Module #10 – Component #6

Geomorphology, Geology & Soil

This section of science is a vast discipline falling under the category of earth sciences. This component will only attempt to familiarise you with basic principles and processes.
How Geomorphology has Created Landforms

The earth’s crust consists of several gigantic tectonic plates that float on top of the earth’s mantle. The continental land masses and oceans sit on top of these dynamic plates. When pushed or pulled, these plates move about very slowly and collide or tear apart from each other. This slow movement is called plate tectonics. It is this force that has created most of the landforms that we know today. Evidence for plate tectonics is seen in the following phenomena:

**Palaeontology:** The striking similarity between fossils found on continents on either side of the Atlantic.

**Structure and rock type:** South America and Africa appear to fit together in terms of outline, rock types and geological structure.

**Paleomagnetic studies:** Indicate that throughout geologic time, continents have changed their position in relation to the magnetic poles.

Practical examples of landforms arising from plate tectonics include: Coastal Mountain Chains, Mountain Chains, Interior Mountain Chains, Rift Valleys and Continental Shelves.
Faults and Deformations Found in Rock Formations

Fig # 1. Symmetrical Anticline

Fig # 2. Symmetrical Syncline

Fig # 3. Recumbent Fold
Terminology Applied to Faulting

**Fig # 4. Normal Fault**

**Fig # 5. Reversed Fault**

**Fig # 6. Thrust**

**Fig # 7. Left or Right Lateral Faulting**
Some Other Features of Geological Formations

**Ripple Marks**
These are often seen in Sandstones and are caused by the action of water as it flows across the bed of a river or other body of water.

**Fossils**
Fossils are often included in sedimentary formations. The remains of dead organisms are trapped and deposited in sediments. The sediments are subsequently compressed and hardened leaving fossil rich deposits behind them.

Only the harder parts of an animal, teeth, shells and bones, have any chance of being preserved. The softer parts such as flesh, vegetation and cartilage quickly rot away. Also, if teeth are left exposed in the surface, they too will be decomposed and broken down by weathering and micro-organisms. When harder parts are buried in suitable sediment occasionally the actual protein and mineral structure is preserved.

Alternatively, the actual hard material is decomposed, but its exact shape, texture and structure may be left in an impression in the sediment. Under very specific conditions softer parts of living organisms have been preserved, including leaves, hair and even feathers and scales.

These deposits are the only means that we have of unlocking the secrets of the past. Almost all our knowledge about the history of life on earth has been derived from the analysis of fossil records. The study of fossils is called palaeontology.

**Coal and Oil**
Similar to some present-day examples, huge masses of plant matter were concentrated in large areas such as swamps, forests or marshes. Due to major earth movements, these areas were covered and heavily compressed for millions of years. When this occurred, they frequently left behind a seam of compressed material known to us as coal. When large deposits of micro-organisms were concentrated together and compressed, they formed crude oil.

From this brief explanation, it is obvious that these materials are not renewable (or won’t be for the next several million years). These fossils fuels are the worst causes of global heating and pollution, when they are burnt for cooking purposes, heating, running our cars or fuelling power stations that produce electricity.

**Amber**
This semi-precious material results from the fossilised remains of plant resin. Fossil insects have frequently been found in these relics of a past era.
Geomorphology and Erosion

The relentless movement of the earth’s surface plates causes landscapes to be uplifted and mountains to be heaved skywards. No sooner is an area of rock raised above sea level, then wind, rain, ice, rivers, the sun and gravity all act to break it down again. The shape of landscapes (geomorphology) can be seen as the temporary balance between these forces.

Natural Decay

When you visit any old cemetery, you will see that the earlier tombstones have begun to decay. The signs of weathering are already quite clear in many cases. Once removed from the ground, rocks begin to weather. The rate of this weathering depends on the type of rock involved and the prevailing climatic conditions.
Types of Weathering

Physical Weathering

This is caused by the mechanical effects of water movement, buffeting winds, heavy frost and the activity of living organisms.

Frost – Frost is one of the most effective physical weathering agents known. Water seeps into cracks in rocks and freezes overnight. When it freezes, it expands, exerting immense pressure. This expansion can crack large chunks of rock off the bedrock. This leaves larger spaces for more water to seep into. This process is also known as “freeze – thaw” fracturing. These chunks are often found on the scree slopes of mountainsides.

Exfoliation – If the area is hot and dry, the variable surface heating and cooling results in expansion and contraction. The affected rocks often crack along the bedding lines. This process is called exfoliation. The process is aided by the release of pressure when the overburden covering a rock is removed by weathering. Occasionally chemical weathering plays a role in the process as well.

Wind – Wind carries small particles of sand that literally “sand blast” the exposed rock. Often this takes place at ground level and leaves mushroom-shaped rocks behind. This type of physical weathering is responsible for many striking landforms, particularly in desert environments. The recently fallen “Finger of G-D” in Namibia and “Ayer’s Rock” in Central Australia are excellent examples.

Action of Living Organisms – The action of roots expanding in cracks causes rock to split. This phenomenon is also well demonstrated in the many pavements that have been uplifted and cracked by the trees that have been planted in or around them. The biggest cause of weathering as a result of living organisms is obviously man.
Chemical Weathering

Rain often dissolves substances in the atmosphere and soil, such as carbon dioxide. This results in the formation of carbonic acid, a substance that weathers many rock types relatively easily.

The Water Cycle and the Effect of Rivers on the Landscape

Fig # 8. The water cycle

Rivers and surface runoff scour the landscape into a shape that is often determined by the age of the river.

- Rivers in their upper courses (close to their source) show steep sided valleys, potholed channels, rapids and waterfalls; and a very fast flow rate.
- Rivers in their middle course have worn the surrounding landscape down a lot more. They have sediments deposited on their inner curves, and show spurs that have been cut through embankments of hard material; and a slower flow rate.
- Rivers in their lower course meander, at a very slow flow rate, and often exhibit features like ox-bow lakes, marshes, deltas and wide flood plains.
River Patterns

Fig # 9. Dendritic

Fig # 10. Radial

Fig # 11. Trellised
**Ice Ages and the effect of Glaciation**

During past periods of **global cooling, several ice ages occurred**. At these times, more than **half the earth’s surface was covered by ice**. **Glaciers** formed from thick layers of snow that were compacted in valleys under enormous weight. This compaction led to the formation of **immense channels of solid ice**. Due to the incredible weight and the effect of gravity, these glaciers began to **creep forward** very slowly.

The action of these immense “blocks of ice” moving through landscapes caused all rocks in its path to be ground down and polished. The glaciers also picked up rocks, and with its continued movement **scraped or scoured** the area it moved over. This has left many different landforms.

The **WURM II glacial period** of ± 40 000 years ago, was the **coldest period** ever known on earth. This is believed to be the period when man ascended to his present form, *Homo sapiens sapiens* (modern man), replacing the former *Homo* species. During this time, massive scouring of the landscape took place. When the **inter-glacial thaw** came along, the results were that glaciers had radically altered the earth’s appearance, especially at higher latitudes.

The last ice age occurred around **10 - 15 000 years ago**. Remnants of this age are still very evident today. An excellent example are the **two glaciers** that are still present on **New Zealand’s South Island**. What makes these glaciers special, particularly one of them known as **Fox glacier**, is that it is the only glacier that **exists at sea level in a non-polar region**.

Landforms that resulted from glacial activities are still evident today. The best examples are found in latitudes that experienced intense glaciation. These are the **northern hemisphere countries** where immense ice sheets covered most of North America, Europe and Asia. There are South African examples, but not one specific feature that is well known.
Geology

Introduction

Geology is the study of the physical components of the earth. It includes the study of forces that form the earth and those that alter or destroy features of it. These may be earthquakes, volcanoes, erosion, landforms and meteor impacts. Additionally, geology is the study of the raw materials that make up the earth.

The three main areas of interest in geology are:

Historical geology

This branch of geology studies the age of rocks and rock formations. It is a vital area of study since it has helped scientists to date the fossil remains of plants and animals and has given us an increased understanding of the origins of man.

Mineralogy

This area of study revolves around the raw materials that comprise the earth. These geologists discover and map areas of mineral and ore deposits for commercial development.

Physical geology

This branch of geology involves the study of landforms, the effects of weathering, plate tectonics and continental drift.
How the Earth is Structured

The Earth (and the rest of our solar system) is believed to have been created from a large cloud of swirling gases and debris about 4.6 billion years ago.

See Module # 11, Component # 6 [ The Night Skies] for more on this

The planet was thought to be initially a cold ball of rock similar to a meteor. Heating of the earth occurred due to an increase in heat and pressure caused by impacting debris, combined with the release of heat from the spontaneous decay of radioactive isotopes within the core of the earth. This radioactivity, responsible for the heating of the earth’s core has given rise to most of the features of the earth with which we are all familiar today.

Volcanoes and plate tectonics caused mountains to be created and the continents and land masses to tear apart and “migrate” away from each other.

Mercury, Venus, Earth and Mars are, in this order, the four planets closest to the Sun. They are all said to be rocky planets, indicating that they are made up mostly of rocky material as compared to the gaseous nature of many other planets.

Of these planets, only Earth is currently endowed with free-flowing surface water. Mercury is too close to the Sun and any water that was there has long since been evaporated off in the intensely hot days that it experiences. Venus is perpetually covered by cloud, and yet we have been unable to obtain accurate scientific data about its surface features, although we do know that its atmospheric temperature is several hundred degrees, its main gas component is Carbon dioxide (96%) and it perpetually rains sulphuric and hydrochloric acid. Mars is too far out from the sun, and consequently all its surface water is frozen.

Astronauts orbiting the earth view it as a perfectly spherical ball. The truth, however, is that it is slightly flattened at the north and south poles. The diameter of the earth at the equator is 12'756 Km [7921 miles], while at the poles it is 12'714 Km [7895 miles]. This is a difference of 42 Km [26 miles]. It may seem like a lot but is not noticeable when considering the vast size of the earth! The ‘bulging’ at the equator is due to the earth’s rotation on its own axis.

If one were to take a cross section of the earth, one would see that there are three distinct layers as viewed from the centre outwards. These are the core, mantle and crust.

The core is a small sphere at the heart of the earth, thought to be made of nickel and iron and comprises a solid inner core and outer liquid core. It is highly compressed with a pressure of up to five million atmospheres and a core temperature of around 5000 °C [9000 °F], several times hotter than the surface of the sun]. Surrounding the liquid outer core is the mantle, which consists of molten (melted) rock between a rigid inner and outer most layer.
The outermost layer of the mantle and the crust of the earth float upon the **semi-liquid layer** of the mantle and comprise the tectonic plates. Under the continental land masses, the crust **forms a layer only 35 Km [± 22 miles] deep.** Here it is made largely of **granite.** Under the oceans, the crust is much thinner (about 6 Km / 3.7 mi) and is made largely of **basalt.**

At the junction of the crust and the mantle is a layer known as the **Mohorovicic Discontinuity** or more simply the **Moho.** When **seismic waves** are conducted through this layer, they change their frequency. This is how scientists were able to discover the Moho discontinuity. This layer indicates a change in rock composition, but not structure. However, the nature of the earth’s core **remains a mystery** because no bore-hole can be drilled deep enough to explore further.

The rocks found in the earth’s crust are formed of **aggregates of minerals.** Minerals are aggregates of molecules and these in turn are aggregates of atoms. There are approximately **2000 minerals,** most of which are rare except for the more common rock forming types.
Minerals That Form Rocks

Silicate Minerals

These consist mostly of silicon and oxygen. Aluminium, potassium, sodium, calcium, magnesium and iron are often included and the content of these determines the type of mineral formed.

The following families are found in the silicate minerals group:

- **Feldspar Family.** Examples of this mineral type are microcline, orthoclase and plagioclase. The former two are common in granite and other light coloured igneous rock. Plagioclase is mainly found in dark coloured rock.

- **Mica Family.** These are common in granites and take the form of muscovite and biotite.

- **Amphibole Family.** Igneous formed rocks take the form of hornblende and metamorphosed rocks take the form of actinolite and tremolite.

- **Pyroxine Family.** Augite is found in dark coloured igneous rocks.

- **Olivine Family.** Comprise olivine and weathered minerals like serpentine, talc and asbestos.

Oxide Minerals

These are minerals which consist of one or more metals combined with oxygen. Hematite (iron combined with oxygen) is an example of an oxide.

Carbonate Minerals

These minerals are composed of carbon and oxygen. When these fuse with calcium they form calcite (limestone). When they fuse with magnesium they form dolomite.
Rock Types

Rocks are aggregates of minerals. Depending on how they are combined and acted upon, they can take on one of three basic forms:

3 Main Rock Types

- Igneous
- Sedimentary
- Metamorphic
Igneous Rocks

Volcanic Igneous Rocks

Rocks formed from volcanic activity (such as basalt) cool very rapidly when they are exposed to the atmosphere. Rocks with a very fine crystal structure are formed. They are logically known as volcanic rocks. **Only if the material comes in** contact with the atmosphere or water before solidifying may they be called volcanic rocks.

Hypabyssal Igneous Rocks

Medium grained rocks are formed when magma pushes up into faults but does not come into contact with the atmosphere because they solidify before reaching the earth’s surface. This rock type is often found in the form of vertical dykes and horizontal sills. These are layers that have pushed their way into or between pre-existing geological strata. Examples are dolerite, quartz and feldspar porphyry.

Plutonic Igneous Rocks

These rocks have a coarse crystal structure and are formed at extreme depths. Plutonic rocks such as granite often occur in very large homogeneous masses known as batholiths.
Sedimentary Rocks

Most of these rocks are the product of weathering and erosion of any pre-existing rock like boulders, sand, mud and shell fragments. These fragments may be transported from their area of origin to the area of deposition by sheets of ice as in glaciers, by gravity in the case of steep slopes, by water or by wind. The composition of the sedimentary rock depends on the nature of the parent material.

Different types of sedimentary rocks are:

Conglomerates

These originate from the accumulation of pebbles and boulders being stuck together with a matrix of sandy material.

Arkose and Sandstone

If the rock is made up mostly of feldspar particles, it is called an arkose. If the sandy material is made up mostly of quartz, then it is called a sandstone.

Shales

These result from the compaction of clay. They are typically banded and split horizontally very easily.

Limestone and Dolomite

These rock types are believed to have been formed from the evaporation of shallow lakes and seas, exposing the calcium-rich shells of organisms. The burying and compaction of these shells results in the formation of limestone. Dolomite is formed when magnesium replaces some of the calcium in the process.

Facies Change in Sedimentary Rocks

When sedimentary materials are deposited at the same time but the resulting rock types are different, then a facies change has said to have taken place.

To explain. If weathered material was being borne by water, then it is very probable that the coarse material would be deposited close to the site of erosion. The medium grained particles would be dropped from suspension a little further on, and the fine clay particles further still. The resultant rocks are of the same age, but they are deposited in a different pattern.
Sedimentary Rocks and Unconformity

When an **underlying layer of old rocks is weathered**, and eroded down and a new and **younger layer is deposited on top of the existing layer**, the younger rocks are said to **lie with unconformity** on top of the older layer. An unconformity often represents a ‘time gap’ in the geological record.

Granite outcrop with Dolomite Intrusion
Metamorphic Rocks

Rocks of this type result from the alteration of pre-existing rocks through the action of excessive pressure or temperature. Sometimes chemicals that are found in solution are the cause of this metamorphism.

The distinctions between rocks of these types are not always clear cut.

Regional Metamorphism

This phenomenon takes place regionally, and is caused more through the action of pressure than temperature. Compression is caused by the mass of other bodies of rock and causes the original rock to move. This movement results in either faulting or folding.

Minerals that may already exist in the rock are changed, and crystallize into new materials. Using the example of a mudstone, these rocks alter under moderate pressure into slates. With further pressure, they change into silver or green schists (intensely folded rocks). If the pressure increases any further, the rock metamorphoses into a gneiss.

Contact (Thermal) Metamorphism

When igneous rocks intrude into areas of sedimentary rocks they bake the surrounding rocks into a different structure. This is thermal metamorphosis. Under these conditions, limestones are converted into marble. Sandstones are baked into a spotty appearance.

Dynamic Metamorphism

This occurs when two bodies of rock are caused to move across each other in opposing directions. The rocks at the interface are ground to a powder and are thereby metamorphosed.

Metamorphic Facies

If rocks are metamorphosed under similar conditions, then the overall appearance of that type of rock is quite similar throughout the area. This fact is useful for determining if one formation is linked to another.

For example, if a mudstone has been metamorphosed under pressure, and andalusite, mica, garnet etc. have appeared as a result, then all mudstones in that area must have been metamorphosed under similar conditions. This is useful for determining whether seemingly unrelated formations of rock are in fact related.

The oldest rocks on earth are approximately 4 000 million years old. These are located on the west coast of Greenland.
Soil

“A naturally occurring surface layer of organic and inorganic particles”

“A layer of living and non-living material, usually on or near the surface capable of supporting plants”

“dirt”

The study of soil can be a complex task. Next to insolation and water, soil is the next most important aspect of any ecosystem. More than 99% of all plant species require a soil medium in which to grow. Soils provide anchorage, nutrients and water, three of the four (4th being sunlight) essential factors for plant growth.
Where does soil come from?

Soil is derived from the rock on which it rests. This rock is known as parent material. Through a process of physical and chemical weathering the rock is slowly broken down into smaller and smaller fragments.

Physical Weathering

This occurs due to the action of climate. Water and wind slowly erode the solid rock. Once tiny cracks occur, water can seep in. In many situations, this water may freeze and expand, cracking the rock further.

Chemical Weathering

Carbonic acid, formed from water dissolving carbon dioxide, weathers rock resulting in soil formation. In addition, once the physical actions of water and wind have broken the top layer of rock, organisms can enter and further the decomposition of the parent material. Bacteria, fungi, algae, lichens, moss and other plant roots all secrete a mild form of acid. This further aids in the breakdown of the rock.

Time frame

It is the combined action of all these factors that eventually turns parent material into soil. And the soil will be comprised of a combination of all the elements that aided in its creation. This process has taken an exceedingly long time. This is dependent on the type of parent material being eroded and the prevailing climatic conditions. A soil of a depth of 1m [3 ft.] may take as long as 1000 – 10000 years to form.

The eventual composition of a soil is generally a combination of:

- Decomposed rock fragments of different texture and size
- Living organisms
- Partially decayed organic material called humus
Classification of soils

Due to the almost endless possibilities under which soils can and do form, they differ remarkably from region to region. Many different factors are looked at when a soil is classified. They include:

- Texture
- Colour
- Clay content
- Silt content
- Sand content
- Humus content
- Colloid content
- Acidity
- Alkalinity
- Parent material
- Structure
- Depth
- Living organisms

The problem, however, is that soil taxonomists world-wide do not agree on how soil should be classified. The result is that there are several different methods that have yielded hundreds of different soil names. For the purposes of this course soil classification is not relevant but it will appear in an upcoming Module.

The most important topic concerning soil is soil management and specifically soil erosion. This topic is thoroughly covered in Module #11, component #7 – Habitat Management.