splitting it along lines of weakness.

Water may then enter the cracks and freeze and cause the physical splitting of material along a path toward the center of the rock, while temperature gradients within the rock can cause exfoliation of "shells". Cycles of wetting and drying cause soil particles to be abraded to a finer size, as does the physical rubbing of material as it is moved by wind, water, and gravity.

Organisms may reduce parent material size and create crevices and pores through the mechanical action of plant roots and the digging activity of animals. Chemical decomposition and structural changes result when minerals are made soluble by water or are changed in structure. The first three of the following list are solubility changes, and the last three are structural changes.

The solution of salts in water results from the action of bipolar water molecules on ionic salt compounds producing a solution of ions and water, removing those minerals and reducing the rock's integrity, at a rate depending on water flow and pore channels. Hydrolysis is the transformation of minerals into polar molecules by the splitting of intervening water. This results in soluble acid-

base pairs.

For example, the hydrolysis of orthoclase-feldspar transforms it to acid silicate clay and basic potassium hydroxide, both of which are more soluble. In carbonation, the solution of carbon dioxide in water forms carbonic acid.

Carbonic acid will transform calcite into more soluble calcium bicarbonate. Hydration is the inclusion of water in a mineral structure, causing it to swell and leaving it stressed and easily decomposed.

Oxidation of a mineral compound is the inclusion of oxygen in a mineral, causing it to increase its oxidation number and swell due to the relatively large size of oxygen, leaving it stressed and more easily attacked by water (hydrolysis) or carbonic acid (carbonation). Reduction, the opposite of oxidation, means the removal of oxygen, hence the oxidation number of some part of the mineral is reduced, which occurs when oxygen is scarce.

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ABOUT THE AUTHOR

Aira Astralis is a science writer specializing in astronomy and space exploration. Her work spans the full breadth of humanity's relationship with the cosmos -- from the earliest naked-eye observations to the engineering marvels of modern space missions.

Her books are built on a foundation of primary sources: peer-reviewed research, mission archives, and direct engagement with the scientific community. She writes for readers who want to understand not just what we know about the universe, but how we came to know it.

She believes that the most important frontier is not out there but in the gap between what scientists discover and what the public understands. Her books exist to close that gap.