高等学校“十一五”规划教材

EARTH SCIENCE

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高等学校“十一五”规划教材
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内 容 提 要

Earth Science 是由河南理工大学负责编写的地球科学双语课教材，主要内容包括 Introduction to Earth Science, Earth in the Solar System, Composition of the Earth, Structure of the Earth, Geologic Time, Earthquake, Volcano, Weathering, Depositional Environments, Running Water, Groundwater, Ocean, Weather and Climate, Energy。全书采用英文编写，采用专题形式，每一章都自成体系；以满足教学需要为原则，精选教材内容，力求使学生易于接受；尽量采用各国际组织最新公布的图片、材料和数据，力求准确和严谨；图表资料丰富，有利于提高学生的兴趣。本书适合作为与地学专业相关的高年级本科生和硕士研究生的双语课教材。

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前　言

为了适应高等院校教学改革的新形势，提高双语教学质量，使地学类专业理工科学生具有较高的专业英语水平，我们组织编写了《Earth Science》作为地学相关专业本科生地球科学双语课教材，以期增强学生对地球科学的兴趣，了解地球科学的概貌和国际上的最新研究成果。

目前国内相关双语课教材主要以普通地质学的内容为主，不利于拓宽学生的知识面，增强学生对地球科学的兴趣，同时国外原版教材非常昂贵，致使教学过程中一直缺乏教材或教学参考书。基于此，编者以近几年来的教学参考资料为基础，同时参考一些原版教材和网络上的文献资料，编写了本教材。

地球科学研究领域广、分支学科多。本书作为高等学校学习地球科学的入门教材，较详细地介绍了地球科学的一些基本知识、基本概念和基本原理，涉及到地质、海洋、水文、水资源、气象与能源等诸多方面。本教材的主要特点是：

1. 全书采用英文编写，尽量吸收国际上地球科学的最新研究进展和研究成果，重视知识的更新。

2. 采用专题形式，每一章都自成体系，对地球科学的某一个分支学科进行较为详细、系统的介绍。

3. 以满足教学需要为原则，精选教材内容，力求使学生易于接受。

4. 尽量采用各国际组织最新公布的图片、材料和数据，力求准确和严谨。图表资料丰富，有利于提高学生的兴趣。

本教材由河南理工大学资源环境学院宋党育和符勇编写。全书共分十四章，包括：Introduction to Earth Science, Earth in the Solar System, Composition of the Earth, Structure of the Earth, Geologic Time, Earthquake, Volcano, Weathering, Depositional Environments, Running Water, Groundwater, Ocean, Weather and Climate, Energy。编写分工如下：第一至第五章、第十二章和第十四章由宋党育编写，第六章至第十一章和第十三章由符勇编写。本书适合于地质工程、地球信息科学、环境工程和水文水资源工程及相关专业高年级本科生和硕士研究生的双语课教学。

由于编者水平有限，书中可能存在一些缺点和错误，望广大使用者批评指正，以便进一步提高教材质量。

编　者

2009 年 4 月

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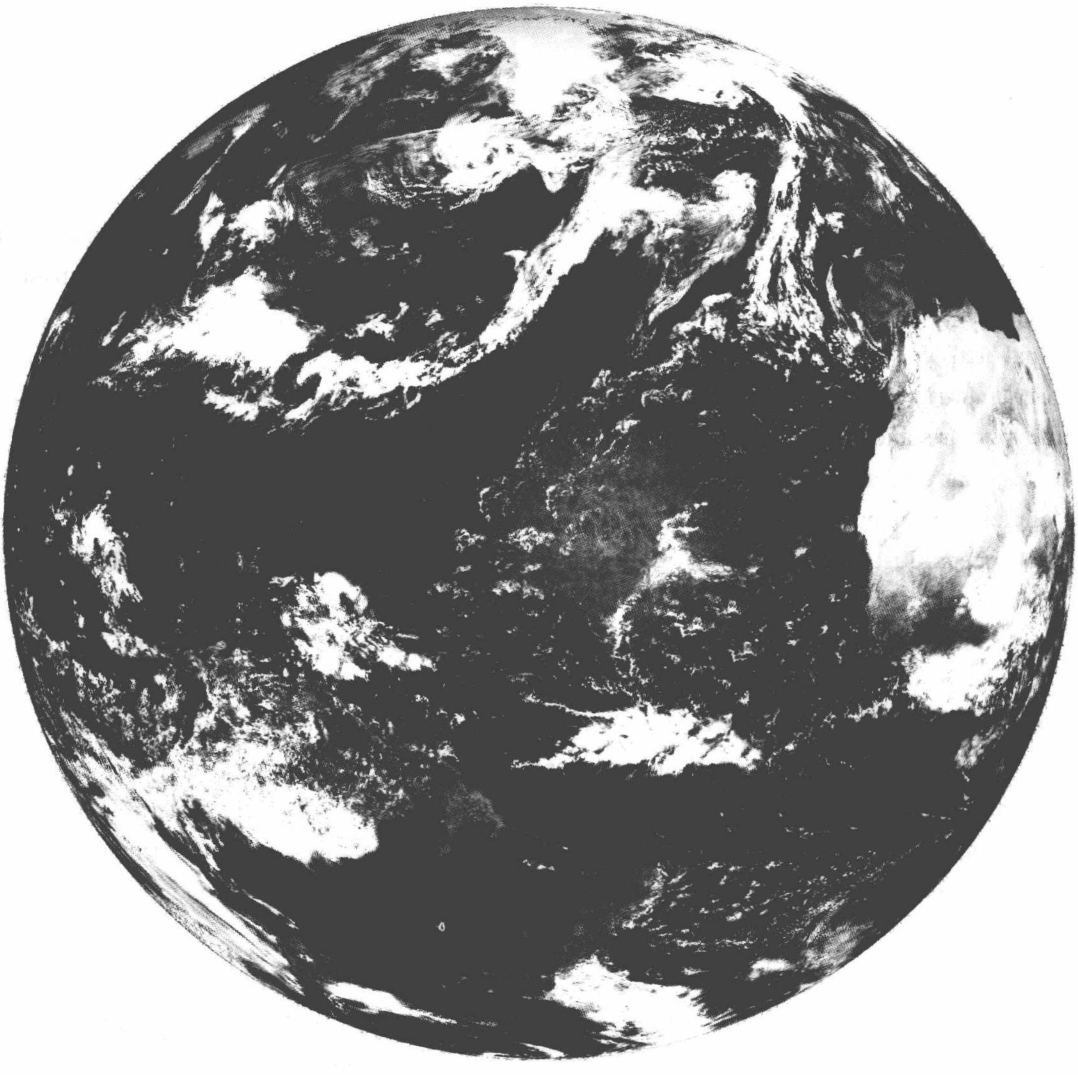
Chapter 1
Introduction to Earth Science



The spectacular eruption of a volcano, the magnificent scenery of a rocky coast, and the destruction created by a hurricane are all subjects for the Earth Science scientist. The study of Earth Science deals with many fascinating and practical questions about our environment. What forces produce mountains? Why is our daily weather so variable? Is climate really changing? How old is the Earth, and how is it related to the other planets in the solar system? What cause ocean tides? What was the Ice Age like? Can a successful well be located at this site?

The subject of this text is Earth Science. To understand the Earth is not an easy task, because our planet is not a static and unchanging mass. Rather, it is a dynamic body with many interacting parts and a long and complex history.

1 What is Earth Science

Earth science also known as geoscience, the geosciences or the Earth Sciences, is an all-embracing term for the sciences related to the planet Earth. It is arguably a special case in planetary science, the Earth being the only known life-bearing planet. There are both reductionism and holistic approaches to Earth science. There are four major disciplines in Earth sciences, namely geography, geology, geophysics and geodesy. These major disciplines use physics, chemistry, biology, chronology and mathematics to build a quantitative understanding of the principal areas or spheres of the Earth system.

To understand Earth science is challenging because our planet is a dynamic body with many interacting parts and complex history. Throughout its long existence, Earth has been changing. In fact, it is changing as you read this book and will continue to do so into the foreseeable future. Sometimes the changes are rapid and violent, as when severe storms, landslides, or volcanic eruption occur. Just as often, change takes place so gradually that it goes unnoticed during a lifetime. Scales of size and space also vary greatly among the phenomena studied in Earth science.

Earth science is often perceived as science that is performed in the out of doors, and rightly so. A great deal of what Earth scientists study is based on observations and experiments conducted in the field. But Earth science is also conducted in the laboratory, where, for example, the study of various Earth materials provides insights into many basic processes, and the creation of complex computer models allows for the simulation of our planet's complicated climate system. Frequently, Earth scientists require an understanding and application of knowledge and principles from physics, chemistry, and biology. Geology, oceanography, meteorology, and astronomy are sciences that seek to expand our knowledge of the natural world and our place in it.

2 Why is Earth Science so Important

Earth science affects all our lives. Our landscape has been shaped by natural processes such as tectonics, weathering, and biological activity over billions of years. We use natural materials everyday, everything from building stone and oil to metals such as iron, copper, gold, and even diamonds have all been extracted from the ground. Natural hazards such as volcanoes, earthquakes, floods and droughts can dramatically affect lives.

As hinted at above, there is a huge range of Earth science topics including, mountain building, the structure of the deep Earth, the creation of oceans, the erosion of continents, the location of natural resources, volcanoes, the hydrological cycle, past climates and the evolution of life.

Understanding how our planet works is essential if we are to properly manage our environment, and if we are to predict how the environment will change in the future. Earth scientists can monitor changes in our environment, model our impact on the environment and suggest solutions to our environmental problems. Environmental issues being studied by Earth scientists include the effects of water extraction from our rivers, the distribution of pollutants in the landscape and the environmental impact of industrial activity, such as mining and landfill.

Natural hazards such as earthquakes, volcanoes and floods are responsible for many deaths, and for the loss of many more homes and livelihoods. Increased knowledge of natural hazards will improve predictions of the occurrence and scale of these potentially life threatening events, giving people a chance to prepare.

Studying the Earth's past can also help us understand what will happen in the future. Within rocks and landscapes is preserved evidence from periods when the Earth was much warmer than today and when it was much colder than today. These warm periods shows us the effect of environmental changes such as sea level rise, desertification, and the loss of rainforests. Fossils demonstrate the evolution of plants and animals can also and record the response of ecosystems to changes in the environment.

2.1 Environmental Problems

Environment refers to everything that surrounds and influences an organism. Some of these things are biological and social, but in this book the factors are called physical environment. The physical environment compasses water, air, soil, and rock, as well as conditions such as temperature, humidity, and sunlight. Interaction between people and the natural environment is an important theme.

It is the common understanding of natural environment that underlies environmentalism—a broad political, social, and philosophical movement that advocates various actions and policies in the interest of protecting what nature remains in the natural environment, or restoring or expanding the role of nature in this environment. While true wilderness is increasingly rare, wild nature (e.g., unmanaged forests, uncultivated grasslands, wildlife, wildflowers) can be found in many locations previously inhabited by humans.

Goals commonly expressed by environmental scientists include:

☆ Reduction and clean up of pollution, with future goals of zero pollution.

☆ Cleanly converting nonrecyclable materials into energy through direct combustion or after conversion into secondary fuels.

☆ Reducing societal consumption of non-renewable fuels.

☆ Development of alternative, green, low-carbon or renewable energy sources.

☆ Conservation and sustainable use of scarce resources such as water, land, and air.

☆ Protection of representative or unique or pristine ecosystems.

☆ Preservation of threatened and endangered species extinction.

☆ The establishment of nature and biosphere reserves under various types of protection; and, most generally, the protection of biodiversity and ecosystems upon which all human and other life on Earth depends.

The potential dangers of global warming are being increasingly studied by a wide global consortium of scientists, who are increasingly concerned about the potential long-term effects of global warming on our natural environment and on the planet. Of particular concern is how climate change and global warming caused by anthropogenic, or human-made, releases of greenhouse gases, most notably carbon dioxide, can act interactively, and have adverse effects upon the planet, it's natural environment and humans' existence. Efforts have been increasingly focused on the mitigation of greenhouse gases that are causing climatic changes, on developing adaptative strategies to global warming, to assist humans, animal and plant species, ecosystems, regions and nations in adjusting to the effects of global warming.

2.2 Resources

Resources are an important focus of the Earth science that is of great value to people. They include water, soil, a great variety of metallic and nonmetallic minerals, and energy. The Earth sciences deal not only with the formation and occurrence of these vital resources but also with maintaining supplies and environmental impact of their extraction and use.

Resources help to produce goods so they have economic value. Natural resources like forests, mountains etc. are very beautiful so they have aesthetic value. Gifts of nature such as water also have a legal value because it is our right to enjoy them. On the other hand, resources have an ethical value as well because it is our moral duty to protect and conserve them for the future generations.

On the basis of renewability, natural resources can be categorized into: renewable Resources and non-renewable Resources. Renewable resources are the ones which can be replenished or reproduced easily. Some of them, like sunlight, air, wind, etc., are continuously available and their quantity is not affected by human consumption. Many renewable resources can be depleted by human use, but may also be replenished, thus maintaining a flow. Some of these, like agricultural crops, take a short time for renewal; others, like water, take a comparatively longer time, while still others, like forests, take even longer. Non-renewable resources are formed over very long geological periods. Minerals and fossils are included in this category. Since their rate of formation is extremely slow, they cannot be replenished once they get depleted. Out of these, the metallic minerals can be re-used by recycling them. But coal and petroleum cannot be recycled.

3 Earth's Spheres

Earth science generally recognizes 4 spheres, the lithosphere, the hydrosphere, the atmosphere, and the biosphere; these correspond to rocks, water, air, and life. Some practitioners include, as part of the spheres of the Earth, the cryosphere (corresponding to ice) as a distinct portion of the hydrosphere, as well as the pedosphere (corresponding to soil) as an active and intermixed sphere.

3.1 Hydrosphere

The abundance of water on Earth's surface is a unique feature that distinguishes the "Blue Planet" from others in the solar system. The Earth's hydrosphere consists chiefly of the oceans, but technically includes all water surfaces in the world, including inland seas, lakes, rivers, and underground waters down to a depth of 2,000 m. The deepest underwater location is Challenger Deep of the Mariana Trench in the Pacific Ocean with a depth of −10,911.4 m. The average depth of the oceans is 3,800 m, more than four times the average height of the continents.

The mass of the oceans is approximately 1.35×10^{18} metric tons, or about 1/4,400 of the total mass of the Earth, and occupies a volume of 1.386×10^{9} km³. If all of the land on Earth were spread evenly, water would rise to an altitude of more than 2.7 km. About 97.5% of the water is saline, while the remaining 2.5% is fresh water. The majority of the fresh water, about 68.7%, is currently in the form of ice.

About 3.5% of the total mass of the oceans consists of salt. Most of this salt was released from volcanic activity or extracted from cool, igneous rocks. The oceans are also a reservoir of dissolved atmospheric gases, which are essential for the survival of many aquatic life forms. Sea water has an important influence on the world's climate, with the oceans acting as a large heat reservoir. Shifts in the oceanic temperature distribution can cause significant weather shifts, such as the El Niño-Southern Oscillation.

3.2 Atmosphere

The Earth's atmosphere is a layer of gases surrounding the planet Earth that is retained by the Earth's gravity. Dry air contains roughly (by molar content) 78.08% nitrogen, 20.95% oxygen, 0.93% argon, 0.038% carbon dioxide, and trace amounts of other gases; but air also contains a variable amount of water vapor, on average around 1%. This mixture of gases is commonly known as air. The atmosphere protects life on Earth by absorbing ultraviolet solar radiation and reducing temperature extremes between day and night.

There is no definite boundary between the atmosphere and outer space. It slowly becomes thinner and fades into space. Three quarters of the atmosphere's mass is within 11 km of the planetary surface. An altitude of 120 km marks the boundary where atmospheric effects become noticeable during re-entry. The Kármán line, at 100 km, is also frequently regarded as the boundary between atmosphere and outer space.

3.3 Biosphere

The biosphere is the broadest level of ecological study, the global sum of all ecosystems. From the broadest biophysiological point of view, the biosphere is the global ecological system integrating all living beings and their relationships, including their interaction with the elements of the lithosphere, hydrosphere, and atmosphere. The Earth's biosphere has existed at least 3.8 billion years, survived five major species extinction events, and one atmospheric transformation, contains about a trillion tons of life distributed perhaps amongst 30,000,000 or more species and whose dynamics are based on mutation and natural selection evolving adaptive behaviors and a guild of biomolecules whose chemistry is able to increase its free energy with the evolution of complex ecosystems such as rainforests and coral reefs. The Earth's biosphere has created and maintains its own improbable atmospheric composition, and produces an ever-growing "necrosphere" or geological strata of biogenic material such as soils, limestone, beaches, coal, oil formations and other deposits. Among its major attributes, it is the matrix of humanity and its entire works, which include projects to take offspring biospheres throughout space.

3.4 Lithosphere

The lithosphere is the solid outermost shell of a rocky planet. The lithosphere includes the crust and the uppermost mantle which is joined to the crust across the mantle. The lithosphere is underlain by the asthenosphere, the weaker, hotter, and deeper part of the upper mantle. The boundary between the lithosphere and the underlying asthenosphere is defined by a difference in response to stress: the lithosphere remains rigid for long periods of geologic time, where as the asthenosphere flows much more readily. As the conductively cooling surface layer of the Earth's convection system, the lithosphere thickens over time. It is fragmented into tectonic plates, which move independently relative to one another. This movement of lithospheric plates is described as plate tectonics. This is when plates move horizontally across the Earth's surface and the continents change their relative positions.

The concept of the lithosphere as Earth's strong outer layer was developed by Barrell, who wrote a series of papers introducing the concept. The concept was based on the presence of significant gravity anomalies over continental crust, from which he inferred that there must exist a strong upper layer (which he called the lithosphere) above a weaker layer which could flow (which he called the asthenosphere). These ideas were enlarged by Daly (1940), and have been broadly accepted by geologists and geophysicists. Although these ideas about lithosphere and asthenosphere were developed long before plate tectonic theory was articulated in the 1960s, the concepts that strong lithosphere exists and that this rests on weak asthenosphere are essential to that theory.

The division of Earth's outer layers into lithosphere and asthenosphere should not be confused with the chemical subdivision of the outer Earth into mantle, and crust. All crust is in the lithosphere, but lithosphere generally contains more mantle than crust.

There are two types of lithosphere: oceanic lithosphere, which is associated with oceanic crust; continental lithosphere, which is associated with continental crust.

Plate tectonics, mountain ranges, volcanoes, and earthquakes are geological phenomena that can be explained in terms of energy transformations in the Earth's crust.

Beneath the Earth's crust lies the mantle which is heated by the radioactive decay of heavy elements. The mantle is not quite solid and consists of magma which is in a state of semi-perpetual convection. This convection process causes the lithospheric plates to move, albeit slowly. The resulting process is known as plate tectonics.

Plate tectonics might be thought of as the process by which the Earth resurfaces itself. Through a process called spreading ridges (or seafloor spreading), the Earth creates new crust by allowing magma underneath the lithosphere to come to the surface where it cools and solidifies—becoming new crust, and through a process called subduction, excess crust is pushed underground—beneath the rest of the lithosphere—where it comes into contact with magma and melts—rejoining the mantle from which it originally came.

Areas of the crust where new crust is created are called divergent boundaries, and areas of the crust where it is brought back into the Earth are called convergent boundaries. Earthquakes result from the movement of the lithospheric plates, and they often occur near convergent boundaries where parts of the crust are forced into the Earth as part of subduction.

Volcanoes result primarily from the melting of subducted crust material. Crust material that is forced into the Asthenosphere melts, and some portion of the melted material becomes light enough to rise to the surface—giving birth to volcanoes.

4 Earth as a System

Anyone who studies Earth soon learns that our planet is a dynamic body with many separate but interacting parts or spheres. The hydrosphere atmosphere, biosphere, and geosphere and all of their components can be studied separately. However, the parts are not isolated. Each is related in some way to the others to produce a complex and continuously interacting whole that we call the Earth system.

A simple example of the interactions among different parts of the Earth system occurs every winter as moisture evaporates from the Pacific Ocean and subsequently falls as rain the hills of southern California, triggering destructive landsides. The processes that moving water from the hydrosphere to the atmosphere and then to the solid Earth have a profound impact on the plants and animals that inhabit the affected regions.

Scientists have recognized that in order to move fully understand our planet, they must learn how its individual components (land, water, air, and life forms) are interconnected. This endeavor, called Earth system science, aims to study Earth as a system composed of numerous interacting parts, or subsystems. Rather than looking through the limited lens of only one of the traditional sciences—geology, atmospheric science, chemistry, biology, etc.—Earth system science attempts to integrate the knowledge of several academic fields. Using this interdisciplinary approach, we hope to achieve the level of understanding necessary to comprehend and solve many of our global environmental problems.

The phrase "Earth system science" the key term is "system". A system is a collection of interdependent parts enclosed within a defined boundary. Within the boundary of the Earth is a collection of four interdependent parts called "spheres". Earth's spheres include: the lithosphere, the hydrosphere, the biosphere, and the atmosphere.

These spheres are closely connected. For example, many birds (biosphere) fly through the