

On completion of the course, students should be able to:

- Understand the basic concepts of rock formation
- Identify, describe and classify the major rocks both in hand specimen and under a microscope
- Recognize, identify and describe textures of various rocks
- Interpret how the rocks originated
- Relate the various rocks to tectonic settings

Course Content

Igneous Petrology

Concepts of magma crystallization

Igneous textures and processes

Ultrabasic rocks

Basic rocks

Intermediate rocks

Felsic rocks

Sedimentary Petrology

Concepts of weathering, erosion and lithification

Sedimentary textures and processes

Clastic sedimentary rocks

Chemical sedimentary rocks

Bio-chemical sedimentary rocks

Metamorphic Petrology

Concept of metamorphism

Metamorphic textures and processes

Regional metamorphic rocks

Contact metamorphic rocks

Dynamic metamorphic rocks

Impact metamorphic rocks

Assessment

Continuous Assessment - 40%

Tests – 20%; Quizzes – 5%; Labs – 10%; Assignments – 5%

Examinations - 60%

Theory – 40%; Practical – 20%

Textbooks

Harvey Blatt and Robert J. Tracy, 2010, PETROLOGY(igneous, sedimentary and metamorphic)

W.H.Freeman and company, New York

Myron Best, 2002, Igneous and Metamorphic Petrology. Blackwell, **832pp**. ISBN: 1405105887.

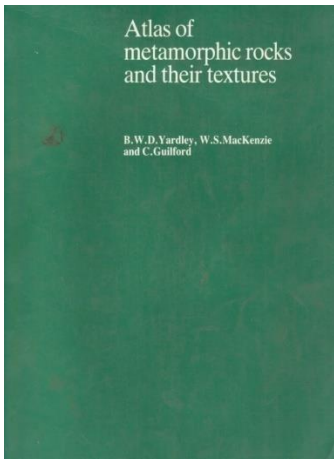
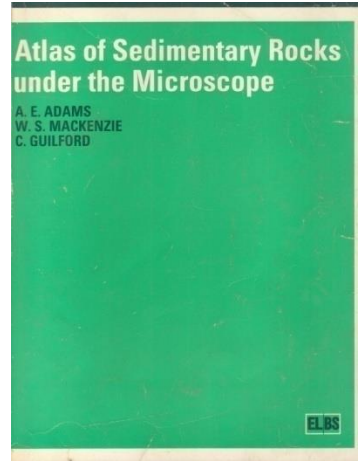
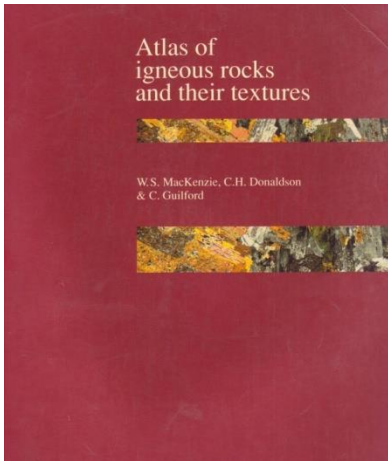
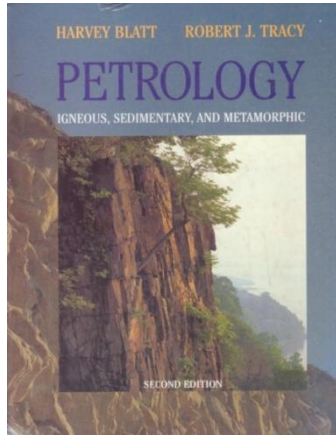
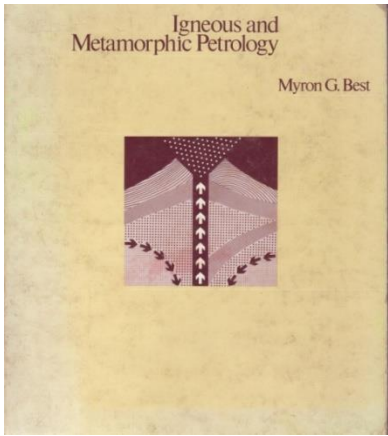
M.E, Tcker, 2003, Sedimentary rocks in the field. John Wiley & Sons, 244pp. ISBN: 0470851236.

Yardley, B.W.D. 2009. An introduction to metamorphic petrology. ELBS.ISBN 0-582-30096-7

W.S.Mackenzie, C.H.Donaldson & C.Guilford, 2010, Atlas of igneous rocks and their textures
Longman ISBN 0-582-30082-7

B.W.D.Yardley, W.S.Mackenzie, and C.Guilford, 2010, Atlas of metamorphic rocks and their textures
Longman ISBN 0-582-30166-6

A.E.adams, W.S.Mackenzie, and C.Guilford, 2008, Atlas of Sedimentary Rocks under the Microscope
Longman ISBN 0 582 02701 2



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PART II

INTRODUCTION TO PETROLOGY

INTRODUCTION

Petros is the Greek word for rock. So, petrology is the science that concerns the genesis of rocks that is the origin and the formation processes of rocks. The word petrography is normally used if only descriptions of rocks are dealt with.

Rocks occur only in a fraction of the earth's volume that is the crust which is about 6 km thick under the oceans up to about 20 km at a maximum under the continents. The top layer of the crust, only found on the continents is often called the SIAL layer (Silicon-ALuminium) and the lower part, the only part present under the oceans, the SIMA layer (Silicon-Magnesium).

The continental crust and the oceanic crust form plates that float on the mantle underneath them. Through convection movements in the upper mantle, the floating plates collide and on ocean-continent borders the oceanic crust plunges under the continental crust. In the centre of the ocean new oceanic crust is continuously formed at the mid-oceanic ridges. The rate of movement at these so-called sea floor spreading centres is in the order of a few centimetres per year.

When rocks are observed a few things are immediately apparent:

- Rocks have variable chemical and mineralogical composition
- Rocks occur in different ways and environments
- Rocks may have different origins

Because of all these variables involved, there is a need for classification. The first division made is on the basis of **origin**, and the three main rock types distinguished are:

Igneous rocks: Solidification from a molten magma

Sedimentary rocks: Accumulation of loose particles on the earth's crust

Metamorphic rocks: Adaptation of igneous or sedimentary rocks to physical/chemical conditions different from those under which the rock was originally formed

CHAPTER ONE

Igneous petrology

OBJECTIVES

On completion of the course, students should be able to:

- Understand the basic concepts of igneous rock formation
- Identify, describe and classify the major igneous rocks both in hand specimen and under a microscope
- Recognize, identify and describe textures of igneous rocks
- Interpret how igneous rocks originated
- Relate the various igneous rocks to tectonic settings

Introduction

An *igneous rock* is any crystalline or glassy rock that forms from cooling of magma.

Igneous rocks are formed by solidification of magma-molten rock matter, usually carrying some amounts of crystals and containing small admixture of dissolved gases. Magma has the general composition of the complex silicate melt: it is composed of a discontinuous, fluctuating matrix of variously linked Si^{4+} , Al^{3+} , and O^{2-} ions which held the main metallic ions (Fe^{2+} , Fe^{3+} , Mg^{2+} , Ca^{2+} , Na^+ , K^+) and other elements (Ti^{4+} , Mn^{2+} , Ni^{2+} , S^{2-} , Cl^- , F^- , OH^- , etc).

The ultimate sources of all magmas lie in the mantle and their crystallization takes place within the crust or on the surface due to the cooling or decreasing the pressure. The first minerals to crystallize are those formed at high temperatures from almost anhydrous melt

Igneous process provides some of the most spectacular geologic activity visible at Earth's surface. Igneous rocks also form deep inside Earth, so they provide information on a host of topics including Earth's antiquity, deep composition,

and past and present tectonic events. Thus, understanding igneous rocks is important to understanding Earth itself

In this exercise emphasis is placed on recognition and interpretation of igneous rocks. Because these rocks solidify from hot molten material (magma), direct observation of igneous rock formation is limited to extrusive igneous materials such as those associated with volcanic activity. Significant knowledge of the environments and conditions under which magmas form and eventually solidify has been achieved, however, based upon studies of composition and texture of igneous rocks, considerable attention will be focused on these two properties in this exercise. Once one develops the ability to correctly use them, recognition and interpretation of igneous rocks can be achieved

A **magma** consists mostly of liquid rock matter, but may contain crystals of various minerals, and may contain a gas phase that may be dissolved in the liquid or may be present as a separate gas phase.

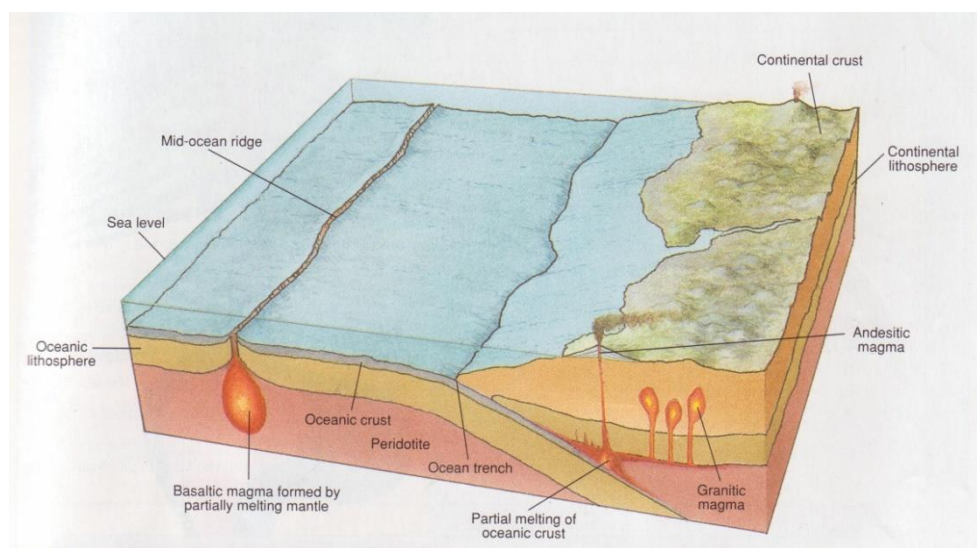


Fig Magma generation in different geologic environments

Magma can cool to form an igneous rock either on the surface of the Earth - in which case it produces a *volcanic* or *extrusive igneous rock*, or beneath the surface of the Earth, - in which case it produces a *plutonic* or *intrusive igneous rock*.



Gases in Magmas

At depth in the Earth nearly all magmas contain gas dissolved in the liquid, but the gas forms a separate vapor phase when pressure is decreased as magma rises toward the surface. This is similar to carbonated beverages which are bottled at high pressure. The high pressure keeps the gas in solution in the liquid, but when pressure is decreased, like when you open the can or bottle, the gas comes out of solution and forms a separate gas phase that you see as bubbles. Gas gives magmas their explosive character, because volume of gas expands as pressure is reduced. The composition of the gases in magma are:

- Mostly H₂O (water vapor) with some CO₂ (carbon dioxide)
- Minor amounts of Sulfur, Chlorine, and Fluorine gases



Figure 3 A fumaroles (volcanic gas vent) in Kilauea caldera Deposits sulphur as the gases cool and mix with air

The amount of gas in a magma is also related to the chemical composition of the magma. Rhyolitic magmas usually have higher dissolved gas contents than basaltic magmas.

Temperature of Magmas

Temperature of magmas is difficult to measure (due to the danger involved), but laboratory measurement and limited field observation indicate that the eruption temperature of various magmas is as follows:

- Basaltic magma - 1000 to 1200°C
- Andesitic magma - 800 to 1000°C
- Rhyolitic magma - 650 to 800°C.

Viscosity of Magmas

Viscosity is the resistance to flow (opposite of fluidity). Viscosity depends on primarily on the composition of the magma, and temperature.

- Higher SiO₂ (silica) content magmas have higher viscosity than lower SiO₂ content magmas (viscosity increases with increasing SiO₂ concentration in the magma).
- Lower temperature magmas have higher viscosity than higher temperature magmas (viscosity decreases with increasing temperature of the magma).

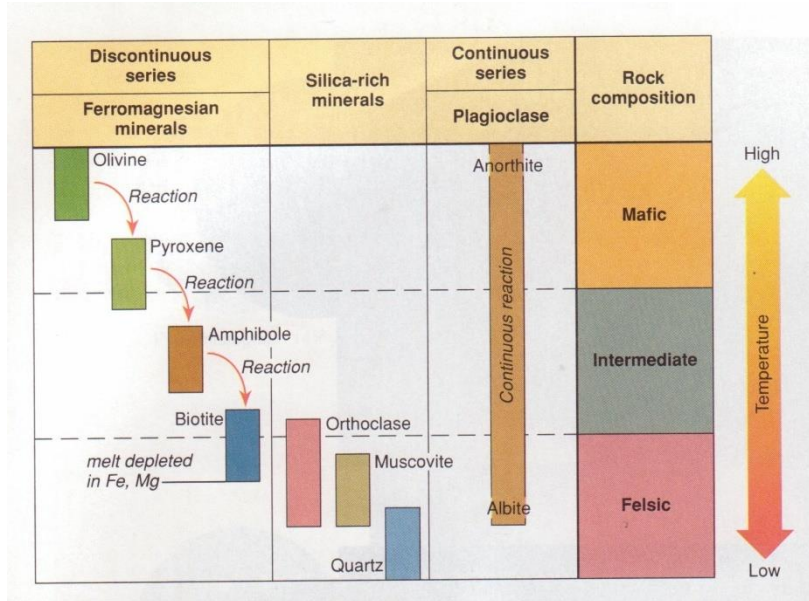
Thus, basaltic magmas tend to be fairly fluid (low viscosity), but their viscosity is still 10,000 to 100,000 times more viscous than water. Rhyolitic magmas tend to have even higher viscosity, ranging between 1 million and 100 million times more viscous than water. (Note that solids, even though they appear solid have a viscosity, but it is very high, measured as trillions time the viscosity of water). Viscosity is an important property in determining the eruptive behavior of magmas.

Magma Type	Solidified Rock	Chemical Composition	Temperature	Viscosity	Gas Content
Basaltic	Basalt	45-55 SiO ₂ %, high in Fe, Mg, Ca, low in K, Na	1000 - 1200 °C	10 - 10 ³ PaS	Low
Andesitic	Andesite	55-65 SiO ₂ %, intermediate in Fe, Mg, Ca, Na, K	800 - 1000 °C	10 ³ - 10 ⁵ PaS	Intermediate
Rhyolitic	Rhyolite	65-75 SiO ₂ %, low in Fe, Mg, Ca, high in K, Na.	650 - 800 °C	10 ⁵ - 10 ⁹ PaS	High

A magma crystallizes as a result of its cooling in the crust or on the surface, reduction of the pressure or separating out of its gaseous components. In the course of crystallization minerals can react with the melt, changing its composition or the composition of melt may be changed by assimilation of the surrounding rocks. The phenomenon of crystallization is very complex. The components of a silicate melt mutually lower than another's freezing temperatures to a considerable degree. Further, the order of crystallization depends also upon the concentration of a given component in the melt and a mineral can crystallize if the melt is saturated with it under the existing conditions. These processes may be traced, however, in the simplified experimental runs which enable to recognize the behavior of the more complex multicomponent systems of magmas during their solidification

However more complicated, the crystallization of magma follows generally the patterns described above with the tendency for equilibrium to be maintained between the solid and liquid phases. To achieve it, the early formed crystals may react with liquid and change their composition. This reaction may be continuous to produce the homogenous solid solution as it is for plagioclases (when temperature falls the crystals become progressively more sodic). For ferromagnesian minerals their reactions with the liquid phase form completely new minerals with different crystal structure (olivines \rightarrow pyroxenes \rightarrow amphiboles). Both types of

transformations, known respectively as Bowen's continuous and discontinuous series point out for the coexistence of certain groups of minerals which in due course of magma cooling crystallize out together within a given range of p/T conditions (e.g. olivine + Mg-pyroxene, mica + alkali feldspar + quartz) and also those which tend to be antl achetic quartz – bytownite, orthoclase-labi diorite). If the reactions are incomplete (e.g. due to the rapid cooling, the early formed members of both series may persist in the final rock (e.g. as zoned crystals).



This described above differentiation of magma is known as its fractionation resulting from crystallization. The following processes are also of some importance: Liquid immiscibility – the separation of liquid sulphide from the liquid silicate fraction, gravitational settling and flotation of the crystals and filter-press action of the residual liquids. Eventually, the composition of magma may also be influenced by its reaction with the wall rock in the process of assimilation or contamination. The other factors of magma differentiation – ionic migration within magma and gaseous transport of some volatile components play the minor role

