CHAPTER 18
Soils in their Environment

Introduction
Soils are natural bodies, formed by a distinct set of processes within the soil body or soil profile. The soil-forming processes (pedogenic processes) involve physical, chemical and biological reactions. The nature and intensity of these are very much a product of the wider environment or ecosystem in which a soil is located. The influence of this general environment is usually and usefully separated into the controls of five soil-forming factors (pedogenic or pedogenetic factors), namely: climate, organisms (plants, animals, humans), parent material, relief and time.

After considering the importance of weathering processes, which alter parent rock and rock minerals to provide soil parent material, this chapter discusses the ten fundamental soil-forming processes which operate in world soils. (Two others – permafrost soil processes and cryopedology, and rubefaction – are treated in later chapters, Chapter 24 and Chapter 25 respectively.) In the case of each process, details are given of the fundamental reactions in soils, the usual horizons produced, together with their notations, and the characteristic soil profile as it occurs in the field.

Chapter summary

Soil development, soil profiles and soil horizons

- Weathering processes act upon rock and rock minerals in the zone of weathering and produce a soil parent material (C horizon).
- Soil-forming processes operate in the zone of soil formation, or solum, to produce a soil profile (O, A, E and B horizons).
- Four components are produced by weathering and soil formation, namely, a resistant residue of minerals which are difficult to break down, new secondary minerals of clay and sesquioxides, organic matter, and a weathering solution of soluble chemicals.
- Horizons in soils are sometimes clear, sometimes obscure, depending on the balance and intensity of a whole set of vertical redistribution or mixing processes.
- Different soil survey organizations around the world use different soil names, soil horizon notations and soil classifications. Names used by the Food and Agriculture Organization (FAO) and the Soil Survey of England and Wales (SSEW) are employed in this text.

The soil-forming environment

- Soils result from the combined influences of five soil-forming factors, namely, climate, organisms, parent material, relief and time.
- Climate operates through temperature and precipitation, the major determinants of the distribution of soils on a global scale.
Organisms include plants, animals and human activities. The production of organic matter and modifications wrought by human activities are important and universal controls of soil type and soil properties.

Parent materials, either solid or unconsolidated deposits, influence many soil properties, especially colour, permeability, base content, particle size, mineralogy and nutrient content.

Relief influences soil-water regimes and drainage, and also the erosion, movement and deposition of solid material. It forms the basis of the soil catena.

**Leaching, decalcification and calcification**

- Rainwater is a mild acid and its continual movement through a soil profile removes soluble chemicals and ions from the soil exchange complex by the process of leaching.
- Under natural conditions, vegetation can recycle nutrients from the subsoil and return them to the soil surface through organic remains.
- Under farming systems, where nutrients are removed in crops and livestock, the effects of continual leaching need to be counterbalanced by the addition of lime and fertilizers.
- Brown Earth soils (Cambisols) are formed by the leaching of soluble chemicals from the upper horizons and the weathering of soil minerals in the lower horizons. The net effect is a soil with pH increasing with depth.
- In semi-arid and arid regions, where leaching is of a low intensity only, calcium carbonate (CaCO₃) and gypsum (CaSO₄·2H₂O) accumulate in the soil, even on non-calcareous parent materials.

**Podzolization**

- Podzols are distinctive soils formed by eluviation processes at the surface and illuviation processes in the subsoil.
- Many chemicals are moved in this way, but iron compounds are important, owing to their effect on soil colour in podzols, producing bleached, white colours in the Ea horizon and orange colours in the Bs.
- Highly reactive organic chemicals (polyphenols, hydroquinones) are able to mobilize iron in chelate form and thus provide an active medium for moving difficulty-soluble compounds (iron, manganese) down the soil profile.
- Humo-ferric podzol (Orthic Podzol) has an accumulation of organic material (Bh or Bh₃) over iron accumulation (Bs), whereas humic podzols (Humic Podzol) have a pronounced Bh horizon but lack a horizon of iron accumulation.
- Iron pan stagnopodzols (Placic Podzols) have a thin iron pan which results from, and itself causes, surface wetness, peaty humus yet well drained subsoils.
Clay formation and translocation

- Clay minerals commonly form in the Bw horizon with the type of clay mineral formed being dependent on three factors, namely, the mineralogy of the parent material, the leaching–weathering ratio, and time.
- Translocation of clay to the Bt horizon is a common feature in cool temperate, warm temperate and humid tropical regions.
- Clay translocation is favoured by the leaching of calcium salts, by climates with marked wet and dry seasons and by the presence of transmission pores (<0.05 mm diameter) in the soil.
- Translocated clay can be distinguished from clay formed in situ only by the study of the soil under the petrological microscope at about 30 magnification.
- Translocated clay shows distinct coatings around stones and along pores, often with bright yellow birefringent colours under crossed polarized light.

Gleying

- Waterlogging of soils, whether permanent or temporary, excludes oxygen from soil pores and leads to chemical processes of reduction.
- Grey and blue-grey colours indicate permanent waterlogging, with the complete reduction of ferric iron to ferrous iron under anaerobic conditions.
- Mottled horizons have red-orange mottles of ferric iron, indicating localized oxidation, set against the grey background; mottles frequently line channels or other porous spots.
- Rice paddies in subtropical and tropical regions have the serious problem of the reduction of nitrate nitrogen to nitrogen gases in the gleyed layer, and the subsequent loss of these gases to the atmosphere.
- Surface-water gleys or stagnogleys result from poor drainage caused by an impermeable horizon, whereas groundwater gleys occur in low-lying positions in the landscape under the influence of ground water.

Salinization, alkalization, solodization

- Soils enriched by soluble salts are called solonchaks and are formed in arid and semi-arid regions in situations where more salts are inputted at the soil surface than can be removed by leaching (topographical hollows, coastal areas, salty parent materials, poor irrigation practices).
- Alkali soils or solonetz have a high sodium content, a high pH and a dispersed structure, and usually occur when soluble salts are removed from the soil.
- Solodized solonetz results when clay is leached into the subsoil to give a pale surface and spectacular Bt with a columnar structure.
- Solodic planosol or solod is the end-point of the sequence, with acidic A over a hard, compact Bt.
Electrical conductivity (mScm$^{-1}$) is a good indicator of salinity, whilst exchangeable sodium percentage (ESP) indicates alkalinity.

**Laterization**

- Intense weathering or katamorphism in tropical regions leads to a weathering product depleted of base cations and silica but enriched in iron, aluminium and manganese oxides.
- Typical lateritic soils (Ferralsols) have a very thin humus, owing to the high litter input being matched by rapid rates of mineralization.
- The lateritic (Ferralsol) profile comprises four zones: concretionary pisolithic ironstones (A/B), main laterite (plinthite) (Box), mottled zone (Bg,ox) and pallid horizon (Cg).
- Many species of iron, manganese and iron oxides are found, but the bright red coloration is due to the presence of anhydrous haematite.
- Lateritic soils (Ferralsols) are deficient in plant nutrients and have difficult physical properties (hardness, induration) for agriculture.

**The soil catena**

- The concept of the soil catena has become a major feature of soil science because of its relevance to all biomes in the world.
- The concept was first developed by Milne in the tropics to explain downslope movements of soil particles, giving erosion, transport and deposition zones on slopes.
- The hydrological sequence is a catena dominated by the hydrology of the slope, with freely draining soils on slope crests giving way to less well drained gley soils in adjacent hollows.
- As well as movements of solid soil particles and water, it is necessary to consider the movement of cations and anions from upslope to downslope locations.
- In Scotland the hydrological sequence is also used as a fundamental unit of soil classification and soil survey, and is termed the soil association.

**The age factor in soil formation**

- A palaeosol is a soil formed under environmental conditions which no longer prevail; an old soil is a soil which has been forming for a long time.
- Most British soils are less than 10,000 years old, though certain relic and fossil soils can result from soil formation in interglacial and/or pre-Pleistocene times.
- Deeply weathered profiles of rock in some parts of Scotland are interpreted as weathering profiles of interglacial and/or pre-Pleistocene times.
- Laterites (plinthites) in tropical latitudes seemed to have been formed in pluvial, humid times in the Tertiary period, and were irreversibly hardened during succeeding arid episodes.
Laterite (plinthite) is a typical palaeosol, as it occurs today in a very wide range of climatic and vegetation environments.

**Essay questions**

1. Explain why gleying is such a common pedogenic feature of the soils of the United Kingdom. Briefly describe the main soil types where it occurs.

2. Outline and account for the changes which you would expect to find in: (a) a transect across a dry valley in a chalk area of southern England, and (b) a transect downslope in a sandstone valley in Upland Britain.

3. Explain, with the use of annotated soil profile sketches, how the following soils are formed: (a) iron-humus podzol, (b) solonchak, (c) chernozem, (d) tropical ferralsol.

**Discussion topics**

1. Choose a relevant Soil Survey publication which covers your local area (Soil Memoir, Soil Record or Regional Bulletin).

2. Discuss the influence of the 5 soil forming factors on the distribution of soil types in your local area. Consider, in addition, the influence of time of soil formation.

3. Discuss the general changes in soil types you would expect to meet along a transect from the Mediterranean coast of Spain to the Arctic Ocean coast of Norway, through France, the Low Countries, Denmark and Norway.

4. Discuss the changes in soil types you would expect to meet along a transect from the east coast of the USA to the west coast of the USA at latitude 40°N.

5. Explain why the fundamental unit for studying soils in fieldwork is the soil catena. What other main factor needs to be taken into account in the United Kingdom?

6. Discuss why rates of pedogenic processes vary widely on a global scale?

**Further reading**


**Web resources**

http://www.cranfield.ac.uk/nsri
The National Soil Resources Institute (NSRI), Cranfield University, England, is the repository of the results of over 60 years of soil surveying, mapping and classification in England and Wales. This is reflected in its many publications in report and map formats.

http://www.fao.org
The Food and Agriculture Organization (FAO) is the chief body of the United Nations concerned with food, agriculture and hunger on the world scale. As well as being involved in soil classification and the production of a Soil Map of the World with UNESCO, it supports and publishes soil studies from throughout the world. In addition it is very active in the fields of agricultural production, trade, and development in Less Developed Countries (LDCs).

http://macaulay.ac.uk
The Macaulay Land Use Research Institute (MLURI), Aberdeen, deals with all aspects of soils in Scotland – their formation, distribution, and mapping.

http://www.usda.gov
The United States Department of Agriculture (USDA) is arguably the foremost government institution in the world in the field of temperate zone agriculture. Its activities in the fields of soil survey and classification can be accessed on its Web Soil Survey.