UNIT ONE
MAJOR GEOLOGICAL PROCESSES ASSOCIATED WITH PLATE TECTONICS

Introduction

Our planet Earth is a dynamic home for all living things, especially human beings. It's constantly shaped by powerful internal and external forces, including earthquakes, volcanic eruptions, tsunamis, fires, and fault ruptures. These forces often occur near plate boundaries, where Earth's tectonic plates diverge, converge, or slide past each other. Understanding these movements and the forces behind them is crucial to predicting natural disasters like earthquakes and volcanic eruptions. This knowledge can help minimize damage and prevent catastrophic failures during such events.

You might recall learning about Ethiopia's geological history and the formation of Earth's continents in previous lessons. This unit builds on that foundation, focusing on the theories of continental drift, plate tectonics, geological processes, and the landforms these processes create.

1.1 The Continental Drift Theory

The Continental Drift Theory suggests that Earth's continents have moved over geological time, appearing to "drift" across the ocean floor. According to this theory, all current continents were once part of a supercontinent called **Pangaea**. Around 350 million years ago, during the Carboniferous period, Pangaea was located near the South Pole.

During the Triassic period of the Mesozoic era, Pangaea began to break apart. The northern part became **Laurasia**, and the southern part became **Gondwanaland**. Over millions of years, these massive landmasses drifted into their current positions.

Geological Evidence Supporting Continental Drift Theory

Alfred Wegener, a German meteorologist, proposed the Continental Drift Theory in 1912. He suggested that the similarities in climate, fossils, and rock structures across continents like Africa and South America provided evidence for a once-united supercontinent. Wegener's key geological evidence includes:

1. **Coastline Similarity:** The coastlines of Africa and South America fit together like pieces of a jigsaw puzzle.
2. **Rock Type and Structural Similarities:** When the continents of Africa and South America are "reunited," similar rock types and mountain belts extend across both continents.
3. **Fossil Evidence:** Fossils of the Mesosaurus, a small reptile that lived about 250 million years ago, are found on both sides of the Atlantic Ocean, indicating that these continents were once joined.
4. **Paleoclimatic Evidence:** Similar climatic data reconstructed from rock structures across the present continents further support the idea of continental drift.

Why Was Wegener's Continental Drift Theory Not Easily Accepted?

Despite its compelling evidence, Wegener's theory was not widely accepted at first due to several reasons:

1. Wegener was not a geologist, which made his theory less credible to his opponents.
2. The majority of influential geoscientists were based in the Northern Hemisphere, while most of the conclusive data came from the Southern Hemisphere.
3. Wegener believed that Pangaea broke up during the Cenozoic era, a timeframe that seemed too short for such significant continental drift.
4. The lack of direct evidence for continental movement and an explanation of the mechanism behind it was a major hurdle.

Despite these challenges, Wegener's most significant contribution was introducing the idea of moving continents, which shifted scientific thinking from a static Earth to a dynamic one.

1.2 Plate Tectonics Theory

Building on Wegener's theory, geologists developed the Plate Tectonics Theory in the late 1960s. This theory revolutionized our understanding of Earth's outer layers. It states that Earth's lithosphere (the uppermost mantle and crust) is divided into large plates that move on the asthenosphere, a ductile layer beneath. These plates, which can be continental, oceanic, or a mix of both, move slowly and interact at their boundaries.

The theory of plate tectonics has proven to be invaluable in predicting geologic events and understanding Earth's features, such as mountains, earthquakes, and volcanoes. It has also reshaped our understanding of Earth's geological processes.

Types of Plate Boundaries

The movement of tectonic plates results in different types of boundaries:

1. **Convergent Boundaries:** Plates move toward each other. When an oceanic plate meets a continental plate, the denser oceanic plate is forced under the continental plate, forming volcanoes. If two continental plates converge, they can create mountain ranges like the Himalayas.
2. **Divergent Boundaries:** Plates move away from each other, often creating new seafloor at oceanic ridges. On land, divergence can form rift valleys, like the East African Rift Valley.
3. **Transform Boundaries:** Plates slide past each other along faults, causing earthquakes. A well-known example is the San Andreas Fault in California.

Plate Tectonics and Geological Processes

The movement of tectonic plates, driven by convection currents in the Earth's mantle, is the primary force behind many geological processes. These processes shape Earth's surface, creating landforms, influencing climate, and affecting life on Earth.

1.4 Major Geological Processes

Learning Objectives:

- Differentiate between endogenic (internal) and exogenic (external) forces of the Earth.
- Understand processes like folding and faulting and their impact on Earth's surface.
- Locate major young fold mountains on a map.
- Draw diagrams showing the formation of horst mountains and rift valleys.
- Identify the Ring of Fire and the countries around it.
- Analyze how internal and external forces shape the Earth's surface.

Earth is constantly changing due to various geological processes. These processes, including plate tectonics, erosion, chemical weathering, and sedimentation, significantly impact Earth's surface. Geologists study these processes to better understand Earth's history, locate valuable resources, and predict natural disasters like earthquakes and volcanic eruptions.

Geological processes are driven by two types of forces:

1. **Endogenic Forces:** These are internal forces originating within the Earth, such as the movement of tectonic plates and volcanic activity.
2. **Exogenic Forces:** These external forces, like weathering and erosion, are driven by external factors like wind, water, and ice.

Understanding these forces helps us grasp how Earth's surface is shaped and how natural disasters can be predicted and mitigated.

1.4.1 Internal (Endogenic) Forces

When we observe the landscape around us, with its hills and valleys, it's natural to wonder how these landforms were created. The answer lies in powerful forces within the Earth called internal or endogenic forces. These forces originate from deep inside the Earth and shape the surface by creating uneven landforms, such as mountains, valleys, and plateaus. The key processes involved include folding, faulting, earthquakes, and volcanic eruptions.

Folding

Folding occurs when layers of rocks within the Earth's crust are compressed due to movements within the Earth. This compression causes the rock layers to bend. When the layers bend upward, they form an **anticline**; when they bend downward, they form a **syncline**.

If the compression is intense, simple folds can become more complex:

- **Asymmetrical Folds**: One side of the fold is steeper than the other.
- **Overfolds**: One limb of the fold is pushed over the other.
- **Overthrust Folds**: When the compression is extreme, a fracture can occur, and one limb of the fold is thrust over the other.

Types of Fold Mountains:

- **Young Fold Mountains**: Formed more recently, such as the Andes, Rockies, Alps, Himalayas, and Atlas Mountains.
- **Old Fold Mountains**: Formed hundreds of millions of years ago, such as the Appalachian Mountains and the Urals. These mountains are generally lower and more eroded than young fold mountains.

Faulting

Faulting is the cracking of the Earth's crust due to forces of tension and compression. Unlike folding, where rocks bend, faulting causes rocks to break and move along the fault line. This movement can create distinct landforms such as **rift valleys** and **block mountains**:

- **Rift Valleys**: Formed when land between two faults sinks, like the East African Rift Valley.
- **Block Mountains**: Formed when land between two faults is pushed upward, such as the Afar Horst.

Earthquakes

An earthquake is the sudden shaking of the ground caused by the shifting of rocks beneath the Earth's surface. This shift releases a significant amount of energy, which travels as shock waves, known as seismic waves. Earthquakes are often associated with faults, especially along the boundaries of tectonic plates.

The strength of an earthquake is measured using the **Richter scale**, which ranges from 0 (no movement) to 9 (extremely severe). Earthquakes can cause massive damage, including ground shaking, landslides, tsunamis, and fires.

Volcanism

Volcanism refers to the process where molten rock (magma), along with gases and solid materials, is expelled onto the Earth's surface. Magma can reach the surface through:

- **Vents**: These are openings in the Earth's crust, which can form volcanic cones.
- **Fissures**: Large cracks through which lava flows out, creating plateaus.

Types of Volcanoes:

1. **Shield Volcanoes**: Have a broad, low profile and are formed by fluid lava flows.
2. **Strato (Composite) Volcanoes**: Have steep profiles and are formed by alternating layers of lava and ash.
3. **Cinder Cones**: Small, steep-sided volcanoes made mostly of volcanic debris.
4. **Calderas**: Large depressions formed when a volcano collapses after an eruption.

Volcanic eruptions vary in intensity and can cause significant changes in the landscape, including the creation of new landforms and the alteration of existing ones. Some volcanoes remain active, while others become dormant or extinct over time.

Understanding these processes is crucial for appreciating how our planet's surface is constantly being reshaped, often in dramatic and powerful ways.

External (Exogenic) Forces

1. External Forces Overview: External forces, also known as exogenic forces, act on the Earth's surface from the outside. These forces include running water, wind, moving ice, and sea waves. These forces generally work to level out the Earth's surface by two main processes:

- **Denudation:** The wearing away or lowering of the Earth's surface.
- **Deposition:** The laying down of material that has been eroded and transported from other areas.

Denudation

Denudation involves the gradual reduction of the Earth's surface through processes like **weathering** and **erosion**.

Weathering is the breakdown of rocks into smaller pieces. It can happen in two main ways:

1. **Physical (Mechanical) Weathering:**
    - Rocks are broken into smaller pieces without changing their chemical composition.
    - Key processes include:
        - **Thermal Expansion and Contraction:** In hot areas, rocks expand during the day when heated and contract at night when cooled. This causes the outer layers of rocks to peel off, a process known as **exfoliation**.
        - **Frost Action:** Water in rock cracks freezes and expands, causing the rock to break apart. This process is common in cold regions and can lead to the formation of **screes** (rock fragments).
        - **Plant and Animal Action:** Plant roots can grow into rock cracks, forcing them wider, while animals like worms and rabbits can break rocks as they dig.
2. **Chemical Weathering:**
    - This involves changes in the chemical composition of rocks.

- Key processes include:
  - **Rain Action:** Rainwater, which can contain dissolved gases like carbon dioxide and oxygen, can cause rocks to chemically break down. For example, rainwater can cause limestone to dissolve, leading to features like **stalactites** (hanging from cave ceilings) and **stalagmites** (rising from cave floors).
  - **Plant and Animal Action:** Bacteria and decaying vegetation can produce acids that break down minerals in rocks.

Erosion and Deposition

Erosion is the process of moving rock and soil particles from one place to another. Major agents of erosion include:

1. **Running Water:**
   - The most powerful erosive force, especially when flowing quickly down a slope.
   - Creates various landforms:
     - **Sheet Erosion:** When water flows evenly over a large area, removing the topsoil.
     - **Rill and Gully Erosion:** Water cuts small channels (rills) or larger ditches (gullies) in the soil.
2. **Wind Action:**
   - Strong in deserts, forming features like **sand dunes** and **loess deposits** (fertile soils).
3. **Sea Waves:**
   - Create coastal features like **beaches**, **spits** (narrow sand deposits), and **lagoons** (saltwater separated by sandbanks).
4. **Glaciers:**
   - Move slowly over land, carving out valleys and transporting debris.

Mass Wasting refers to the downward movement of rock and soil due to gravity. It can be triggered by:

- **Water:** Water can reduce the friction between particles, making it easier for them to move.
- **Slope Angle:** Steeper slopes are more prone to mass wasting.
- **Human Activities:** Farming, deforestation, and construction can destabilize slopes, leading to landslides and other forms of mass wasting.

These processes, together with internal forces, continuously shape the Earth's surface, creating and transforming landforms over time.