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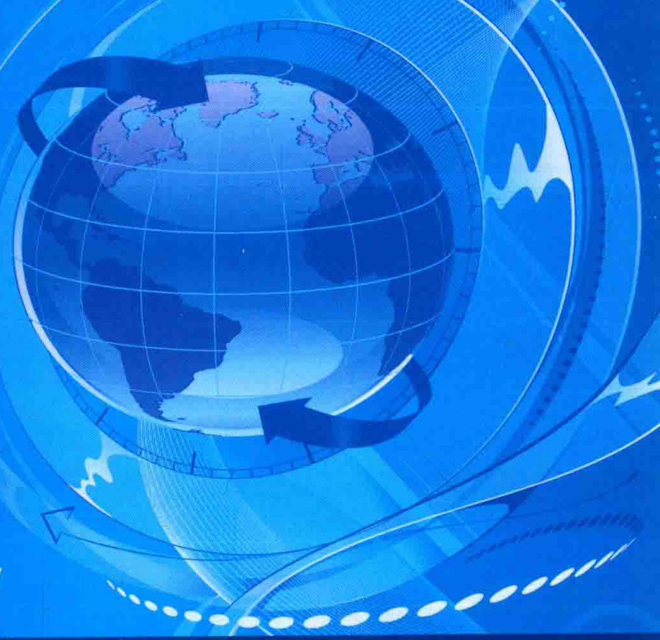

Specialized English of Geochemistry

地球化学专业英语

冯进来　李娇娜　刘杰秀◎编著

申家年◎主审

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前　言

地球化学是20世纪30~40年代兴起的一门独立学科。经过近70年的迅猛发展，如今已成为地球科学领域的三大二级学科之一，在地球科学前沿领域具有重要的支撑作用。地球化学的研究领域广泛，是由现代地质学、化学、物理学等相关学科相结合而产生的，要求学生具有较广的知识面，而且还要有国际视野，时刻掌握所研究地球化学领域的最新科研进展。因此，学生需要具有扎实的外语应用能力。培养“懂专业，精外语”的复合型人才是地球化学专业人才培养的目标之一。

《地球化学专业英语》(校内教材)已在我校地球化学专业的本科教学实践中连续应用了8年。在教学实践中，授课教师对授课内容进行了拓展和补充，对授课方法有了不断的提高，对教学目标有了更深的理解。在多年的外语翻译教学实践过程中，我们认为专业英语的学习，不仅仅是翻译的问题，而应该是相关专业知识的复习、拓展、融会贯通的过程。石油院校地球化学专业的学生，应该具备扎实而广泛的地质学、地球化学和石油地质学方面的专业知识。同时，我们发现，对于专业性较强的句子或段落，准确的翻译和理解需要专业背景知识的比重占60%，而外语知识特别是翻译技巧则仅占40%。编者在充分消化吸收教学的经验成果和地球化学最新的前沿知识的基础上，对原校内教材进行了大量的修订，既增加了国外同步外文原版教材相应的内容，又对原教材的内容进行了增删和修改，使之更适合当前地球化学专业及地球科学相关专业本科教学之用。此外，我们还增加了科技英语翻译技巧概述章节，对外文翻译的定义、翻译的标准、翻译的技巧、翻译的过程进行了详细地阐述，提高了学生的理论翻译水平。

本书共分为5个部分，即地质学(Geology)、油气地球化学(Petroleum and

Natural Gas Geochemistry)、地球化学(Geochemistry)、环境地球化学(Environmental Geochemistry)和科技英语翻译技巧概述(A General Introduction of the Translation Skills in EST)。本书内容涉及面广，单词覆盖量大。教学过程中，在学时不足的情况下，教师可选择代表性课文进行讲解，其他课文可做为学生课后阅读练习。

教材各章的编写情况分别为：前言、PartⅠ 和PartⅢ由冯进来编写，PartⅡ的Chapter1 ~7部分由李娇娜编写，PartⅡ的Chapter8、PartⅣ和PartⅤ由刘杰秀编写，最终由冯进来统编定稿。教材编写之初，主审申家年教授对全书的编写提出了宝贵意见，按照主审提出的意见，编者进行了多次修改。

本书适合高等院校地球化学专业的师生使用，也可供从事油气资源勘查工作的科学技术人员、研究生参考。由于编者水平有限，加之编写时间仓促，书中错误或不妥之处，敬请读者批评指正。感谢中国石化出版社对本教材出版的大力支持。

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Geology

Chapter 1 Basic Geology

1.1 Structure of Earth

1.1.1 Origin of Earth

Earth is one of nine planets that revolve around the Sun along with several dozen moons and numerous smaller bodies. The orderly nature of our solar system leads most astronomers to conclude that its members formed at essentially the same time and from the same primordial material as the Sun. This material formed a vast cloud of dust and gases called a nebula.

The nebular hypothesis suggests that the bodies of our solar system formed from an enormous nebular cloud composed mostly of hydrogen and helium with only a small percentage of the heavier elements.

About five billion years ago, this huge cloud of minute rocky fragments and gases began to contract under its own gravitational influence. The contracting material somehow began to rotate. Like a spinning ice skater pulling in her arms, the cloud rotated faster and faster as it contracted. This rotation in turn caused the nebular cloud to flatten into a disk. Within the rotation disk, smaller accumulations formed nuclei from which the planets eventually coalesced. However, the greatest concentration of material was pulled toward the center of this rotating mass. As it packed inward upon itself, it gravitationally heated, forming the hot protosun (sun in the making).

After the protosun formed, the temperature out in the rotating disk dropped significantly. This cooling caused substances with high melting points to condense into small particles, perhaps the size of sand grains. Iron and nickel solidified first. Next to condense were the elements of which rocky substances are composed. As these fragments collided over a few tens of millions of years, they accreted into the planets. In the same manner, the processed of condensation and accretion acted to form the moons and other small bodies of the solar system on a lesser scale.

As the protoplanets (planets in the making) accumulated more and more debris, the space within the solar system began to clear. This removal of debris allowed sunlight to reach planetary surfaces unimpeded and to heat them. The resulting high surface temperatures of the inner planets (Mercury, Venus, Earth, Mars), coupled with their comparatively weak gravitational fields, meant that Earth and its neighbors were unable to retain appreciable amounts of the lighter components of the primordial cloud. These light materials, which included hydrogen, helium, ammonia, methane, and water, vaporized from their surfaces and were eventually whisked from the inner solar system by streams of solar particles called the solar winds.

1.1.2 Earth's Internal Structure

In general, Earth's interior is characterized by a gradual increase in temperature, pressure, and density with depth. Estimates based on experimentation and modeling indicate that the temperature at 100 kilometers is between 1200℃ and 1400℃, whereas the temperature at the core-mantle boundary is calculated to be about 4500℃ and it may exceed 6700℃ at Earth's center. Clearly, Earth's interior remains "hot"; however, energy is slowly, but continuously, flowing toward the surface where it is lost to space.

However, pressure also increases with depth. Melting, which is accompanied by an increase in volume, occurs at higher temperatures at depth because of greater confining pressure. The increase in pressure with depth also causes a corresponding increase in density. Further, temperature and pressure greatly affect the mechanical behavior or strength of Earth materials. In particular, when a mineral approaches its melting temperature, its chemical bonds weaken and its mechanical strength (resistance to deformation) is greatly reduced.

Compositional Layers

The segregation of material, which began early in Earth's history, is still occurring, but on a much smaller scale. Because of this chemical differentiation, Earth's interior is not homogeneous. Rather, it consists of three major regions that have markedly different chemical compositions.

The principal divisions of Earth include:

(1) Crust. As the rigid outermost layer of Earth, it is divided into oceanic and continental crust. Typically, oceanic crust ranges from 3 to 15 kilometers in thickness and is composed of dark igneous rocks called basalt. By contrast, the upper continental crust consists of a large variety of rock types, which have an average composition of a granitic rock called granodiorite. The rocks of the oceanic crust are younger (180 million years or less) and denser (about 3.0 g/cm^3) than continental rocks. Continental rocks have an average density of about 2.7 g/cm^3 and some have been discovered that exceed 3.8 billion years in age.

(2) Mantle. Over 82 percent of Earth's volume is contained in the mantle, a rocky shell about 2900 kilometers thick. The boundary between the crust and mantle reflects a change in composition. Although the mantle behaves like a solid when transmitting earthquake waves, mantle rocks are able to flow at an incredibly slow rate.

(3) Core. The core is composed mostly of iron with lesser amounts of nickel and other elements. At the extreme pressure found in the core, this iron-rich material has an average density of

about 11 g/cm^3 and approaches 14 times the density of water at Earth's center. The inner core and outer core are compositionally very similar, their division is based on differences in mechanical strength. The outer core is a liquid that is capable of flow. It is the circulation within the core of our rotating planet that generates Earth's magnetic field. The inner core, despite its higher temperature, is stronger than the outer core and behaves like a solid.

1.1.3 Mechanical layers

It is known that Earth's outer layer, including the uppermost mantle and crust, forms a relatively cool, rigid shell. This shell consists of materials with markedly different chemical compositions, but they act as a unit and behave similarly to mechanical deformation. This outermost rigid unit of Earth has been named the lithosphere ("sphere of rock"). Averaging about 100 kilometers in thickness, the lithosphere may be 250 kilometers or more in thickness below the older portions (shields) of the continents. Within the ocean basins the lithosphere is only a few kilometers thick along the oceanic ridges and increases to perhaps 100 kilometers in regions of older and cooler crustal rocks.

Beneath the lithosphere (to a depth of about 660 kilometers) lies a soft, relatively weak layer located in the upper mantle known as the asthenosphere ("weak sphere"). The region encompassing the upper 150 kilometers or so of the asthenosphere has a temperature/pressure regime in which a small amount of melting takes place (perhaps 1 to 5 percent). Within this very weak zone, the lithosphere is effectively detached from the asthenosphere located below. The result is that the lithosphere is able to move independently of the asthenosphere.

It is important to emphasize that the strength of various Earth materials is a function of both their composition and the temperature and pressure of their environment. You should not get the idea that the entire lithosphere is brittle, like the rocks found on the surface. Rather, the rocks of the lithosphere get progressively weaker (more easily deformed) with increasing depth. At the depth of the upper asthenosphere, the rocks are close enough to their melting temperature (some melting may occur) that they are easily deformed. Thus, the asthenosphere is weak because it is hot, just as hot wax is weaker than cold wax. However, in the material located below this weak zone, increased pressure offsets the effects of increased temperature. Therefore, these materials gradually stiffen with depth, forming the more rigid lower mantle. Despite their greater strength, the materials of the lower mantle are still capable of very gradual flow.

1.2 The Geologic Time Scale

In the late 1700s, James Hutton recognized that Earth is very old. But how old? For many years there was no reliable method to determine the age of Earth or the dates of various events in the geologic past. Rather, a geologic time scale was developed that showed the sequence of events based on relative dating principles. What are these principles? What part do fossils play? With the discovery of radioactivity and radiometric dating techniques, geologist now can assign fairly accurate dates to many of the events in Earth history. What is radioactivity? Why is it a good "clock" for dating the geologic past?

In 1869 John Wesley Powell, who was later to head the U. S. Geological Survey, lead a pioneering expedition down the Colorado River and through the Grand Canyon. Writing about the rock layers that were exposed by the downcutting of the river, Powell noted that " the canyons of this region would be a Book of Revelations in the rock-leaved Bible of geology. " He was undoubtedly impressed with the millions of years of Earth history exposed along the walls of the Grand Canyon.

Powell realized that the evidence for an ancient Earth is concealed in its rocks. Like the pages in a long and complicated history book, rocks record the geological events and changing life-forms of the past. The book, however, is not complete. Many pages, especially in the early chapters, are missing. Others are tattered, torn, or smudged. Yet, enough of the book remains to allow much of the story to be deciphered.

Interpreting Earth history is a prime goal of geology. Like a modern-day sleuth, the geologist must interpret the clues found preserved in rocks, and the features they contain, geologist can unravel the complexities of the past.

Geological events by themselves, however, have little meaning until they are put into a time perspective. Studying history, whether it be the Civil War or the age of Dinosaurs, requires a calendar. Among geology's major contributions to human knowledge is the geologic time scale and the discovery that Earth history is exceedingly long.

Relative Dating-Key Principles

During the late 1800s and early 1900s, attempts were made to determine Earth's age, Although some of the methods appeared promising at the time, none of these early efforts proved to be reliable. What these scientists were seeking was an absolute date. Such dates pinpoint the time in history when something took place. Today radiometric dating allows us to accurately determine absolute dates for rock units that represent important events in Earth's distant past. However, prior to the discovery of radioactivity, geologists had no reliable method of absolute dating and had to rely solely on relative dating(we will address radiometric dating later in this chapter).

Relative dating means that rocks are placed in their proper sequence of formation. Relative dating can not tell us how long ago something took place, only that it followed one event and preceded another. The relative dating techniques that were developed are still widely used. Absolute dating methods did not replace these techniques; they simply supplemented them. To establish a relative time scale, a few simple principles or rules had to be discovered and applied. Although they may seem obvious to us today, they were major breakthrough in thinking at the time, and their discovery was an important scientific achievement.

Law of Superposition

Nicolaus Steno, a Danish anatomist, geologist, and priest (1638—1668), is credited with being the first to recognize a sequence of historical events in an outcrop of sedimentary rock layers. Working in the mountains of western Italy, Steno applied a very simple rule that has come to be the most basic principle of relative dating—the law of superposition. The law simply states that in an undeformed sequence of sedimentary rocks, each bed is older that the one above and younger than the one below. Although it may seem obvious that a rock layer could not be deposited with nothing beneath it for supported, it was not until 1669 that Steno clearly stated this principle.

This rule also applied to other surface—deposited materials such as lava flows and beds of ash from volcanic eruptions. Applying the law of superposition to the beds exposed in the upper portion of the Grand Canyon, we can easily place the layers in their proper order. Among those that are pictured, the sedimentary rocks in the Supai Group are the oldest, followed in order by the Hermit Shale, Coconino Sandstone, Toroweap Formation, and Kaibab Limestone.

Principle of Original Horizontality

Steno is also credited with recognizing the importance of another basic principle, called the principle of original horizontality. Simply stated, it means that layers of sediment are generally deposited in a horizontal position. Thus, if we observe rock layers that are flat, they have not been disturbed and still have their original horizontality. But if they are folded or inclined at a steep angle they must have been moved into that position by crustal disturbances sometime after their deposition.

Principle of Cross-Cutting Relationship

When a fault cuts through other rocks, or when magma intrudes and crystallizes, we can assume that the fault or intrusioin is younger than the rocks affected. For example, the faults and dikes clearly must have occurred after the sedimentary layers were deposited.

This is the principle of cross-cutting relationships. By applying the cross-cutting principle, you can see that fault A occurred after the sandstone layer was deposited because it "break" the layer. Likewise, fault A occurred before the conglomerate was laid down because that layer is unbroken.

We can also state that dike B and its associated sill are older than dike A because dike A cuts the sill. In the same manner, we know that the batholith was emplaced after movement occurred along fault B but before dike B was formed. This is true because the batholith cuts across fault B while dike B cuts across the batholith.

The Geologic Time Scale

Geologists have divided the whole of geologic history into units of varying magnitude. Together, they comprise the geologic time scale of Earth history. The major units of the time scale were delineated during the nineteenth century, principally by workers in western Europe and Great Britain. Because absolute dating was unavailable at that time, the entire time scale was created using methods of relative dating. It has only been in this century that radiometric methods permitted absolute dates to be added.

Structure of the Time Scale

The geologic time scale was formulated during the early 1800s on the basis of information gained by relative age dating of sedimentary rocks and fossils in Europe. Large divisions of geologic time are called eras. Eras are subdivided into periods, periods into epochs, and epochs into ages.

It is known, primarily from radioactive age dating, that the earth is about 4.5 billion years old. For the first part of the Precambrian Era, there is no evidence for life. The first life, which was probable algae floating in the ocean, appeared approximately 3 billion years ago. The fossil record throughout the later portion of the Precambrian is sparse and indicates that just simple life forms of plants and animals existed in the ocean. Because of the sparsity of life, there is very little organic matter preserved in Precambrian sediments and, therefore, little in the way of petroleum source rocks. Many of the Precambrian sediments have been buried deep and are metamorphosed. They offer little in the way of reservoir rocks. Therefore, no significant deposits of gas and oil are known in Precambrian rocks.

The geologic time scale subdivides the 4.6-billion-year history of Earth into many different units and provides a meaningful time frame within which the events of the geologic past are arranged. As shown in Figure 1.1.1, Eons represent the greatest expanses of time. The eon that began about 570 million years ago is the Phanerozoic, a term derived from Greek words meaning visible life. It is an appropriate description because the rocks and deposits of the Phanerozoic eon contain abundant fossils that document major evolutionary trends.

Another glance at the time scale reveals that the Phanerozoic eon is divided into eras. The three eras within the Phanerozoic are the Paleozoic ("ancient life") the Mesozoic ("middle life"), and the Cenozoic ("recent life"). As the names imply, the eras are bounded by profound worldwide changes in life-forms.

Each era is subdivided into time units known as periods. The Paleozoic has seven, the Mesozoic three, and the Cenozoic two. Each of these dozen periods is characterized by a somewhat less profound change in life-forms as compared with the eras. The eras and periods of the Phanerozoic, with brief explanations of each, are shown in Table 1.1.1.

Table 1.1.1 Major Divisions of Geologic Time

Cenozoic Era (Age of Recent Life)	Quaternary period	The several geologic eras were originally named Primary, Secondary, Tertiary and Quaternary. The first two names are no longer used; Tertiary and Quaternary have been retained but used as period designations.
	Tertiary	