

Essentials of GEOLOGY



JUDITH ROSALES



Delve Publishing

Essentials of Geology

Geology means, literally, the study of the earth, the materials of which it is made, the structure of those materials, and the processes acting upon them. It includes the study of organisms that have inhabited our planet. An important part of geology is the study of how Earth's materials, structures, processes and organisms have changed over time. Geologists work to understand the history of our planet. The better they can understand Earth's history the better they can foresee how events and processes of the past might influence the future. Geology is also about understanding the evolution of life on Earth; about discovering resources such as metals and energy; about recognizing and minimizing the environmental implications of our use of those resources; and about learning how to mitigate the hazards related to earthquakes, volcanic eruptions, and slope failures. All of these aspects of geology, and many more, are covered in this textbook. Geology gives insight into the history of the Earth by providing the primary evidence for plate tectonics, the evolutionary history of life, and past climates. Geology is important for mineral and hydrocarbon exploration and exploitation, evaluating water resources, understanding of natural hazards, the remediation of environmental problems, and for providing insights into past climate change. The majority of geological data comes from research on solid Earth materials. These typically fall into one of two categories: rock and unconsolidated material. Seismologists can use the arrival times of seismic waves in reverse to image the interior of the Earth. Early advances in this field showed the existence of a liquid outer and a dense solid inner core. Methods for relative dating were developed when geology first emerged as a formal science. Geologists still use the following principles today as a means to provide information about geologic history and the timing of geologic events. Geology also plays a role in geotechnical engineering and is a major academic discipline.



Prof. Judith is an Ecologist and Environmental Specialist with more than 30 years of academic and consulting experience. She holds a PhD in geography from the University of Birmingham UK and wrote the PhD and Master Academic Programs of Environmental Sciences for the Universidad de Guayana, Venezuela.



Delve Publishing

ISBN 978-1-68095-735-8



9 781680 957358

Rosales

Essentials of Geology



Delve Publishing

ESSENTIALS OF GEOLOGY

Edited by
Judith Rosales



Delve Publishing

Essentials of Geology

Edited by Judith Rosales

© 2017



Delve Publishing

Published by

Delve Publishing LLC

708 3rd Avenue, 6th Floor

New York

NY 10801

United States of America

www.delvepublishing.com

ISBN: 978-1-68095-735-8 (Hardback)

Library of Congress Control Number: 2016920415

This book contains information obtained from highly regarded resources. Some content has been published with permission under Creative Commons License or similar. A Wide variety of references are listed. Reasonable efforts have been made to publish reliable data and views articulated in the chapters are those of the individual contributors, and not necessarily those of the editors or publishers. Editors or publishers are not responsible for the accuracy of the information in the published chapters or consequences of their use. The publisher believes no responsibility for any damage or grievance to the persons or property arising out of the use of any materials, instructions, methods or thoughts in the book. The editors and the publisher have attempted to trace the copyright holders of all material reproduced in this publication and apologize to copyright holders if permission has not been obtained. If any copyright holder has not been acknowledged, please write to us so we may rectify.

Notice: Registered trademark of products or corporate names are used only for explanation and identification without intent of infringement. Although care has been taken to check accuracy of formulas and procedures, the detailed methods should be tested further on a small scale before being adopted commercially.

Delve Publishing publishes wide variety of books and eBooks. For more information about Delve Publishing and its products, visit our website at www.delvepublishing.com



About the Editor

Judith Rosales

Prof. Judith is an Ecologist and Environmental Specialist with more than 30 years of academic and consulting experience. She holds a PhD in geography from the University of Birmingham UK and wrote the PhD and Master Academic Programs of Environmental Sciences for the Universidad de Guayana, Venezuela.

List of Abbreviations

CCS	Carbon capture and storage
CO	Carbon monoxide
CAMP	Central Atlantic Magmatic Province
CTL	Coal to Liquid
CWS	Coal-water slurry fuel
IGCC	Impurities from the coal, gasification
ICE	Intercontinental Exchange
IOCG	Iron oxide copper gold
LAPs	Large andesitic provinces
LBRPs	Large basaltic–rhyolitic provinces
LGP	Large granitic provinces
LIP	Large igneous province
LPP	Large plutonic provinces
LRPs	Large rhyolitic provinces
LVP	Large volcanic provinces
GIS	Geographic Information System
GPS	Global Positioning System
GPR	Ground penetrating radar
NRM	Natural remanent magnetization
PGE	Platinum-Group Element
SDRS	Seaward-dipping reflector sequences
UHP	Ultra-High-Pressure
TNOs	Trans-Neptunian objects
STD	Submarine tailings disposal

Preface

Geology means, literally, the study of the earth, the materials of which it is made, the structure of those materials, and the processes acting upon them. It includes the study of organisms that have inhabited our planet. An important part of geology is the study of how Earth's materials, structures, processes and organisms have changed over time. Geologists work to understand the history of our planet. The better they can understand Earth's history the better they can foresee how events and processes of the past might influence the future. Geology is also about understanding the evolution of life on Earth; about discovering resources such as metals and energy; about recognizing and minimizing the environmental implications of our use of those resources; and about learning how to mitigate the hazards related to earthquakes, volcanic eruptions, and slope failures. All of these aspects of geology, and many more, are covered in this textbook. Geology gives insight into the history of the Earth by providing the primary evidence for plate tectonics, the evolutionary history of life, and past climates. Geology is important for mineral and hydrocarbon exploration and exploitation, evaluating water resources, understanding of natural hazards, the remediation of environmental problems, and for providing insights into past climate change. The majority of geological data comes from research on solid Earth materials. These typically fall into one of two categories: rock and unconsolidated material. Seismologists can use the arrival times of seismic waves in reverse to image the interior of the Earth. Early advances in this field showed the existence of a liquid outer and a dense solid inner core. Methods for relative dating were developed when geology first emerged as a formal science. Geologists still use the following principles today as a means to provide information about geologic history and the timing of geologic events. Geology also plays a role in geotechnical engineering and is a major academic discipline.

Content Coverage

Chapters One and Two focus on geology fundamentals and history of the geology, respectively. The history of geology is concerned with the development of the natural science of geology.

Chapters Three and Four are about principles of geology and geologic province, separately. A province may include a single dominant structural element such as a basin or a fold belt, or a number of contiguous related elements.

Chapter Five provides the theory of plate tectonics which deals with the dynamics of earth's outer shell, the lithosphere that revolutionized Earth sciences by providing a uniform context for understanding mountain-building processes, volcanoes, and earthquakes, as well as understanding the evolution of Earth's surface and reconstructing its past continental and oceanic configurations.

Chapters Six and Seven present information about structural geology and planetary geology, separately. Structural geology focuses on the study of geological structures, with the goal of learning how, when, and why they formed, whereas planetary geology is concerned with the geology of the celestial bodies such as the planets and their moons, asteroids, comets, and meteorites

Chapters Eight and Nine present information about engineering geology and economic geology, separately. Engineering geology is concerned with how the geological factors regarding the location, design, construction, operation and maintenance of engineering works are recognized and accounted for, whereas Economic geology deals with metal ores, fossil fuels, and other materials of commercial value, such as salt, gypsum, and building stone.

Table of Contents

List of Abbreviations xi

Preface xiii

1 INTRODUCTION TO GEOLOGY

Introduction 1

Geologic Materials 2

 Rock 2

 Unconsolidated Material 3

Whole-Earth Structure 3

 Plate Tectonics 3

 Earth Structure 4

 Geologic Time 5

 Important Milestones 6

 Brief Time Scale 7

Dating Methods 7

 Absolute Dating 10

Geological Development of An Area 10

Methods Of Geology 14

 Field Methods 14

 Petrology 17

 Structural Geology 18

 Stratigraphy 19

Planetary Geology 19

Applied Geology 20

 Economic Geology 20

 Mining Geology 20

 Petroleum Geology 20

 Engineering Geology 21

 Hydrology and Environmental Issues 21

 Natural Hazards 21

History of Geology.....	22
References.....	25

2 HISTORY OF GEOLOGY

Introduction	31
Antiquity.....	32
Middle Ages.....	33
17Th Century	33
18Th Century	34
19Th Century	36
20Th Century	38
Modern Geology.....	40
Stratigraphy.....	40
Historical Development	41
Lithostratigraphy	42
Biostratigraphy	42
Chronostratigraphy	43
Archaeological Stratigraphy.....	44
Geological History of Earth	44
Precambrian	44
Phanerozoic Eon.....	46
Permian Period	49
Timeline of Geology.....	55
References.....	57

3 PRINCIPLES OF GEOLOGY

Cross-Cutting Relationships.....	62
Types	62
Scale.....	63
Other Use.....	64
Law Of Included Fragments.....	64
Uniformitarianism.....	64
History	65
Principle Of Original Horizontality.....	69
Law Of Superposition.....	71
Archaeological Considerations	71
Principle Of Faunal Succession	72
References.....	72

4 GEOLOGIC PROVINCE

Introduction	75
Geologic Provinces By Resources	77
Shield (Geology)	77
Geologic Provinces of the World (Usgs)	77
Platform (Geology)	79
Orogeny	79
Physiography	80
History of The Concept	85
Structural Basin	87
Examples of Structural Basins	87
Large Igneous Province	89
Motivations for study of LIPs	90
Large Igneous Province Formation	91
Classification	94
Correlations with LIP formation	96
Relationship to Extinction Events	97
Ore Deposits	97
Large Plutonic Provinces (LPP)	100
Related Structures	100
References	102

5 PLATE TECTONICS

Introduction	107
Key Principles	108
Types of Plate Boundaries	110
Driving Forces Of Plate Motion	112
Driving Forces Related to Mantle Dynamics	113
Driving Forces Related to Gravity	114
Driving Forces Related to Earth Rotation	114
Relative Significance of each Driving Force Mechanism	116
Development of The Theory	116
Summary	116
Continental Drift	118
Floating Continents, Paleomagnetism, and Seismicity Zones	120
Mid-oceanic Ridge Spreading and Convection	121
Magnetic striping	123
Definition and Refining of the Theory	125
Implications for biogeography	125
Plate Reconstruction	125

Defining Plate Boundaries	126
Past Plate Motions.....	126
Formation and break-up of Continents	126
Current Plates	126
Other celestial bodies (planets, moons)	127
Venus	127
References.....	128

6 STRUCTURAL GEOLOGY

Introduction	133
Use And Importance.....	134
Methods	134
Geometries	134
Measurement Conventions.....	135
Plane, Fabric, Fold and Deformation Conventions	136
Stereographic Projections.....	137
Rock macro-Structures	137
Rock Microstructures.....	137
Kinematics.....	142
Stress Fields.....	143
References.....	143

7 PLANETARY GEOLOGY AND GEOLOGY OF SOLAR TERRESTRIAL PLANETS

Planetary Geology	145
History of Planetary Geology	146
Features and Terms	147
By Planet.....	150
Geology of Solar Terrestrial Planets	151
Formation of Solar Planets.....	151
Ceres	162
Small Solar System bodies	163
Asteroid Belt.....	163
Origin	168
Characteristics	170
Composition.....	171
Collisions.....	175
Exploration.....	178
References.....	179

8 ENGINEERING GEOLOGY AND GEOTECHNICAL ENGINEERING

Engineering Geology	188
History	189
The Practice	189
Scope of Studies.....	189
Geohazards and Adverse Geological Conditions.....	190
Soil and Rock Mechanics.....	191
Methods And Reporting.....	191
Geotechnical Engineering	191
Practicing Engineers	194
Soil Mechanics	194
Soil Properties.....	195
Specific weight or Unit Weight	195
Geotechnical Investigation	196
Lateral earth Support Structures.....	199
Earthworks.....	201
Ground Improvement	202
Offshore Geotechnical Engineering.....	204
Geosynthetics.....	205
References.....	205

9 ECONOMIC GEOLOGY

Introduction	207
Purpose of Studies.....	208
Mineral Resources	208
Ore Geology	209
Coal And Petroleum Geology.....	210
Coal.....	210
Etymology	211
Formation.....	212
Ranks	213
Uses Today	217
Coking Coal and Use of Coke	219
Coal Industry	223
Environmental and Health Effects	223
Energy Density and Carbon Impact.....	228
Underground Fires	228
Production Trends.....	229
Petroleum Geology.....	234

Sedimentary Basin Analysis	234
Mining.....	238
Medieval Europe	242
Mine Development and Lifecycle	247
Mining Techniques.....	248
Processing.....	252
Records	259
Metal Reserves and Recycling.....	260
References.....	261
Index.....	267