教育部新世纪高等教育教学改革项目

Geology, Environment & Civil Engineering

地质工程、环境工程、土木工程（专业英语）

万新南　董孝壁　编著

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内容简介

本书参考英美等国有关专业的最新教材与科学文献，根据学科发展的需要用英语编写而成。本书共分五大部分，重点介绍与人类生活居住有关的自然地质环境、灾害、污染及相关地质、建筑工程与环境治理、保护工程等内容。该教材在专业上自成体系，在英语文字上集英、美各家所长，专业术语与语法现象多，词汇涵盖面宽，并附有英语难点注释。全书文句活泼，部分章节充满文学色彩，知识性、趣味性强。

本书适合作为地质工程、水文地质与工程地质、岩土工程、建筑工程、环境工程及相关专业本科生、研究生的专业英语或专业教学参考书，也可作为英语爱好者的自学读物。

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序

“专业英语”的教学方式与教材编写大多数院校都承袭或仿照“基础英语”，即教学是千篇一律的“课堂教学”；而教材是利用“课文＋注释＋语法＋译文技巧＋专业词汇＝专业外语”的模式，没有专业英语的自身特色，效果极差，缺乏专业英语教学的特殊性，缺乏“语言与专业”的有机统一性。因此，教学方式、教材内容与考核方式的改革势在必行，以充分利用教本的空间资源与教学的时间资源，充分发挥教师“教”与学生“学”的主观能动性，增加学生阅读的实践空间，提高专业教学质量与学生用英语阅读、作文与思维的水平。

根据国际学术交流与目前“双语教学”的需要，作为双语教学的“语言与专业”的桥梁工具，作者对专业英语教材的编写内容与方式做了大的改革，以“土木”与“环境”四年专业基础内容为主导，以英语语言的渐进性为依据，编写了本教材，以适应现代教学的需要。

本书分五大部分，第一部分为基础地球环境，包括太阳系的形成与计算机模拟，地球上的元素、岩石与矿物，地质构造与板块运动、地质时代与遥感成像等；第二部分主要讨论危害人们生活安全的地质灾害问题，如地震、滑坡、沉陷与水土流失等；第三部分主要讨论地质工程的理论基础与地质灾害治理方法；第四部分讨论建筑基本理论问题，包括材料力学、建设设计与建筑评论等内容；第五部分涉及人口、全球环境变化、污染与健康、环境治理等问题，主要讨论流水过程、温室效应、工农业污染、元素迁移与污染治理方法。总之，该教材内容涵盖面宽，系统性强。除了整体的系统性外，每部分还自成体系，因而可满足地质、水文地质、地质工程、建筑结构与环境工程等专业的专业英语教学需求。

本教材1998年10月被成都理工大学立项作为“环境与土木工程学院”各专业的通用自编教材。2000年2月申报《教育部新世纪高等教育改革项目》，并于2000年10月被教育部正式批复立项，本教材的编写是该项目研究的重要内容。经过近4年的编写、试用、充实、提高，几经修改（已有4个版本，5次印刷，7次开课，3个专业使用），反映良好，今正式定稿。本教材在近4年的编改、试用过程中得到了校、院有关领导以及教务处各级领导的大力支持，特别是教务处胡宗清副处长的关心、支持、指点，在此深表感谢；全书的英文校对，得到人事处赵朝秀女士的全力支持，深表敬意！

编　者
2003年3月

Contents

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Part One — Essential Geology

§ 1-1 Solar System and Our Planet

Our Planetary Environment

1 Billions of years ago, out of a swirling mass of gas and dust, evolved a system of varied planets hurtling around a nuclear-powered star-our solar system①. One of these planets, and one only, give rise to complex life forms. Over time, a tremendous diversity of life forms and ecological system developed, while the planet too evolved and changed, its interior churning 搅拌, its landmasses shifting 漂移, its surface constantly being reshaped②. Within the last several million years, the diversity of life on earth has included humans, increasingly competing for space and survival on the planet's surface③. With the control over one's surroundings made possible by the combination of intelligence and manual dexterity④ 机敏, humans have found most of the land on the planet inhabitable; they have learned to use not only plant and animal resources, but minerals, fuels, and other geologic materials; in some respects, humans have even learned to modify natural processes that inconvenience or threaten them. As we have learned how to study our planet in systematic ways, we have developed an ever-increasing understanding of the nature of the processes shaping, and the problems posed by, our geological environment⑤. As the human population grows, however, it becomes increasingly difficult for that population to survive on the resources and land remaining, to avoid those hazards that cannot be controlled, and to refrain from making irreversible and undesirable changes in environmental system. The urgency of perfecting our understanding, not only of natural processes but also of our impact on the planet, is becoming more and more apparent⑥

1-① 此句为倒装名，正常语序为… a system (had been) evolved out of …。数十亿年前，旋转的气体与尘埃物质演化成了我们的太阳系，即一个由不同行星组成同时绕核能星体——太阳高速旋转的星系。1-② … Over time, 漫长的一段时间，…与此同时，地球剧烈演化与变迁，其内部物质发生重组，其外部发生大陆漂移，其表面不断重塑更新。1-③ 不断为空间竞争,以便在地球表面生存。其中 competing for 与 survival on 并列。/1-④ 随着能对周边环境加以控制…, made possible by…为 the control 的定语。1-⑤ … and the problems posed by … 地质环境(变化)所产生的问题。1-⑥ 最紧迫的是,我们不仅应该清楚地了解地球的自然过程，而且要了解我们对地球的影响。该句主语为 The urgency, 谓语为 is becoming, 但译成中文时主语进行了代换。

The Early Solar System

2 In recent decades, scientists have been able to construct an ever-clearer picture of the origins of the solar system and, before that, of the universe itself. Most astronomers now accept some sort of "Big Bang" as origin of today's universe①. At that time, enormous quantities of matter were created and flung 投掷 violently apart across an ever-larger volume of space②. The time of Big Bang can be estimated in several ways. Perhaps the most direct is the back-calculation of the universe's expansion to its apparent beginning. Other methods depend on astrophysical 天体物理 models of creation of the elements or the rate of evolution of different types of stars③. Most age estimates overlap in the range of 15 to 20 billion years④, although a few researchers suggest an age closer to 10 billion years.

2-① 大爆炸，天文术语。The time of Big Bang 大爆炸时代。2-② 那时，产生了大量物质，并剧烈地向外太空飞逸，apart across an …分离并穿越一个更大体积的空间，即宇宙膨胀。2-③ 把宇宙膨胀反推恢复到

原始状态计算,另外也可利用元素产生的天体物理模型,或不同类星体演化速度计算。2-④ billion 美、法代表 10 亿（1,000,000,000），而英、德代表万亿（1,000,000,000,000）；million, 百万。

3 From the debris of the Big Bang formed the stars, as locally high concentrations of mass were collected together by gravity, and some became large and dense enough that energy-releasing atomic reactions were set off deep within them. Stars are not permanent objects. They are constantly losing energy and mass as they burn their nuclear fuel. The mass of material that initially formed the star determines how rapidly the star burn; some stars burned out billions of years ago, while others are probably forming now from the original matter of the universe mixed with the debris of older stars.

4 Our sun and its system of circling planets, including the earth, are believed to have formed from a rotating cloud of gas and dust, starting nearly 5 billion years ago. Most of the mass of the cloud coalesced to form the sun, which became a star and began to "shine", or release light energy, when its interior became so dense and hot from the gases remaining in the flattened cloud disk rotating around the young sun. The dust clumped into planets, the formation of which was essentially complete over 4.5 billion years ago.

The Planets

5 The compositions of the planets formed depended largely on how near they were to the hot sun. The planets formed nearest to the sun contained mainly high-temperature materials: metallic iron and a few minerals with very high melting temperatures, with little water or gas. Somewhat farther out①, where temperatures were lower, the developing planets incorporated much larger amounts of lower-temperature minerals, including some that contain water locked within their crystal structures. (This development later made it possible for the earth to have liquid water at its surface.) Still farther from the sun, temperatures were so low that nearly all of the materials in the original gas cloud condensed—even materials like methane and ammonia, which are gases at normal earth surface temperatures and pressures.

5-① 有的离太阳稍远的星体温度较低，演化中的星体携有大量低温矿物，包括晶架中固定一定量的水分。

6 The result was a series of planets with a variety of compositions, most quite different from that of earth. This is confirmed by observations and measurements of the planets. For example, the planetary densities listed in Table 1.1 are consistent with a higher metal content in planets close to the sun and a larger proportion of ice and gas in the planets farther from the sun. These differences should be kept in mind when it is proposed that other planets could be mined for needed minerals. Both the basic chemistry of these other bodies and the kinds of ore-forming or other resource-forming processes that might occur on them would differ considerably from those on earth, and may not lead to products we would find useful (This is leaving aside any questions of the economics or technical practicability of such mining activities!). In addition, our principal current energy sources required living organisms to form, and so far, no such life forms have been found on other planets or moons. Even Venus—close to Earth in space, similar in size and density—shows marked differences: Its dense, cloudy atmosphere is thick with carbon dioxide, producing planetary surface temperatures hot enough to melt lead through run away greenhouse-effect heating①.

6-① 这些星体基本物质的化学组成与其成矿类型或成矿过程极不同于地球，很难产生我们认为有价值的矿产资源（这里暂且不谈开采中的经济与技术的可行性）。另外，地球上目前主要能源的形成离不开生物作用，而至今在其他星球或卫星上还没有发现类似生命的形式。即使大小、密度与地球相似，空间上离地球最近的金星，也与地球有很大差别，其大气层是一层厚而稠密的二氧化碳云团，温室效应作用的高温足以熔融金属铅等。

Table 1.1 Some Basic Data on the Planets

Planet	Mean distance from Sun (millions of km)	Equatorial diameter, relative to Earth	Density (g/cu.cm)	
Mercury	58	0.38	5.4	
Venus	108	0.95	5.2	Predominatly rock/metal planets
Earth	150	1.00	5.5	
Mars	228	0.53	3.9	
Jupiter	778	11.19	1.3	
Saturn	1,427	9.41	0.7	
Uranus	2,870	4.06	1.2	Gaseous planets
Neptune	4,479	3.88	1.7	
Pluto	5,900	0.23	1.1	

The Earth

7 The earth has changed continuously since its formation, undergoing some particularly profound changes in its early history. The early earth was very different from what it is today, lacking the modern oceans and atmosphere and having a much different surface from its present one, probably more closely resembling the barren, cratered surface of the moon. The planet was heated by several processes: **the impact** of the colliding dust particles and meteorites as they came together to form the earth, **compression** of the interior by gravity (that materials heat up when compressed can be demonstrated by pumping up a bicycle tire and then feeling the barrel of the pump①), and **energy** release from decay of the small amounts of several naturally radioactive elements that the earth contains.

7-① 压缩使物质发热的现象就如同给自行车打气时气筒发热一样。

8 These three heat sources combined to raise the earth's internal temperature enough that parts of it, perhaps eventually most of it, melted, although it was probably never molten all at once. Dense materials, like metallic iron, would have tended to sink toward the middle of the earth. As cooling progressed, lighter, low-density mineral crystallized and floated out toward the surface. The eventual result was an earth differentiated into several major compositional zones; the central core; the surrounding mantle; and a thin crust at the surface (Fig1.1.1). The process was complete before 4 billion years ago.

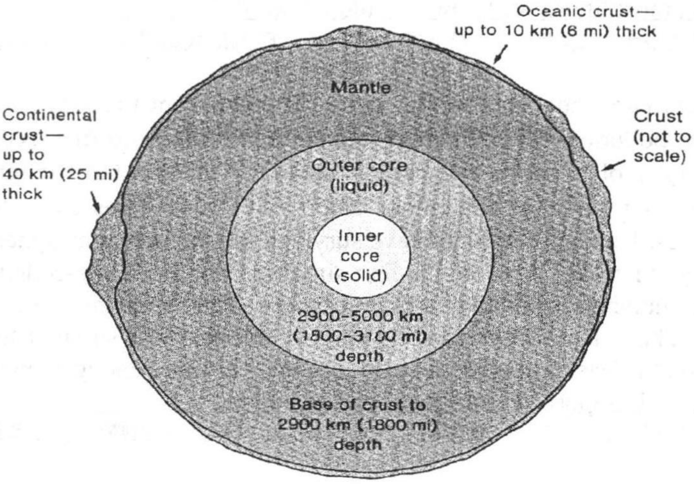

Fig.1.1.1 Earth model

9 Although only the crust and a few bits of uppermost mantle *that are carried up into the crust by volcanic activity* can be sampled and analyzed directly, we nevertheless have a good deal of information on the composition of the earth's interior. First, scientists can estimate from analyses of stars *the starting composition of the cloud* from which the solar system formed①. Geologists can also infer aspects of the earth's bulk composition from analyses of certain meteorites believed to have formed at the same time as, and under conditions similar to, the earth②. Geophysical data demonstrate that the earth' interior is zoned and also provide information on the densities of the different layers within the earth, which further limits their possible compositions. These and other kinds of data indicate that the earth's core is made up mostly of iron, with some nickel and a few minor elements, and that the mantle consists mainly of iron, magnesium 镁, silicon 硅, and oxygen combined in varying proportions in several different minerals. The earth's crust is much more varied in composition and very different chemically from the average composition of the earth (see Table 1.2). As is evident from that table, many of the metals we have come to prize as resources are relatively uncommon elements in the crust.

9-① …太阳系形成时期云团的初始成分。9-② …形成于同一时间、同等条件…

Table 1.2 Most Common Chemical Elements in the Earth

Whole earth		Crust	
Element	Weight percent	Element	Weight percent
Iron	32.4	Oxygen	46.6
Oxygen	29.9	*Silicon*	27.7
Silicon	15.5	Aluminum	8.1
Magnesium	14.5	Iron	5.0
Sulfur	2.1	Calcium	3.6
Nickel	2.0	Sodium	2.8
Calcium	1.6	Potassium	2.6
Aluminum	1.3	Magnesium	2.1
(All others, total)	.7	(All others, total)	1.5

(Compositions cited are averages of several independent estimates.)

10 The heating and subsequent differentiation of the early earth led to another important result: formation of the atmosphere and oceans. Many minerals that had contained water or gases in their crystals released them during the heating and melting, and as the earth's surface cooled, the water could condense to form the oceans. Without this abundant surface water, which in the solar system is unique to earth, most life as we know it could not exist①

10-① 没有丰富的地表水（太阳系中地球上惟一拥有），已知的大多数生命是无法存在的。

11 The earth's early atmosphere was quite different from the modern one, aside from the effects of modern pollution①. The first atmosphere had little or no free oxygen in it. It probably consisted dominantly of nitrogen and carbon dioxide (the gas most commonly released from volcanoes, aside from water②) with minor amounts of such gases as methane, ammonia, and various sulfur gases. Humans could not have survived in this early atmosphere. Oxygen-breathing life of any kind could not exist before the first simple plants-the single-celled blue-green algae 藻-appeared in large numbers to modify the atmosphere. Their remains are found in rocks several billion years old. They manufacture food by photosynthesis, using sunlight for energy, consuming carbon dioxide, and releasing oxygen as a by-product. In time, enough oxygen accumulated that the atmosphere could support oxygen-breathing organisms.

11-① 早期的大气与现代大不相同，不存在现代大气污染。11-② 火山喷发绝大多数释出气体，也有部分水。

Life on Earth

12 The rock record shows when different plant and animal groups appeared. Some are represented schematically in Fig1.1.2. The earliest creatures left very few remains because they had no hard skeletons, teeth, shells, or other hard parts that could be preserved in rocks. The first multicelled oxygen-breathing creatures probably developed about 1 billion years ago, after oxygen in the atmosphere was well established. By about 600 million years ago, marine animals with shells had become widespread.

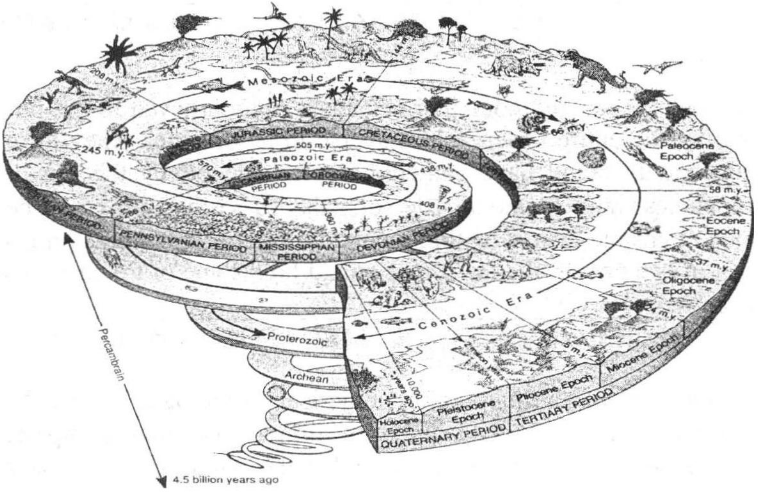

Fig1.1.2 The "geologic spiral". Important plant and animal groups appear where they first occurred in significant numbers. All complex organisms-especially humans-have developed relatively recently in the geologic sense.

13 The development of organisms with hard parts--shells, bones, teeth, and so on—greatly increased the number of preserved animal remains in the rock record; consequently, biological developments since that time are far better understood. Dry land was still barren of large plants or animals half a billion years ago①. In rocks about 500 million years old is the first evidence of animals with backbones—the fish—and soon thereafter, early land plants developed, before 400 million years ago. Insects appeared approximately 300 million years ago. Later, reptiles 爬虫 and amphibians 两栖动物 moved onto the continents. The dinosaurs 恐龙 appeared about 200 million years ago and the first mammals 哺乳动物 at nearly the same time. Warm-blooded animals took to the air with the development of birds about 150 million years ago, and by 100 million years ago, both birds and mammals were well established.

13-① 干燥的土地仍不存在大型植物与动物。

14 Such information has current applications. Certain energy sources have been formed from plant or animal remains. **Knowing the times** *at which particular groups of organisms appeared and flourished* **is helpful** in assessing the probable amounts of these energy sources available and in concentrating the search for these fuels on rocks of appropriate ages①.

14-① in assessing … and in concentrating …在评估与深入研究方面…

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§ 1-2 Cosmos in a Computer

Capturing the full sweep of observable a space and time, the largest cosmological simulation to date shows how gravity built the giant structures that fill the visible universe①

① 由于对可观测的时空域进行全方位扫描，分时段的最大的宇宙模拟显示了充满宇宙的重力作用如何建造巨大星体。

1 A team of astrophysicists and computer scientists has journeyed to the far reaches of space and time by capturing the entire observable universe in a computer. They have created the first simulation of how gravity could have gathered ripples 涟漪 left by the big bang into colossal structures—walls, clumps, and filaments 细丝 of galaxies—filling all of space. The result is a coarse-grained look at cosmic history within a cube 10 billion light-years on a side, a volume so big that if Earth sat in one corner, the far corner would hold some of the most distant galaxies and quasars 类星体 ever seen①.

1-① 体积是如此之大，假如把地球置于宇宙的一端，则另一端可能是一些超巨型的星系与类星体。

2 "This simulation marks a turning point in numerical cosmology," ① says Michael Norman, a computational astrophysicist at the University of Illinois, Urbana-Champaign, who is not a member of the multinational simulation team, called the Virgo 室女座 Consortium 协会. Many times larger than any earlier effort, the whole-universe computation taxed the ingenuity of programmers and the number-crunching prowess of a 512-processor Cray supercomputer at the Max Planck Society's computing center in Garching, Germany.② Other cosmologists have had little time to absorb the results, which were discussed late last week at a cosmology meeting in Paris by Jory Colberg of the Max Planck Institute for Astrophysics (MPA) in Garching and which will be the subject of a talk by August Evrard of the University of Michigan at next week's American Astronomical Society meeting in San Diego. But they say they expect this model universe to be a powerful tool for interpreting data from large surveys of the real sky.

2-① 本次模拟是数字宇宙研究的一个里程碑。2-② 数倍于早期的努力，整个宇宙的计算机模拟凝聚了所有程序员的智慧、动用了具有 512 个处理器的数字智能 Cray 芯片超级计算机系统（位于德国 Gerching 的 Max Planck 协会计算中心）。

3 Norman, for instance, notes that even the biggest survey of the real sky, the 5-year Sloan Digital Sky Survey, will map just 100th of the visible universe, so astronomers can't be sure they're getting a true sample of galaxy clusters and voids①. But because the simulation covers "essentially the entire visible universe," he says, even rare structures should crop up often enough to settle questions about how typical they are. Adds Martin Rees, a cosmologist at Combridge University in the United Kingdon, "It is splendid that the modeling and simulations have attained this level of sophistication just at the time when we are starting to get a flood of high quality data."

3-① 例如诺曼强调，即使是规模最大的真实宇宙调查——五年规划的 Sloan 数字宇宙调查——也仅能绘制可见宇宙的百分之一,因而天文学家不能确信，本次模拟是否能表达真实星云团及其空间状况。

4 To simulate cosmic evolution, the Virgo Consortium began by calculating how the slight density variations rippling through the matter of the very early cosmos might have grown①. Those ripples are thought to have originated as "quantum 量子 fluctuations"—in essence, waves of uncertainty in particle positions—during the first instants of the big bang, when the entire observable universe was no larger than a grapefruit②. Relatively simple calculations predict how radiation in the hot young cosmos would have smoothed out some of these perturbations 混乱 while allowing others to intensify③.

4-① rippling through the matter of the very early cosmos 修饰 variations ，“ might have grown” 为 variations 的谓语，整句大意是：室女座国际协会模拟宇宙演化是从计算开始的，其目的是研究初始宇宙爆炸波产生的轻密度物质如何成长聚集；4-② 在大爆炸初期，整个所观测到的宇宙有如一个葡萄大小，大爆炸所产生的波（涟漪）实质上是一种不确定的颗粒状态的波，其成因有如“夸脱的波动”。4-③ 相对简单的计算就可显示，处于炽热状态的年青宇宙其辐射作用可能减弱（平滑）一部分波动，而增强另一部分波动。

5 As the universe expanded and cooled, gravity took over. And after about a billion years, when the cosmos was about 10% of its present age, concentrations of mass equaling tens of Milky Ways began to “go nonlinear, ” becoming too closely bunched 束 for simple mathematics to handle—just as seaside ripples on a calm spring day are less complex than breakers in a typhoon①. At that point, the researchers could no longer trace cosmic evolution by solving a single set of equations. Instead they divided the mass in a cubic cosmos into a billion particles and calculated how each particle affected the motion of all its neighbors in 500 time steps. Over the course of the simulation, the cosmic wrinkles 使起皱, like waves on a stormy seascape, became more and more pronounced 显著 as the particles attracted one another.

5-① 宇宙不断膨胀与冷却，引力起着主导作用，大约经历数十亿年后，当时宇宙相当于现今年龄的十分之一，质量相当于数十个银河系；其质量聚集（过程的数学表达式）呈“非线性”态，并高度收敛，这并非简单数学式可以应对的，正像表达台风中的惊涛骇浪不能等同于春天平静海边的涟漪。

6 Each run of this stage of the simulation, says Simon White of Max Planck, a leader of the effort, required about 70 hours on the Cray T3E, which split the universe up among its 512 processors. To streamline communications among the processors and to even 变平 out the voracious 贪婪 memory requirements 满足巨量内存的需要, says White, “the Virgo Consortium codes had to be rewritten from scratch 擦痕在可写芯片中重写.” Even so, the 600 billion bytes of raw data streaming from the computation filled memory banks almost to capacity, and the first attempts to download the data from active memory onto tapes crashed the Garching computer center.

7 Yet the result is only a sketchy picture of cosmic evolution, the researchers acknowledge. Each of the billion particles is the equivalent of 10 galaxies or so, and to save computer time, the calculations leave out factors other than gravity, such as pressure and radiation, that govern galaxy formation. The team also stresses that the computations follow only the invisible “dark matter” that is thought to account for most of cosmic mass, and not the bright galaxies that, in nature, trace the dark mass like campfires dotting the ridgelines of hills①. But Michigan's Evrard notes that the largest dark and bright structures are thought to be roughly equivalent.

7-① 研究组也强调模拟只是针对不可见部分，即“暗物质”，它们代表宇宙体的主体，而亮星系物质实质上只是暗物质的示踪体，有如黑暗中点点营火可以勾画整个山脊。

8 So far, the team has done calculations on two model universes. One is filled with enough matter to stop cosmic expansion after an infinite time, a condition called omega matter = 1 (see graphics). ω 常数等于 1 This is the cosmic recipe 宇宙谱 most theorists opted for in the past. The other, called the lambda model, is the kind of universe suggested by new measurements of the cosmic expansion rate: one that has an omega matter of 0.3 and a substantial cosmological constant, or large-scale repulsive force①.

8-① λ 模型是根据宇宙膨胀速率测量新数据创建的——相当于 ω 常数等于 0.3，具有一个实质性的宇宙常数，即具有一种巨大的反冲力）。

9 The team then created both “snapshots 快照” of fully formed universe and views of what an observer would actually see in looking deeper and deeper into the universe from one point. The farther the observer looks, the longer it has taken for light to arrive from that point, so the view gradually moves to earlier times in cosmic history along a wedgelike bundle of lines of sight. Even veteran researchers in the consortium were taken aback by the stunning detail seen in these time-lapse pictures, which were created mostly by Evrard 协会最有经验的研究者通过主要由 Evrard 创建的极精妙的时间消逝场景而带入过去. Says Carlos Frenk of the University of Durham in the U.K., who co-directs the consortium with White, “I was amazed that even at very early times, you see a huge amount of structure” —filaments and walls like the ones that observers have seen in the nearby universe. Agrees Evrard: “You start to pick out subtleties that you wouldn't have imagined. It blows you mind.”

10 So far, the lambda model seems to be a little closer to the real universe. Large clusters of galaxies form earlier in the lambda model than in the omega = 1 version, more in line with observations. Both models have difficulty accounting for some of the most massive and distant clusters seen in the real sky, however.

11 As cosmologist David Weinberg of Ohio State University in Columbus and others see it, the simulations should be most valuable as a point of comparison for surveys of the real sky such as the Sloan and the Anglo Australian 2-degree Field (2dF) Survey. In such surveys, explains Richard Ellis of Cambridge University, a co-principal investigator of the 2dF Survey, “it's as if one was conducting an opinion poll but was a bit worried that the sample.questioned might be unrepresentative.” The new simulations, say Weinbery and Ellis, should help cosmologists distinguish true indicators of the type of universe we live in from statistical flukes(侥幸成功). “You have a volume big enough that you can plunk a ‘theoretical observer’ down in the simulation and create an artificial Sloan survey” to see what kinds of features are typical, says Weiberg, who is a member of the Sloan collaboration①.

11-① plunk a ‘theoretical observer’ down, … plunk——投掷，置身于“理论观测者”…

12 Already, says Frenk, the simulations are pouring out clues to everything from how often galaxy clusters would tend to clump together into superclusters to the likelihood that we might live in a relatively tenuous纤细 “bubble” within the cosmos, as observations are beginning to suggest. And because the team plans to make its data public, other researchers will be able to make their own journeys through the far reaches of this silicon universe.

§ 1-3 Elements，Minerals and Rock

Atoms, Elements, Isotopes, Ions, and Compounds

1 Considering the limited number of chemical elements in nature, **the variety of substances** found on earth and the diversity of the their physical properties **are astonishing**. The same is true even of just the rocks and minerals. Most of these are made up of an even smaller subset of elements, yet they are very diverse in color, texture, and other properties. The differences in the physical properties of rocks, minerals, and soils determine their suitability for different purposes-extraction of water or of metals, construction, manufacturing, waste disposal, agriculture, and other uses. For this reason it is helpful to understand something of the nature of these materials. Also, each rock contains clues *to the kinds of processes* that formed it and *to the geologic setting* where it is likely to be found. For example, we will see that the nature of a volcano's rocks may indicate what hazards it presents to us; our search for new ores or fuels is often guided by an understanding of the specialized geologic environments in which they occur.

Atomic Structure

2 All natural and most synthetic substances on earth are made from the ninety naturally occurring chemical elements. An atom is the smallest particle into which an element can be divided while still retaining the chemical characteristics of that element (Fig 1.3.1). The nucleus, at the center of the atom, contains one or more particles with a positive electrical charge (protons 质子) and usually some particles of similar mass that have no charge (neutrons 中子). Circling the nucleus 核 are the negatively charged electrons.

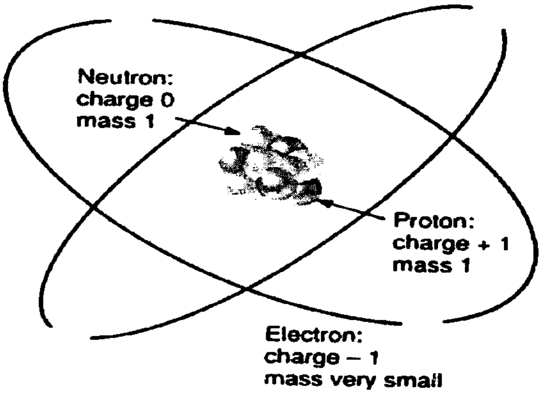

Fig1.3.1 Schematic drawing of atomic structure

3 **The number** of protons in the nucleus **determines** what chemical element that atom is. Every atom of hydrogen contains one proton in its nucleus; every oxygen atom contains eight protons; every carbon atom, six; every iron atom, twenty-six; and so on. The characteristic number of protons is the atomic number of the element.

Elements and Isotopes

4 With the exception of the simplest hydrogen atoms, all nuclei contain neutrons, and the number of neutrons is similar to or somewhat greater than the number of protons. The number of neutrons in atoms of one element is not always the same. The sum of the number of protons and the number of neutrons in a nucleus is the atom's atomic mass number. Atoms of a given element with different atomic mass numbers—in other words, with the same number of protons but different numbers of neutrons—are distinct isotopes of that element. Some elements have only a single isotope, while others may have ten or more. (The reasons for there phenomena involve principles of nuclear physics and the nature of the processes by which the elements are produced in the interiors of stars, and we will not go into them there!)

5 For most applications, we are concerned only with the elements involved, not with specific isotopes. When a particular isotope is to be designated, this is done by naming the element (which, by definition, specifies the atomic number, or number of protons) and the atomic mass number (protons plus neutrons). Carbon, for example, has three natural isotopes. By far the most abundant is carbon-12, the isotope with six neutrons in the nucleus in addition to the six protons common to all carbon atoms. The two rarer isotopes are carbon-13 (six protons plus seven neutrons) and carbon-14 (six protons plus eight neutrons). Chemically, all behave alike. The human body cannot,

for instance, distinguish between sugar containing carbon-12 and sugar containing carbon-13. Other differences between isotopes may, however, make a particular isotope useful for some special purpose. Carbon-14 is naturally radioactive, which means that, over a period of time, carbon-14 nuclei decay at a known rate; this fact allows carbon-14 to be used to date materials containing carbon. Differences in the properties of two uranium isotopes are important in understanding nuclear power options :only one of the two common uranium isotopes is suitable for use as reactor fuel, and must be extracted and concentrated from natural uranium as it occurs in uranium ore. The fact that radioactive elements will inexorably 无情、冷酷 decay—releasing energy—at their own fixed, constant rates is part of what makes radioactive-waste disposal such a challenging problem .

Ions

6 In an electrically neutral atom, the number of protons and the number of electrons are the same; the negative charge of one electron just equals the positive charge of one proton. Most atoms, however, can gain or lose some electrons. When this happens, the atom has a positive or negative electrical charge and is called an ion. If it loses electrons, it becomes positively charged, since the number of protons then exceeds the number of electrons. If the atom gains electrons, the ion has a negative electrical charge. Positively and negatively charged ions are called, respectively, cations and anions. Both solids and liquids are, overall, electrically neutral, with the total positive and negative charges of cations 阳离子 and anions 阴离子 balanced. Moreover, free ions do not exist in solids; cations and anions are bonded together. In a solution, however, individual ions may exist and move independently. Many minerals break down into ions as they dissolve in water. Individual ions may then be taken up by plants as nutrients or react with other materials. The concentration of hydrogen 氢 ions determines a solution a acidity 酸度.

Compounds

7 The electrical attraction between oppositely charged ions can cause them to become chemically bonded together. This is called ionic bonding 离子束缚. Bonds between atoms may also form if the atoms share electrons. This is covalent bonding 共价束缚. Whatever the nature of the bonding, when atoms or ions of different elements combine in this way, they form compounds. A compound is a chemical combination of two or more chemical elements, in particular proportions, that has a distinct set of physical properties, usually very different from those of any of the individual elements in it. Consider, as a simple example, common table salt (sodium chloride). Sodium is a silver metal, and chlorine is a greenish gas that is poisonous in large doses. When equal numbers of sodium and chlorine atoms combine to form table salt, or sodium chloride, the resulting compound forms colorless crystals that do not resemble either of the component elements.

Chemical Symbols

8 Each chemical element is denoted by a one-or two-letter symbol. Many of these symbols make sense in terms of the English name for the element—O for oxygen, He for helium, Si for silicon, and so on. Other symbols reflect the fact that, in earlier centuries, scientists were generally versed in Latin or Greek: The symbols Fe for iron and Pb for lead, for example, and derived from *ferrum* and *plumbum,* respectively, the Latin names for these elements.

9 The chemical symbols for the elements can express the compositions of substances very precisely. Subscripts after a symbol indicate the number of atoms/ions of one element present in proportion to the other elements in the formula. For example, the formula $Fe_3Al_2Si_3O_{12}$ represents a compound in which, for every twelve oxygen atoms, there are three iron atoms, two aluminum

atoms, and three silicon atoms. (This happens to be a variety of the mineral garnet 石榴石、深红色.) The chemical formula is much briefer than describing the composition in words. It is also more exact than the mineral name "garnet," for there are several compositions of garnets with the same basic kind of formula and crystal structure: Other examples include a calcium-aluminum garnet with the formula $Ca_3Al_2Si_3O_{12}$ and a calcium-chromium garnet, $Ca_3Cr_2Si_3O_{12}$. Moreover, chemical formulas are understood by all scientists, while mineral names are known primarily to geologists.

10 Sample formulas of some common minerals appear in Table 1.3. Formulas can become very complex, especially when different elements can substitute for each other in the same site in the crystal structure. Iron and magnesium often do this in silicates. Biotite 黑云母, a common, dark-colored mica, may be rich in iron and have a formula of $KFe_3AlSi_4O_{10}(OH)_2$, or it may be rich in magnesium and have a formula of $KMg_3AlSi_4O_{10}(OH)_2$, or, more commonly, it may contain some iron and some magnesium, which together total three atoms per formula. The generalized formula is then $K(Fe,Mg)_3AlSi_4O_{10}(OH)_2$.

Table 1.3 Sample formulas of Some Common Minerals

Mineral	Chemical composition	Chemical formula
Quartz	silicon dioxide	SiO_2
Microcline (微斜长石) (a potassium feldspar)	potassium aluminum silicate	$KAlSi_3O_8$
calcite (方解石)	calcium carbonate	$CaCO_3$
hematite (赤铁矿)	ferric iron oxide	Fe_2O_3
pyrite (黄铁矿)	iron disulfide	FeS_2

Minerals—General

Minerals Defined

11 A mineral is naturally occurring, inorganic, solid element or compound with a definite chemical composition and a regular internal crystal structure. Naturally occurring, as distinguished from synthetic, means that minerals do not include the thousands of chemical substances invented by humans. Inorganic means not produced solely by living organisms or by biological processes. That minerals must be solid means that the ice of a glacier is a mineral, but liquid water is not. Chemically, minerals may consist either of one element-like diamonds, which are pure carbon—or they may be compounds of two or more elements. Some mineral compositions are very complex, consisting of ten elements or more. Minerals have a definite chemical composition or a compositional range within which they fall. The presence of certain elements in certain proportions is one of the identifying characteristics of each mineral. Finally, minerals are crystalline, at least on the microscopic scale, Crystalline materials are solids in which the atoms are arranged in regular, repeating patterns. These patterns may not be apparent to the naked eye, but most solid compounds are crystalline, and their crystal structures can be recognized and studied using X rays and other techniques. Examples of noncrystalline 非晶质 solids include glass and plastic.

Identifying Characteristics of Minerals

12 The two fundamental characteristics of a mineral that together distinguish it from all other

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