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Lesson One

Text

The Earth (1)

From classical times it has been known that the earth is roughly spherical in shape. Actually, the planet is shaped more like a slightly flattened ball whose polar radius is about 21 km shorter than its equatorial **radius. The average radius is 6371 km. The earth's specific gravity** is 5.5. It is 5.5 times as heavy as an equal volume of water. This specific gravity is greater than that of any other planet in the solar system, but not appreciably different from that of Mercury, Venus, and Mars. Because the average specific gravity of surface rocks is only about 2.7, the material existing deep within the earth must have a specific gravity well in excess of the 5.5 average. Very likely, the material at the earth's center has a specific gravity as high as about 15.

The splendid photographs of the earth taken from space by the Apollo astronauts remind us that our planet is more than a rocky globe orbiting the sun. Whispy patterns of white clouds above the azure blue color tell us of the presence of an atmosphere and hydrosphere. Here and there one can even discern patches of tan that indicate the existence of continents. Greenish hues provide evidence of the planet's most remarkable feature: there is life on earth.

THE ATMOSPHERE

We live beneath a thin but vital envelope of gases called the atmosphere. We refer to these gases as *air*. "Pure air" is composed mainly of nitrogen (78.03%) and oxygen (20.99%). The remaining 0.98% of air is made of argon, carbon dioxide, and minute quantities of other gases. One of these "other" components found mostly in the upper atmosphere is a form of oxygen called ozone. Ozone absorbs much of the sun's lethal ultraviolet radiation, and is thus of critical importance to organisms on the surface of the earth. Air also contains from 0.1 per cent to 5.0 per cent of water vapor. However, because this moisture content is so variable, it is not usually included in lists of atmospheric components.

Each day, the atmosphere receives radiation from the sun. This solar radiation provides the energy that heats the atmosphere and drives the winds.

Distribution of solar radiation is one of the most important factors in determining the various kinds of climate we experience on the earth.

THE HYDROSPHERE

The discontinuous envelope of water that covers 71 per cent of earth's surface is called the

hydrosphere. It includes the ocean, as well as water vapor, the water contained in streams and lakes, water frozen in glaciers, and water that occurs underground in the pores and cavities of rocks. If surface irregularities such as continents and deep oceanic basins and trenches were smoothed out, water would completely cover the earth to a depth of more than two kilometers.

Water is an exceedingly important geologic agent. Glaciers composed of water in its solid form alter the shape of the land by scouring, transporting, and depositing rock debris. Because water has the property of dissolving many natural compounds, it contributes significantly to the decomposition of rocks and, therefore, to the development of soils on which we depend for food. Water moving relentlessly down hill as sheetwash, in rills, and in streams, loosens and carries away the particles of rock to lower elevations where they are deposited as layers of sediment. Clearly, the process of sculpturing our landscapes is primarily dependent upon water.

By far the greatest part of the hydrosphere is contained within the ocean basins. These basins are of enormous interest to geologists, who have discovered that they are not permanent and immobile as once believed, but rather are dynamic and ever changing. There is ample evidence that the sea floors move, and that these movements have a direct relation to the formation of mountains, chains of volcanoes, deep sea trenches and mid-ocean ridges. In the ocean are collected the layers of sediment from which geologists decipher earth history. Here also one finds mineral resources and clues to the location of ore deposits elsewhere on the planet. The ocean provides part of our food supply and has a pervasive influence on the climate we experience.

(From Contemporary Physical Geology: An Overview of the Third Planet', pp6—7)

New Words and Expressions

1. classical ['klæsikəl] a. 传统的；古典的
2. spherical ['sferikəl] a. 球的；球形的
3. planet ['plænit] n. 行星
4. gravity ['græviti] n. 重力；引力；地球引力
   specific ~ 比重
5. mercury ['mə:kjuri] n. 水星
6. venus ['vi:nəs] n. 金星
7. excess [ik'ses] n. 超越，越过；过量，过剩
   in ~ of 超过
8. splendid ['splendid] a. 有光彩的，灿烂的；壮丽的，辉煌的
9. astronaut ['æstrənɔ:t] n. 宇宙航行员
10. rocky ['rɔki] a. 岩石的；稳固的
11. whispy ['hwispi] a. 充满沙沙声的
12. azure ['æʒə] a. 天蓝色的；蔚蓝的；无云的；晴空的
13. atmosphere ['ætməsfiə] n. 大气；大气层；空气
14. hydrosphere ['haidrəsfiə] n. 水圈
15. patch [pætʃ] n. 补片；补块
16. tan [tæn] n. 棕褐色；棕黄色
17. greenish ['gri:niʃ] a. 略呈绿色的
18. hue [hju:] n. 颜色；色彩；形式；样子
19. vital ['vaitl] a. 有生命力的；充满活力的；生气勃勃的；生命的；生机的
20. argon ['ɑ:gɔn] n. 氩
21. minute [mai'nju:t] a. 微小的；微细的；不足道的
22. ozone ['ouzoun] n. 臭氧
23. lethal ['li:θəl] a. 致死的；致命的

24. ultraviolet [ˌʌltrəˈvaiəlit] a. 紫外的；紫外线的
25. irregularity [iˌregjuˈlæriti] n. 不规则；不整齐
26. trench [trentʃ] n. 深沟；地沟
27. exceedingly [iksiːdiŋli] ad. 极端地；非常地
28. geologic [dʒiəˈlɔdʒik] a. 地质的
~ agent 地质营力
29. alter [ˈɔːltə] vt. 改变；改动
30. scour [ˈskauə] vt. 冲洗；冲刷成；侵蚀
31. relentlessly [riˈlentlisli] ad. 无情地
32. sheetwash [ˈʃiːtwɔʃ] n. 片流；层状冲刷
33. rill [ril] n. 小河；溪流
34. sculpture [sˈkʌlptʃə] vt. 刻蚀
35. immobile [iˈmoubail] a. 不动的；不变的；静止的
36. dynamic [daiˈnæmik] a. 能动的；动态的
37. ample [ˈæmpl] a. 足够的；充分的；宽大的
38. pervasive [pə (ː) vəːsiv] a. 反常的；歪曲性的
39. decipher [diˈsaifə] vt. 解释

Notes to the Text

1. In the ocean are collected the layers of sediment from which geologists decipher earth history. 在海洋，形成了地质学家藉以推断地史的沉积地层。
倒装句，主语为 the layers of sediment.
2. Here also one finds mineral resources and clues to the location of ore deposits elsewhere on the planet. 这里也是人们发现矿产资源和矿床线索的场地。

Word Building

Word Composition（词的组成）

英语单词的组成具有一定的规律和特点。从词素的角度对英语单词进行分析，掌握词素的组合及构词法的规律和特点，进而理解词根的含义，就会比较容易记住同一词根所派生及合成的一连串同族词。用这种科学方法记忆单词，就会收到举一反三、触类旁通的效果，有助于科技工作者在短期内掌握大量科技词汇，迅速提高阅读英语科技书刊能力。

下面仅就英语构词法及英语词汇的组成作一简要介绍。

1. 英语构词词素

组成英语单词的要素，即构成一单词的有意义的音节，叫做词素（word-element）。每个词素是词的一小部分，它在词中包含有一定的意义，从词义的角度来看，是不能再分的最小词义单位。

一个单词里的各个词素在词中起着不同的作用。如在 workers（工人们）这个词里，可以分出 work，它是构成这个词的词义基础，称为词根；构词后缀-er，它赋予词以行为主体的意义；构形后缀-s 是词形变化（inflexion），它表达一定的语法意义，在这里指名词词素和变词词素。一般来讲，变词词素是附加在词的基本结构上的构形词缀，也就是构形后缀，它只是表示词的语法关系，即名词和代词的数或格、动词的时态、形容词和副词的比较级、最高级等。

2. 构词词素的分类

英语构词词素按词的结构，可分为词根词素（或词干词素）和派生词素（也叫构词附加词素）。它们在词的结构中各占有一定的地位。词根词素是一个词中最原始的形式，也是一个词最根本的成分。在一组同族词（cognate words）里面，词根表示词的基本意义。同

族词都是从同一个词根派生出来的词，它们在意义上互有联系；懂得了词根的含义，就可以大体上了解各个派生词的意义。因而，掌握英语词根含义是学会英语单词的一个重要环节。

对于词根有两种不同的理解：一种是把词根严格看作单音节的原始意义单位，这种词根为数不多，在英语中大约只有几百个，它们可以单独成为单词，如 act（动作），man（人），sun（太阳）等；另一种是把词根看作同根词共有的可以辨认的部分，不一定是单音节。例如，central（中心的），excenter（外心），concentrate（集中），concentric（同心的），epicenter（震中），识别出这几个词之中的词根 centr（含有“中心”的意义），它们的不同词义就容易掌握了。

词干词素是未经词形变化的原词，也可以是在加后缀以前词根所发生的一种变形。词根加后缀后随着语言的发展，后缀逐渐失去其单独的意义，而为词根所同化形成词干（stem）。前者比如动词 love 的词根是 lov，词干是 love；后者比如 modify，词根为 mod，词干是 modi，后缀是 -fy。

词根和构词词缀一起组成词干。词干的意义决定词根和构词词缀的意义总和。例如在 reader（读者），readable（可阅读的），reading（读物）这一组词里，词根表示一定的行为。这个意义是这一组词族里各个词都具有的，而词干则随着加缀在词根后面的构词后缀的不同，各有不同的意义。词干和词根同形的词，称为根词或单根词。

派生词素也叫做辅助词素，即构词中的构词词缀。很多词的词根的前头或末尾加上接词部分，借以变更词根的意义，这些叫做构词词缀。

词缀（affix）按构词的结构位置可分为前缀（prefix），后缀（suffix），半后缀（semi suffix），中缀（infix）四种。

关于词根及各类词缀以及由它们构成的有关地质词汇，将在以后几课分别介绍。

Exercises

1. Question for review:
   1) What is the general shape of the earth?
   2) What is the atmosphere composed of ?
   3) What is the hydrosphere?
   4) Why must the material existing deep within the earth have a specific gravity well in excess of the 5.5 average?
   5) Where does the greatest part of the hydrosphere exist?
2. Complete the following sentences by choosing appropriate prepositions given below:
   in, on, behind, at, with, above, in front of, under, as, around
   1) The earth is slightly flattened _____ the poles.
   2) You might think of the earth _____ being constructed much like a baseball _____ a two-layered cores, a thick layer _____ the core and a thin skin _____ the surface.
   3) The outer core is believed to be composed mostly of iron and nickel _____ a molten

state _____ a very high temperature.

4) The most common element _____ the crust of the earth is oxygen.

5) The mountain is _____ 2.5 miles _____ sea level.

6) There is a yard _____ the house, and a garden _____ it.

7) There is a bridge _____ the river.

3. Choose the correct form from the alternatives in brackets for each of these sentences:

1) The earth which we _____ on is a ball of matter about 7927 miles in diameter.
(are living, have lived, live)

2) The earth _____ round the sun.
(is moved, moves, moved)

3) The earth _____ of three parts.
(is consisted, consists, is consisting)

4) What _____ the earth made of ?
(is, are, was)

5) The atmosphere _____ of oxygen and nitrogen.
(is composed mostly, is consisted mostly, has been made up)

4. Choose one of the following adverbs for each of the sentences below:

generally, perfectly, presently, heavily, regularly, actually, nearly, probably

1) I am coming _____ .

2) It is _____ eight o'clock.

3) _____ speaking, it is not cold here in winter.

4) It will _____ rain tonight.

5) The earth is not _____ round.

5. Translate the following passage into Chinese:

The discontinuous envelope that covers 71 percent of the earth's surface is called the hydrosphere. It includes the ocean, as well as water vapor, the water contained in streams and lakes, water frozen in glaciers, and water that occurs underground in the pores and cavities of rocks. If surface irregularities such as continents and deep oceanic basins and trenches were smoothed out, water would completely cover the earth to a depth of more than two kilometers.

6. Translate the following sentences into English:

1) 科学家认为地球由几层组成。

2) 地球的固态部分称为岩石圈。(lithosphere)

3) 地质学家发现大部分海洋下地壳厚 4～10 英里。

4) 水和空气在地球历史上是作用于地球表面的最重要的因素。

5) 大气圈是由环绕地球固体和液体部分的气体组成。

Reading Material

The Earth (I)

THE LITHOSPHERE AND THE "SPHERES" BENEATH

Somewhat like the concentric shells of an onion, the solid earth is composed of a series of layers. As will be described in a later chapter, the existence of these layers has been deduced from the study of earthquake waves which have passed through the earth. At the surface is the thin outer shell known as the **crust**. The base of the crust is defined by a plane below which the velocity of certain earthquake waves is significantly greater than in the rocks above. A plane of this kind is called a seismic discontinuity, and the seismic discontinuity at the bottom of the crust has been named the **Mohorovicic discontinuity** after its discoverer.

The crust of the earth really consists of two kinds of rock, each with its own distinctive general composition, thickness, and density. The continental crust has a composition somewhat similar to granite, has a relatively low density, and ranges in thickness from about 35 to 60 kilometers. The crust beneath the ocean basins is somewhat denser, rarely exceeds 5 km in thickness, and is composed of blackish rocks similar to those that form the Hawaiian Islands.

By analogy to the fleshy layer that secretes the hard shell of a clam, the layer beneath the earth's crust is called the **mantle**. The mantle has not yet been penetrated by drilling, but earthquake data indicate that it extends from the base of the crust to a depth of about 2900 km. It comprises nearly 83per cent of the earth's volume. At the base of the mantle is yet another discontinuity that serves as the boundary between the mantle and the core. Geophysicists have recognized two parts of the core: a liquid outer zone and a solid inner core. Both parts are believed to be composed mainly of iron and nickel. As we have noted earlier, the specific gravity of the earth as a whole is greater than that of the common rocks making up its outer parts. Thus, we may conclude that the material of the core is indeed heavy.

Two additional terms for upper zones of the earth's interior have come into wide usage because of their relationship to the movement and evolution of the crust. For example, there exists a layer of the upper mantle, beginning at depths from about 60 to 120 km, and extending to 650 to 700 km in which the velocity of earthquake (seismic) waves is distinctly lower. Geophysicists believe that seismic waves are slowed in this area because it is composed of relatively weak material, which is possibly able to flow plastically. The zone has been named the **asthenosphere**. Above the asthenosphere is a more rigid layer that includes, not only the crust, but an uppermost part of the mantle as well. This cooler and more solid layer is called the lithosphere.

MAJOR FEATURES OF THE CONTINENTS AND OCEAN

It requires only a quick glance at a map of the world to become convinced that the most conspicuous elements of the earth's surface are continents and ocean basins. Both continents and ocean basins contain distinctive geologic features that have developed in response to particular geological processes. For example, the major features of continents are **stable regions** and **orogenic belts**. As is suggested by the name, stable regions are parts of the continents that are no longer disturbed by the kind of geological forces that tend to distort rock layers and raise mountains. Plains and plateaus are characteristic of stable regions. **Orogeny** means mountain building, and thus orogenic belts are zones in which great thicknesses of layered rocks have been strongly compressed, altered, and raised into lofty mountain chains.

Because of a lack of information, the ocean floors were once considered to be rather featureless plains. Actually, they exhibit a variety of major features. Around the edges of the oceans are the submerged margins of the continents called **continental shelves**. The shelves are of enormous importance because they contain many offshore oil traps, as well as deposits of sand, gravel, oyster shells, and diamonds. They are bounded seaward by the steeper **continental slopes** which in turn drop off into less steep **continental rises**, and eventually into the **abyssal plains** rising above the floors of the abyssal plains in the Atlantic, Pacific, and Indian oceans are perhaps the most impressive features of the ocean basins. These features, called **midoceanic ridges**, tower over 3500 meters above the sea floor. In contrast to the ridges, the ocean floor is cleaved by long narrow earthquake prone **deep sea trenches**. The Marianas trench in the western Pacific descends to the awesome depth of 11, 034 meters below sea level.

The world-encircling mid-oceanic ridges, the deep sea trenches, and even our great mountain ranges are neither haphazardly formed nor randomly located. These features are manifestations of a dynamic unifying process called **plate tectonics**. Plate tectonics is a concept that explains the formation of new oceanic crustal material along the mid oceanic ridge, the migration of the newly produced ocean floor away from the ridge, and the ultimate descent of that material into the mantle along zones marked by deep sea trenches. It is an exciting concept that cannot be fully appreciated without knowing more about earth materials.

(From Contemporary Physical Geology: An Overview of the Third Planet, pp8—12)

New Words and Expressions

1. concentric [kɔn'sentrik] a. 同一中心的；同轴的
2. seismic ['saizmik] a. 地震的
3. crust [krʌst] n. 地壳
4. Mohorovicic [mouhou'rəvisik] n. (人名) 莫霍罗维奇
   ~ discontinuity 莫霍罗维奇不连续面
5. granite ['grænit] n. 花岗岩；花岗石
6. Hawaiian [hu:'waiiən] a. 夏威夷的
   ~ Islands 夏威夷群岛

7. analogy [ə'nælədʒi] n. 比拟；类推
8. fleshy ['fleʃi] a. 多肉的；肥胖的
9. secrete [si:krit] vt. 藏匿
10. clam [klæm] n. 蛤
11. mantle [mæntl] n. 地幔
12. geophysicist [dʒi (:) ou'fizisist] n. 地球物理学家
13. plastically [p'læstikəli] ad. 可塑地；塑性地
14. asthenosphere [ə'θenəsfiə] n. 软流圈
15. lithosphere ['liθousfiə] n. 岩石圈
16. conspicuous [kən'spikjuəs] a. 明显的；显著的
17. orogenic [ɔ:rə'dʒenik] a. 造山的
~ belts 造山带
18. orogeny [ɔ'rɔdʒini] n. 造山运动，造山作用
19. lofty ['lɔfti] a. 高耸的，极高的
20. continental [kɔnti'nentl] a. 大陆的
~ shelves 大陆架；陆棚
~ slopes 陆坡
~ rises 陆隆
21. gravel [grævəl] n. 砾；砾石
22. oyster ['ɔistə] n. 牡蛎；蚝
23. abyssal [ə'bisəl] a. 深渊的；深不可测的
~ plain 深海平原
24. cleave [kli:v] vt. 劈，劈开
25. prone [proun] a. 易于…的；有…倾向的
26. Mariana [mæəri'ænə] n. 马里亚纳
~ trench 马里亚纳海沟
27. awesome ['ɔ:səm] a. 可畏的
28. haphazardly [hæp'hæzədli] ad. 任意地
29. manifestation [mænifes'teiʃən] n. 形式；现象；表明；表现
30. unify [ju:nifai] vt. 统一；一致；使成一体
31. plate [pleit] n. 板，块
~ tectonics 板块构造

Lesson Two

Text

Common Minerals

QUARTZ

The mineral quartz is one of the most familiar and important of all the silicate minerals. It is common in many different families of rocks. As mentioned earlier, quartz represents the ultimate in cross-linkage of silica tetrahedra; it therefore will not break along smooth planes. In quartz, the tetrahedra are joined only at the corners and in a relatively open arrangement. It is thus not a dense mineral, but it is quite hard because of the strong bonding in its framework structure. When quartz crystals are permitted to grow in an open cavity, they may develop the hexagonal prisms topped by pyramids that are prized by crystal collectors. More frequently, the crystal faces cannot be discerned because the orderly addition of atoms had been interrupted by contact with other growing crystals.

Such minerals as chert, flint, jasper, and agate are varieties of a form of quartz called chalcedony. Chalcedony is composed of extremely small fibrous crystals of quartz. The crystals are so tiny that their study often requires the use of an electron microscope. Spaces between the small crystals are usually occupied by water molecules. Among the varieties of chalcedony, chert is exceptionally abundant in many sedimentary rock units. It is a dense, hard, usually white mineral or rock. Flint is the popular name for the dark gray or black variety of chalcedony much used by stone-age humans for making tools. Jasper is recognized by its opaque appearance and red or yellow color derived from ironoxide impurities. The term agate is used for chalcedony that exhibits bands of differing color or texture. There are many other varieties of quartz minerals than those briefly mentioned here.

THE FELDSPARS

Feldspars are the most abundant constituents of rocks, composing about 60 per cent of the total weight of the earth's crust. There are two major families of feldspars: the orthoclase or potassium feldspar group which are the potassium aluminosilicates, and the plagioclase group, which are the aluminosilicates of sodium and calcium. Members of the plagioclase group exhibit a wide range in composition -from a calcium-rich end member called anorthite ($CaAl_2Si_2O_8$) to a sodium-rich end member called albite ($NaAlSi_3O_8$). Between these two extremes, plagioclase minerals containing both sodium and calcium occur. The substitution of sodium for calcium, however, is not random but rather is governed by the temper-

...ture and composition of the parent material. Thus, by examining the feldspar content of ... once molten rock it is possible to infer the physical and chemical conditions under which it originated. Feldspars are nearly as hard as quartz and range in color from white or pink to bluish-gray. Silica tetrahedra in the feldspars are joined in a strong three-dimensional lattice that is characterized by planes of weaker bonding in two directions at (or nearly at) right angles to each other. Because of this, the feldspars have good cleavage (break along smooth planes) in two directions. The resulting rectangular cleavage surfaces and a hardness of 6 are properties useful in the identification of feldspars.

The plagioclase feldspars provide an example of the manner in which ions can be interchanged in a mineral group. A chemical analysis of specimens of plagioclase taken from several different rocks would very probably reveal that the proportions of calcium, sodium, aluminum, and silicon (the principal cations in plagioclase) would differ among the specimens. This variability occurs because some ions resemble each other in size and electrical properties, and are thus interchangeable in a given crystal. Calcium and sodium ions are large and nearly identical in size. Both aluminum and silicon are small ions and not greatly different in size. Thus, calcium ions might substitute for sodium ions freely if size alone were the only requirement. However, the electrical neutrality of the crystal must also be maintained. The electrical charge of the calcium ion is $+2$, whereas that of the sodium ion is $+1$. To counteract the surplus positive charge, an aluminum ion ($+3$) may substitute for a silicon ion ($+4$) to maintain electrical neutrality. Thus, $Ca^{2+}+Al^{3+}$ can interchange with Na^{+} and Si^{4+}. This process of interchange is called solid solution.

THE MICA GROUP

As noted earlier, mica is a silicate mineral having sheet structure, and is easily recognized by its perfect and conspicuous cleavage in one directional plane. The two chief varieties are the colorless or palecolored muscovite mica, which is a hydrous potassium aluminum silicate ($KAl_2(AlSi_3O_{10})(OH)_2$) and the dark colored biotite mica, which also contains iron and magnesium ($K(Mg,Fe)AlSi_3O_{10}(OH)_2$). In muscovite mica, two sheets of tetrahedra are strongly held together along their inner surfaces by positively charged ions of aluminum. These sandwich like paired sheets are in turn weakly joined to others by positively charged ions of potassium. When muscovite is cleaved into paper-thin layers, the separation occurs primarily along the weaker plane where the potassium ions are located. In biotite, magnesium and iron ions hold the inner surfaces of the sheets together, but once again potassium ions serve to weakly join each basic set of paired sheets to its neighbor.

Identification of large specimens of mica is rarely a problem because of its planar perfect cleavage and the way cleavage flakes snap back into place when they are bent and suddenly released. The micas are common constituents of igneous and metamorphic rocks, where they can be recognized by their shiny surfaces and the ease with which they can be plucked loose with a pin or pen knife. Before the manufacture of glass, one of the chief uses

/plasma 血浆 /plummet: 坠线 铅锤 plump' adj 丰满 v/t plump out (up) 鼓起

/plummet: 坠线 铅锤 plump² v/i 1. 突然扑次坠地 2. plump for 投票赞成

of muscovite mica was as window panes. This clear mica was quarried in Muscovy (Russia) and thus came to be known as "Muscovy glass," and eventually to muscovite. Today, mica is used in the manufacture of electrical insulators, and as a filler in plaster, roofing products and rubber.

filter: 滤

HORNBLENDE

Hornblende is a vitreous black or very dark green mineral. It is the most common member of a larger family of minerals called amphiboles, which have generally similar properties. As can be seen from its chemical formula, $NaCa_2(Mg,Fe,Al)_5(Si,Al)_8O_{22}(OH)_2$, hornblende contains a relatively large number of elements. Because of the presence of iron and magnesium, hornblende (along with biotite, augite, and olivine) is designated a ferromagnesian mineral. Crystals of hornblende tend to be long and narrow. Two good cleavages are developed parallel to the long axis and intersect each other at angles of 56° and 124°. This cleavage is a reflection of the location of planes of weaker bonds that exist between the double-chain units of silica tetrahedra in the atomic lattice.

AUGITE

Just as hornblende is only one member of a family of minerals called amphiboles, augite is an important member of the pyroxene family, in which many other mineral species occur. Its chemical formula, $Ca(Mg,Fe,Al)(SiAl)_2O_6$, indicates that it too is a ferromagnesian mineral and thus dark colored. An augite crystal is typically rather stumpy in shape. Two good cleavages developed along two planes that are nearly at right angles (87° and 93°). Thus, the cross section of a crystal appears nearly square, (rather than rhombic as in hornblende). Unlike hornblende, which has a double-chain silicate structure, augite is constructed of single chains, and this accounts for its having differently shaped cleavage fragments.

OLIVINE

Olivine, another ferromagnesian mineral, has been mentioned earlier as having isolated silicon-oxygen tetrahedra bonded together by iron and/or magnesium ions. Its formula, $(Fe,Mg)_2SiO_4$, indicates that it is a solid solution mineral, containing variable proportions of iron and magnesium. The substitution of these ions for each other is facilitated by their having similar ionic radii and two electrons in their outer electron shell. The ions in olivine are so strongly held by ionic bonding, that the mineral has a hardness of 6.5 to 7 on Mohs'scale. As you might guess from its name, this glassy-looking mineral often has a green color. Frequently, it occurs as masses of small sugary grains, or as tiny vitreous crystals in black lavas. It is also an important constituent of stony meteorites. If large unbroken crystals of magnesium-rich olivine are found, they may be cut, and polished into attractive gemstones called peridot.

(*From Contemporary Physical Geology*, pp 36—40)

/plagiarize v. 抄袭. /placid: adj 平静的

11

New Words and Expressions

1. silicate ['silikit] n. 硅酸盐
2. cross-linkage ['krɔs-'liŋkidʒ] n. 交链，交联
3. silica ['silikə] n. 叶石，二氧化硅
4. tetrahedra [ˌtetrə'hedrə] n. [复] 四面体
5. chert [tʃəːt] n. 燧石，黑硅石
6. flint [flint] n. 燧石，打火石；(打火机用的)电石
7. jasper ['dʒæspə] n. 碧玉，墨绿色
8. agate ['ægət] n. 玛瑙
9. chalcedony [kæl'sedəni] n. 玉髓
10. sedimentary [sedi'mentəri] a. 沉积的，由沉积物形成的
11. feldspar ['feldspɑː] n. 长石
12. orthoclase ['ɔːθəukleis] n. 正长石
13. potassium [pə'tæsjəm] n. 钾
14. aluminosilicate [əˌluːminəu'silikit] n. 铝硅酸盐
15. plagioclase ['pleidʒiəukleis] n. 斜长石
16. anorthite [ə'nɔːθait] n. 钙长石
17. albite ['ælbait] n. 钠长石
18. cleavage ['kliːvidʒ] n. 解理，劈理，劈开
19. cation ['kætaiən] n. 阳离子，正离子
20. mica ['maikə] n. 云母
21. muscovite ['mʌskəvait] n. 白云母
22. biotite ['baiətait] n. 黑云母
23. flake [fleik] n. 薄片
24. snap [snæp] v. 突然折断
    ～ back 恢复
25. igneous ['igniəs] a. 火成的
26. metamorphic [ˌmetə'mɔːfik] a. 变质的，变性的
27. pluck [plʌk] v. 拔，弹
28. pane [pein] n. 窗格玻璃
29. quarry ['kwɔri] n. 采石场
30. vitreous ['vitriəs] a. 玻璃状的
31. hornblende ['hɔːn'blend] n. 角闪石
32. amphibole ['æmfibəul] n. 闪石
33. augite ['ɔːdʒait] n. (普通)辉石
34. olivine [ˌɔli'viːn] n. 橄榄石
35. ferromagnesian [ferəumæg'niːʃən] a. 含铁镁的
36. pyroxene [pai'rɔksiːn] n. 辉石
37. stumpy ['stʌmpi] a. 短柱状的
38. rhombic ['rɔmbik] a. 菱形的
39. Mohs' scale 莫氏硬度
40. lava ['lɑːvə] n. 火山岩，熔岩
41. meteorite ['miːtjərait] n. 陨石
42. unblemished [ʌn'blemiʃt] a. 无疵的，清白无瑕的
43. gemstone ['dʒemsːəun] n. 宝石
44. peridot ['peridɔt] n. 贵橄榄石

Notes to the Text

1. When quartz crystals are permitted to grow in an open cavity, they may develop the hexagonal prisms topped by pyramids that are prized by crystal collectors. 当石英晶体在开阔的洞穴中生长时，它们可以发育成顶端为锥体的六方柱，这类晶体深受收藏家们的喜爱

   句中 topped by…为分词短语，作 prisms 的定语，that…collectors 为定语从句，修饰 prisms。

2. Identification of large specimens of mica is rarely a problem because of its planar perfect cleavage and the way cleavage flakes snap back into place when they are bent and suddenly released. 由于云母具有极完全解理，而且当把云母薄片弯曲并迅速放开时，它们能恢复到原来的位置，所以鉴定大的云母标本几乎不成什么问题。

   句中 snap back 的意思是恢复；cleavage flakes…released 为定语从句，修饰 way，注意在 way 后跟一定语从句时，不需要关系代词或副词，如：

That was the way she looked after us. 她就是这样照顾我们的。

Word Building

Root (I)

1. 词根与单词

如上节所述，词根和前缀、后缀一样是构成单词的词素，是一个单词的核心，表示一个单词的基本意义。通常，根据词根的意义就可以理解单词的意义。如：

词根		单词
lith 石	———	lithic 石的，结石的
petr 石	———	petrify 石化
ign 火	———	igneous 火成的
morph 形	———	geomorphic 地貌的
rupt 破	———	rupture 破裂

上述例子表明，词根的意义代表了单词的中心意义，在单词中占主导地位。词根的意义结合前后缀的意义，就构成了单词的意义。这样，只要记住词根的意义，并能从单词中辨认出词根，就能理解并记住这个单词，而且记得牢，不易忘记。

2. 词根与一组词汇

一个词根不仅是一个单词的核心，同时也是一组单词的共同核心，是一组单词中可以辨认出来的共同部分。一个词根能派生出许多单词。例如：

(1) **lith-** 石

lithic [lith 石，-ic 形容词后缀，…的] 石的，结石的
lithology [lith 石，-o 连接字母，logy…学] 岩性学
lithological [见上，-ical 形容词后缀，…的] 岩性的
lthotype [lith 石，-o，type 类型] 岩型
microlithotype [micro 微，见上] 显微岩型
lithosphere [lith 石，-o-，sphere 球，圈] 岩石圈
lithofacies [lith 岩，facies 相] 岩相
lithification [lith 石，-i-，-fication 名词后缀，…化] 石化作用

(2) **petr-** 石

petrology [petr 石，-o-，logy…学] 岩石学
petrological [见上，-ical 形容词后缀，…的] 岩石学的
petrologist [见上，-ist 名词后缀，…的人] 岩石学家
petrify [petr 石，i-，-fy 动词后缀，…化] 石化
petrification [petr 石，-i-，fication 名词后缀，…化] 石化作用
petrous [petr 石，-ous 形容词后缀，…的] 岩石的
petrochemistry [petr 石，o，chemistry 化学] 岩石化学
petrochemical [petr 石，o，chemical 化学的] 岩石化学的
petrogenesis [petr，石，o-，genesis 成因] 岩石成因

petrography [petr 石，o，graph 写，记录，-y 名词后缀] 岩类学

(3) **morph** 形

metamorphism [meta 变化，morph 形，ism 名词后缀，表示现象、行为] 变质作用

metamorphic [见上，-ic 形容词后缀，…的] 变质的

geomorphology [geo 地，morph 形，o-，logy…学] 地貌学

geomorphic [geo 地，morph 形，ic 形容词后缀，…的] 地貌的

pseudomorph [pseudo 假，morph 形] 假象

pseudomorphic [见上，-ic 形容词后缀，…的] 假象的

amorphous [a 无，morph 形，-ous 形容词后缀，…的] 无定形的，非晶态的

isomorphic [iso 同，morph 形，ic 形容词后缀，…的] 类质同象的

isomorphism [见上，ism 名词后缀，表示现象] 类质同象

从上述举例中可以看出，认识一个词根，就易于认识一组单词，每个单词的意义都是以这个词根的意义为基础。

Exercises

1. Questions for review:
   1) What is meant by solid solution?
   2) Name four common rock forming silicate minerals rich in iron and magnesium.
   3) In terms of atomic structure, explain why the mineral quartz does not break into fragments with smooth surfaces?
   4) Name the varieties of chalcedony.
   5) What is the difference between amphibole and pyroxene?
2. Fill in each blank with the proper words given below:
   orthoclase, quartz, augite, plagioclase, agate, amphiboles
   1) The term _____ is used for chalcedony that exhibits bands of differing color or texture.
   2) Hornblende is the most common member of a larger family of minerals called _____.
   3) _____ is a mineral having a perfect framework structure.
   4) _____ is an important member of the pyroxene family.
   5) The two major families of feldspars are _____ and _____.
3. Select the best term to complete the following statements:
   1) Mica is a silicate mineral with _____ structure.
      (a) single tetrahedra (b) single or double chain
      (c) sheet (d) framework
   2) In the mineral olivine, the silicate tetrahedra are linked together by _____.
      (a) partly covalent bonds to shared oxygen atoms

(b) predominantly ionic bonds to the cations Mg, Fe

(c) shared oxygen atoms and cation bonds

(d) Van der Waal's bonds only

3) The structure of augite consists of ___ .

(a) isolated silica tetrahedra

(b) linked pairs of silica tetrahedra

(c) single chains of silica tetrahedra

(d) double chains of silica tetrahedra

4) The structure of hornblende consists of ___.

(a) isolated silica tetrahedra

(b) linked pairs of silica tetrahedra

(c) single chains of silica tetrahedra

(d) double chains of silica tetrahedra

4. Complete the following sentences:

1) The plagioclase group exhibits a wide range in composition from a calcium-rich end member called ___ to a sodium-rich end member called _____.

2) The two chief varieties of the mica group are the colorless _____ and the dark-colored ___.

3) If large unblemished crystals of magnesium-rich _____ are found, they can be cut and polished into gemstones called peridot.

4) ___ is composed of extremely small fibrous crystals of quartz.

5) Hornblende has a ___ ___ silicate structure.

5. Translate the following into Chinese:

Some occurrences of silicate minerals introduced in this chapter are so attractive, durable, and rare that they are highly valued as gems. Their beauty is dependent upon color, luster, and brilliance-properties which are enhanced when the "rough stones" are cut, faceted, or shaped and polished. Gems are sold by weight, and the basic unit of weight is called a gem carat. One gem carat is equal to 1/5 of a gram. (The gem carat is not to be confused with the gold carat, which indicates the proportion of gold in an alloy, and is not a unit of weight.)

Such familiar minerals as quartz, corundum, feldspar, olivine, and garnet occur sporadically as materials of gem quality. Gems in the quartz family are particularly well known, and include the purple variety known as amethyst, yellow quartz or citrine, rose quartz, opal, the banded microcrystalline quartz called agate, and the mysterious tiger's-eye quartz which results from the replacement of asbestos by microcrystalline quartz. Jasper is opaque to semiopaque microcrystalline quartz that contains an abundance of iron oxide.

The two most famous gems in the corundum family are blue sapphire and red ruby. The color differences in these corundum minerals result from small traces of metal

oxides. These impurities may also produce exquisite hues of green, purple, and gold in sapphires. Feldspar gems include the attractive white opalescent moonstone, and the green orthoclase called amazonite. Peridot is the gem variety of olivine. In the garnet family, almandite is prized for its clear wine-red color. There are, however, many other beautifully colored garnets, including pink, orange, and green varieties. Topaz, known to us as the third hardest mineral in Mohs'scale, may occur as a lovely yellow gem, although stones colored pale blue and light green are also prized.

6. Translate the following sentences into English:

1) 大约地壳重量的 75%是由氧和硅这两种元素组成的。

2) 硅酸盐晶体中最基本的单位称之为硅氧四面体。

3) 矿物的硬度主要取决于矿物空间格子中原子或离子之间化学键的强度。

4) 矿物沿着一定的方向破裂成光滑面的性质称为解理。

5) 虽然已经发现了 2000 多种矿物并进行了科学的描述，但是它们当中的大多数在地壳中占的比例很少而且很难遇到。

Reading Material

Minerals

GARNET

Garnet is the name used for a group of mineral species closely related in composition, crystal form, and physical properties. In general composition, these minerals are silicates of aluminum with iron, calcium, or magnesium. The iron rich variety, almandite $Fe_3Al_2(SiO_4)_3$, is widely used in jewelry because of its rich dark red color. However, depending on their composition, garnets are found in all colors except blue. For example, if calcium fills the place of iron in the lattice, the garnet is called grossularite, and may have a pale green color, although other hues may also develop. Garnets can usually be identified by their well formed equidimensional crystals and their resinous to vitreous luster. Crystals will not cleave, but rather break with a conchoidal fracture. Because of the sharp edges produced on fracturing and its hardness (7 to 7.5 on Mohs'scale), garnet is widely mined and sold as an abrasive material.

CHLORITE

The chlorites are a group of greenish minerals having a platy form similar to that of micas. In composition, the minerals of the chlorite group are hydrous aluminum silicates of iron and magnesium. Chlorite can usually be identified by its perfect cleavage in one direction, greenish color and streak, and relative softness. It is a common constituent of metamorphic rocks and also occurs as an alteration product of ferromagnesian minerals.

CLAY MINERALS

The clay minerals are silicates of hydrogen and aluminum with additions of magnesium, iron, and potassium. At one time, clays were assumed to be amorphous mixtures of metal oxides and hydroxides. Through the use of X-ray equipment, however, it was demonstrated that clays are composed of crystalline units which, like mica, have sheet structure. The individual flakes are extremely small and require the magnification provided by the electron microscope for adequate examination Sheets of tetrahedra in clays are weakly bonded, and the potassium, sodium, and magnesium ions may enter and leave exchangeable locations within the lattice structure. Clays are formed through the decomposition of other aluminum silicate minerals, especially the feldspars. Clay minerals are characteristically very soft, have low density, occur in earthy masses, and become rather plastic when wet. These characteristics permit one to recognize clay, but in order to identify the individual species of clay minerals it is necessary to use X-ray diffraction techniques.

CARBONATES

Calcite and dolomite are the two most important members of the carbonate mineral group. Calcite ($CaCO_3$), which is the main constituent of limestone and marble, forms in many ways. It is secreted as skeletal material by certain invertebrate animals, precipitated directly from sea water, or formed as dripstone in caverns. Calcite is easily recognized by its rhombohedron-shaped cleaved fragments and by the fact that an application of hydrochloric acid on its surface will cause effervescence. Clear cleavage rhombs of calcite exhibit a property called double refraction. For example, if a transparent piece of calcite is held over a dot that has been placed on white paper, two dots will appear when the calcite is held in certain positions. As the mineral is slowly rotated one dot will appear to rotate around the other. The explanation for this bit of "magic" is that the light entering the specimen is bent or refracted and divided into two rays, one of which is bent more than the other. The image from the more refracted ray appears to move around the image of the less refracted ray as the piece of calcite is rotated. Although double refraction is so extreme in calcite that it can easily be observed, it is not a phenomenon unique to calcite. All minerals exhibit double refraction, except those in the isometric crystal system. In most of these other minerals, however, optical instruments are required to measure the phenomenon.

Dolomite $CaMg(CO_3)_2$ is a carbonate of calcium and magnesium that occurs as extensive layers of a rock called dolostone. In the field, geologists often distinguish dolomite by the fact that it will not effervesce in dilute hydrochloric acid unless it is powdered. Many ancient dolostones are thought to have been formed by recrystallization of still older limestones. Because calcium and magnesium ions are nearly the same size, it is possible for the magnesium to replace calcium in the atomic structure.

EVAPORITES

Evaporites are minerals that have precipitated from bodies of water subjected to intense evaporation. They include common rock salt, or halite (NaCl), and gypsum. Halite is easily identified from its salty taste and perfect cubic cleavage. Gypsum is a soft (2 on Mohs' scale) hydrous calcium sulfate ($CaSO_4 \cdot 2H_2O$). The variety of gypsum called satinspar has a fine fibrous structure, whereas selenite will split into thin plates. The finelycrystalline massive variety known as alabaster is widely used in carvings and sculpture because of its uniform texture and softness.

IRON OXIDE MINERALS

The chief iron oxide minerals that occur abundantly at or near the earth's surface are hematite (Fe_2O_3) and the hydrous oxide of iron called limonite ($Fe_2O_3 \cdot 2H_2O$). Magnetite (Fe_3O_4) is of less importance because it is less abundant.

Bedded deposits of hematite supply the bulk of the world's iron ore. The mineral varies in color from steel gray to brownish red, but always exhibits a distinctive reddish streak. In contrast, limonite has a yellow-brown streak and is generally yellow or brown in color.

One is not likely to confuse magnetite with the other common iron oxides. Its magnetic properties, high specific gravity, and black streak are distinctive. Magnetite occurs in concentrations that can be mined as iron ore, but is also common as disseminated crystals in rocks rich in ferromagnesian minerals.

MINERALOGICAL CLUES TO GEOLOGICAL EVENTS

Minerals are studied by geologists not as mere constituents of the crust but as clues to the history of the rocks in which they occur. Some minerals develop exclusively in ocean water and provide the geologist with evidence that a particular sediment was deposited in the sea rather than in a freshwater lake. A thick bed of halite indicates aridity and evaporation so extreme that the brine had become ten times saltier than ordinary sea water. The magnetic properties of magnetite can, in certain situations, provide clues to the position of continents relative to the earth's magnetic poles. Certain minerals form within a narrow range of conditions and can therefore be used to diagnose the pressures and temperatures involved in the formation of crustal rocks and mountains. Diamonds, for example, form only at high temperatures and extremely high pressures. Like diamond, graphite is a crystalline variety of carbon. However, it forms at lower temperatures and pressures. Other minerals contain radioactive isotopes that permit us to know the age of the parent rocks. By their size, crystals of feldspar give the geologist information about the rate at which ancient molten mass congealed. Even ordinary grains of quartz may hold clues as to what has happened to them since they were eroded from some ancient granitic terrain. The ancient buried mineral prod

rocks of weathering may provide information about past climatic conditions in a region.

(*From Contemporary Physical Geology*, pp 40~ 43)

New Words and Expressions

1. garnet ['gɑ:nit] n. 石榴石
2. almandite ['ælməndait] n. 铁铝榴石
3. grossularite ['grɔsjuləraɪt] n. 钙铝榴石
4. equidimensional ['i:kwidi'menʃənəl] a. 等大的，等尺度的
5. resinous ['rezinəs] a. 树脂的，象树脂的
6. luster ['lʌstə] n. 光泽，光彩
7. conchoidal [kɔŋ'kɔidl] a. 贝壳状的
8. abrasive [ə'breisiv] a. 研磨的 n. 磨料
9. chlorite ['klɔ:rait] n. 绿泥石
10. streak [stri:k] n. 条痕
11. amorphous [ə'mɔ:fəs] a. 无定形的，非晶质的
12. hydroxide [hai'drɔksaid] n. 氢氧化物
13. crystalline ['kristəlain] a. 结晶状的
14. diffraction [di'frækʃən] n. 衍射
15. calcite ['kælsait] n. 方解石
16. dolomite ['dɔləmait] n. 白云石
17. marble ['mɑ:bl] n. 大理石
18. invertebrate [in'vɔ:tibrit] n. 无脊椎动物
19. precipitate [pri'sipiteit] v. 沉淀
20. dripstone ['drip'stəun] n. 钟乳石，石笋
21. cavern ['kævən] n. 洞穴，山洞
22. rhombohedron shaped [rɔmbə'hedrənfeipt] a. 具有菱形六面体形状的
23. hydrochloric ['haidrə'klɔrik] a. 盐酸的
- acid 盐酸
24. effervescence [efə'vesns] n. 起泡，冒泡
25. effervesce [efə'ves] v. 冒气泡，起泡沫
26. rhomb [rɔm] n. 菱形
27. double refraction 双折射
28. refract [ri'frækt] v. 使折射
29. isometric [aisou'metrik] a. 等轴的，等轴晶的，立方的
30. dolostone [dɔlə'stəun] n. 白云岩
31. dilute [dai'lju:t] v. 稀释，冲淡
32. recrystallization ['ri:kristəlai'zeiʃən] n. 再结晶，重结晶
33. evaporite [i'væpəraɪt] n. 蒸发岩
34. halite ['hælait] n. 岩盐，石盐
35. gypsum ['dʒipsəm] n. 石膏
36. hydrous ['haidrəs] a. 含水的，水合的，水化的
37. sulfate ['sʌlfeit] n. 硫酸盐
38. satinspar ['sætin'spɑ:] n. 纤维石膏
39. fibrous ['faibrəs] a. 纤维状的
40. selenite ['selnait] n. 透明石膏，亚硒酸盐
41. alabaster ['æləbɑ:stə] n. 雪花石膏
42. hematite ['hemətait] n. 赤铁矿，红铁矿
43. limonite ['laimənait] n. 褐铁矿
44. magnetite ['mægnitait] n. 磁铁矿
45. disseminate [di'semineit] v. 散布
46. aridity [æ'riditi] n. 干旱
47. brine [brain] n. 盐水，咸水
48. isotope ['aisoutoup] n. 同位素
49. congeal [kən'dʒi:l] v. 凝结
50. erode [i'roud] v. 侵蚀，腐蚀
51. terrain ['terein] n. 岩体，地体

Graphite 石墨

Lesson Three

Text

Sedimentary Rocks

Once weathering products have been formed from pre-existing rocks, the next stage in the sequence of events leading to sedimentary rock is the removal and transport of those products. Many denudational agencies, including running water, and moving ice, and wind, assist in this removal. The wind is an effective agent in picking up and blowing away the smaller and lighter particles. Glacial ice can move very large pieces of rock and carry an immense load of coarse sediment. Streams are also exceptionally effective in carrying not only solid particles of sediment but invisible dissolved salts as well. Ultimately, sediment-laden streams flow into lakes or the sea and their load of sediment is deposited. It may form sandy beaches, silty flood-plains, and sometimes muddy boggy areas of estuaries and deltas.

The solid particles carried by wind or water will be deposited whenever there is insufficient energy to carry them further. For example, if the velocity of dust-laden wind abates, there will be insufficient energy to carry particles of a given size, and those particles will be dropped. Similarly if a stream's velocity is checked, as when entering a standing body of water, the stream also loses energy and is unable to continue to carry the material formerly carried at the higher velocity.

A reduction in a stream's velocity does not, of course, affect the dissolved materials as it does suspended solid particles. Material carried in solution is deposited by a process called precipitation, in which dissolved material is changed to a solid and separated from the liquid in which it was formerly dissolved. For example, calcium carbonate, the principal substance in the widespread sedimentary rock known as limestone, may be precipitated from water that contains calcium in solution as indicated below:

$$Ca^{\cdot\cdot} + 2HCO_3^- \rightleftharpoons CaCO_3\downarrow + \overset{H_2CO_3}{\overbrace{H_2O + CO_2}}$$

(dissolved calcium ions) (dissolved bicarbonate ions) (calcium carbonate) (water) (carbon dioxide)

The bicarbonate ions that participate in the above reaction can be derived from the ionization of carbonic acid. As indicated by the arrows, the reaction is reversible. If carbon dioxide is removed from sea water, the reaction will proceed toward the right, and calcium carbonate will be precipitated. If, however, carbon dioxide is added to sea water, then the

amount of carbonic acid in the water would build, and the reaction would proceed to the left. This would result in a chemical environment not conducive to calcium carbonate precipitation, and one in which existing calcium carbonate might begin to dissolve. As is evident here, the precipitation of calcium carbonate is a complex and delicate process in nature. It is influenced by organisms that utilize or liberate carbon dioxide, by processes that alter the acidity or alkalinity of the water, by the presence of organic compounds, and by ions of sulfur, phosphorus, and magnesium which may be present.

Many changes take place in sediment after it has been deposited. Mineral grains may be dissolved away, some may grow by additions of new mineral matter, and the shapes of particles may be distorted by compaction. The result of some of these changes is to convert sediment into sedimentary rock. The conversion process is called lithification. Cementation compaction, and crystallization are the principal means by which unconsolidated sediment is lithified.

Cementation involves the precipitation of minerals in the pore spaces between larger particles of sediment. The precipitated mineral, which most frequently is either calcium carbonate ($CaCO_3$) or silica (SiO_2), is called the cement. Cement is added to a sediment after deposition. It differs from a rock's matrix which consists of clastic particles (often clay) that are deposited at the same time as the larger grains and help to hold the grains together.

The reduction in pore spaces in a rock as a result of the pressure of overlying rocks or pressures of earth movements is termed compaction. During compaction, individual grains are pressed tightly against one another, causing the expulsion of water and rearrangement of particles. The result is often the conversion of loose sediment into hard, indurated rock. Compaction is greatest and most important as a lithification process in finer-grained sediments like clay and mud.

Lithification by crystallization may begin with an initial chemical precipitate in which the developing crystals grow together to form a crystalline solid. The process of crystallization, however, may also result in a change in the form of grains that have already been deposited. For example, quartz may be precipitated onto rounded quartz grains to form a strong interlocking mosaic of crystals. clay may be converted to a matted aggregate of tiny mica crystals, or calcium carbonate skeletal debris may be reorganized into hard, crystalline calcite. The migration of watery solutions through sediment favors crystallization, as does deep burial and consequent increases in temperature and pressure.

Sedimentary rocks are identified and named according to their composition and texture. In regard to composition, the three most abundant mineral components of sedimentary rocks are clay minerals, quartz, and calcite. Evaporite minerals and dolomite, although less abundant, nevertheless form an appreciable portion of many sedimentary sequences. Sedimentary rocks nearly always also contain variable amounts of limonite and hematite. A generalization one can make about the mineral composition of sedimentary rocks is that

most are mixtures of two or more components in which one mineral may predominate. Thus, sandstones composed mostly of quartz grains nearly always contain some clay or calcite, and limestones made mostly of calcite nearly always are contaminated with clay and quartz grains.

Texture refers to the size and shape of individual mineral grains and to their arrangement in the rock. A rock that has a clastic texture (from the Greek klastos, broken) is composed of particles of clay, silt, sand, and gravel, or fragments of parent rock or fossils that have been moved individually from their place of origin. In contrast to these clastic rocks, non-clastic rocks form by chemical or biochemical precipitation within a sedimentary basin. Most non-clastic rocks are crystalline, and include certain limestones and evaporites.

Sedimentary rocks made of the remains of plants and animals are categorized as biogenic. Coal, for example, can be considered a sedimentary rock derived from the accumulation of plant remains. Limestones composed predominantly of the skeletal remains of invertebrate animals would also be considered biogenic.

Although it is convenient to separate sedimentary rocks into such discrete categories as clastic, crystalline, and biogenic, it becomes quickly apparent to anyone who enjoys collecting rocks that there are many gradational types, and some rocks can be placed in either of two categories with equal validity. For example, many limestones are distinctly crystalline, but a limestone composed of fragments of a pre-existing limestone could be termed a clastic limestone.

(*From Contemporary Physical Geology*, *pp*101—104)

New Words and Expressions

1. denudational [ˌdiːnjuːˈdeiʃənəl] a. 剥蚀的
2. glacial [ˈgleiʃjəl] a. 冰的；冰川的
3. sediment [ˈsedimənt] n. 沉积物
4. silty [ˈsilti] a. 粉砂质的；淤泥的
5. silt [silt] n. 粉砂
6. boggy [ˈbɔgi] a. 沼泽的
7. estuary [ˈestjuəri] n. 河口湾
8. delta [ˈdeltə] n. 三角洲
9. abate [əˈbeit] v. 减少
10. precipitation [prisipiˈteiʃən] n. 沉淀
11. bicarbonate [baiˈkɑːbənit] n. 碳酸氢盐
12. ionization [ˌaiənaiˈzeiʃən] n. 电离
13. conducive [kənˈdjuːsiv] a. 有助于…的；有益于…的
14. acidity [əˈsiditi] n. 酸度；酸性
15. alkalinity [ˌælkəˈliniti] n. 碱度；碱性
16. phosphorous [ˈfɔsfərəs] a. 含磷的
17. lithification [liθifiˈkeiʃən] n. 成岩作用
18. cementation [ˌsiːmenˈteiʃən] n. 胶结作用
19. unconsolidated [ˌʌnkənˈsɔlideitid] a. 未固结的
20. matrix [ˈmeitriks] n. 基质；填隙物
21. expulsion [iksˈpʌlʃən] n. 驱逐；开除
22. rearrangement [ˌriːəˈreindʒmənt] n. 重新排列
23. indurate [ˈindjuəreit] v. 使硬化；变硬
24. interlock [ˌintəːˈlɔk] v., n. 联锁；连结
25. mosaic [məˈzeiik] n. 镶嵌
26. debris [ˈdebriː] n. 岩屑，碎石
27. contaminate [kənˈtæmineit] v. 弄脏；污染
28. clastic [ˈklæstik] a. 碎屑状的
29. fossil [ˈfɔsl] n. 化石
30. biochemical [ˈbaiouˈkemikəl] a. 生物化学的
31. biogenic [ˈbaiouˈdʒenik] a. 生物所产生的，生命活动所必需的
32. skeletal [ˈskelitl] a. 骨架的；骸骨的

Notes to the Text

1. Similarly, if a stream's velocity is checked… 同样，如果河流的速度减弱…

句中 checked 为过去分词，在此处的意义不是“检查”而是“受到阻止”的意思，此处可以转译为减弱。举例如下：

This movement cannot be checked by any force on earth.

世界上的任何力量都阻挡不了这种运动。

2. It is influenced by organisms that utilize or liberate carbon dioxide, by processes that …, by …, and by … present. 它受到吸收或释放二氧化碳生物的影响，还受…过程的影响，…

句中一共出现了四个介词 by 组成的介词短语，它们都是修饰动词 influenced 的。另外，句中的第一个 that 引导的从句为定语从句，修饰 organisms，第二个 that 引导的定语从句修饰 processes。

3. The migration of watery solutions through sediment favors crystallization, as does deep burial and consequent increases in temperature and pressure. 水溶液在沉积物中的运移有助于结晶作用，深埋藏作用以及由此引起的温度和压力的升高也同样有利于结晶作用。

句中 as 引导状语从句，表示比较，该从句为倒装结构，例如：

John is very healthy, as are his sisters. 约翰的身体很健康，他的姊妹也一样。

Word Building

Root (Ⅱ)

1. 词根意义的引申

一般地说，知道了词根的意义，再结合词缀的意义就可得出单词的完整意义。然而，实际情况并不完全如此，有相当一部分单词的词义并不完全等于词根和词缀的意义。例如：

词根	单词
(1) rupt 破裂	erupt 喷发
(2) grad 走	degrade 退化，变坏
(3) cur 跑	occurrence 产状
(4) pos 放置	exposure 露头
(5) pos 放置	deposit 沉积
(6) text 编织	texture 结构
(7) ori 升起	orientation 方位
(8) sect 切割	section 剖面

从上述举例可以看出：词根的意义与单词的意义似乎互不关联。但是，实际上它们之间存在着内在的联系，这种现象的产生多数是由于词义在形成过程中比较曲折。下面对这些词义逐一进行分析：

(1) erupt 向外，出，rupt 破裂；向外破裂→爆裂出来→喷发

(2) degrade [de-下，向下，grad 走；往下走→降级→] 退化，变坏

(3) occurrence [oc-表示 to 或 towards，cur 跑，-ence 名词后缀，跑来→来临→出现→] 产状

(4) exposure [ex-出，外，pos 放，摆，-ure 名词后缀；摆出来→暴露→] 露头

(5) deposit [de-下，pos 放；放下→] 沉积

(6) texture [text 编织，-ure 名词后缀，表示行为的结果；编织→组织→] 结构

(7) orientation [ori 升起→"太阳升起的地方"→东方 orient，-ation 名词后缀；指向东方→定向→] 方位

(8) section [sect 切，-ion 名词后缀，表示行为及行为的结果；切开→切开的部分→] 剖面

由上面的分析可以看出，一个单词的意义与其词根的意义虽然相距很远，但根据词根的意义，经过一些曲折的途径就可以找出这个单词的意义。一旦理解了该词词义的来源，就能比较容易地记住这个单词。

2. 词根构词的方式

词根和前缀、后缀一起可以构成大量的单词。其构词方式常见的有一个词根添加一个前缀或后缀，也可以是一个词根添加几个词缀。在一个单词中也可以出现多个词根。例如：

(1) 前缀 + 词根 + 后缀

de- + form + -ation →deformation

(否定，离开)(形)(名词后缀) (变形)

(2) 前缀 + 词根 + 词根

tri- + gon (o) + metry → trigonometry

(三) (角) (测量) (三角学)

(3) 前缀 + 前缀 + 词根 + 后缀 + 后缀

un + pre- + ced + ent + -ed → unprecedented

(无)(先，前) (行) (表事物)(…的) (无先例的)

Exercises

1. Questions for review:

1) What characteristics of sedimentary rocks are most useful in their classification and identification?

2) What are some of the changes that take place in a sediment after deposition and lead ultimately to lithification?

3) What is the distinction between clastic and non-clastic (chemical) sedimentary rocks?

4) How does matrix in a rock differ from cement?

5) Define sedimentary rocks based on the text.

2. Fill in the blanks with correct terms given below:

cementation, detas, compaction, clastic, weathering, texture, precipitation

1) Material carried in solution is deposited by a process called _____.

2) _____ refers to the size and shape of indvidual mineral grains and to their arrangement in the rock.

3) _____ refers to the precipitation of minerals in the pore spaces between larger particles of sediment.

4) _____ is the name given to the processes which break down rock at the earth's surface to form discrete particles.

5) _____ are accumulation of sediment at the end of a channel where it discharges into a standing body of water.

6) The reduction in pore spaces in a rock as a result of the pressure of overlying rocks is termed _____.

7) A rock composed of particles of clay, silt, sand, and gravel has a _____ texture.

3. Give the Chinese/English equivalents for the following:

1) denudational agencies	6) 杂基
2) glacial ice	7) 胶结物
3) sediment-laden streams	8) 沉积物的搬运
4) clastic limestone	9) 松散沉积物
5) parent rock	10) 褐铁矿

4. Choose the correct term to complete each sentence:

1) Lithification does not involve _____.

a. cementation b. crystallization c. weathering

2) _____ is classified as a biogenic rock.

a. coal b. sandstone c. silt

3) One of the most abundant mineral components of sedimentary rocks is _____.

a. carbon dioxide b. calcite c. hematite

4) The precipitation of calcium carbonate is not influenced by _____.

a. acidity b. organic compounds c. wind

5) Clay may be converted into a matted aggregate of tiny mica crystals by the process of _____.

a. precipitation b. weathering c. crystallization

5. Translate the following into Chinese:

From that time when the earth acquired its atmosphere and hydrosphere, the mechanical and chemical break down of the original igneous rocks began. The weathering of igneous and other rocks through chemical and mechanical action produces gravel, sand, silt, clay, lime-bearing materials, and salts. These products, after they are deposited in the sea or in continental environments, are bound together by rock lithification processes such as cementation, compaction, and crystallization to form sandstones, shales, limestones, and evaporites.

Sedimentary rocks represent the material record of environments that once existed on earth. Their composition and texture provide clues to the nature of the source

areas that provided the sediment, the kinds of transporting media, and the general environment of deposition. Fossils in sedimentary rocks are particularly instructive as environmental indicators. They tell us if strata are marine or nonmarine, if the water at the depositional site was deep or shallow, or if the climate was warm or cool. They also can be used to ascertain the geologic age of strata. Color in a sedimentary rock sometimes helps one to decide if it was deposited in nonmarine or terrestrial environments. From the size and shape of grains in clastic rocks, geologists can sometimes infer if the sediment was deposited in quiet water or turbulent currents, whether it had been sorted by wind or wave action, or whether it had experienced many or few cycles of erosion and deposition. Similar kinds of information can sometimes be elucidated by the study of such sedimentary features as graded-bedding, cross-bedding, and current ripple marks. Sandstones are particularly useful in investigations of ancient depositional environments. Quartz sandstones, graywackes, arkoses, and subgraywackes each accumulate in particular paleogeographic and tectonic situations. It is the geologist's task to discover the details of those situations by examining the rocks.

6. Translate the following sentences into English:

1) 总的来说，变质岩的特征取决于变质因素的种类和强度，以及母岩本身的性质。

2) 沉积岩大约只占地壳的8%，然而它们却覆盖着全部陆地的75%。

3) 喷发过程是宁静的还是爆发的，其主要决定因素是岩浆的温度、粘度（viscosity）以及岩浆中包含气体的数量。

4) 大多数变质岩可以根据其结构与岩浆岩、沉积岩区分开来。

5) 在沉积岩中可以找到化石。

Reading Material

Igneous Rocks

Texture and mineral composition are the most useful properties for inferring the origin of igneous rocks and are the basis for classification and identification. Although there are hundreds of names used for igneous rocks, most of these represent variations of the relatively few major groups. In a widely used simple scheme, there are eight groups of crystalline igneous rocks: granite, granodiorite, diorite, gabbro, peridotite, rhyolite, andesite, and basalt.

In order to identify rocks in each of these groups it is necessary to recognize texture and a few of the mineral constituents as they appear in the rock itself. To better identify the more common minerals, hold the rock in strong light and turn it back and forth so that you can see reflections from cleavage planes and crystal faces. Quartz can be recognized by its glassy appearance and mostly irregular reflecting surfaces. Feldspars show cleavage faces, may be white, gray, or pink, and often have rectangular outlines. Ferromagnesians are black or green. Among ferromagnesians, hornblende is more shiny and elongated than

pyroxene, and biotite may be distinguished by its smooth gleaming cleavage surfaces.

ROCKS OF THE GRANITIC CLAN

The light-colored igneous rocks are, as we have already noted, derived from high silica magmas. When such magmas crystallize, they yield a high proportion of feldspar and quartz. Granite is a familiar representative of this group and is recognized by its light color, phaneritic texture, and the presence of about 25 per cent quartz grains along with larger quantities of potassium feldspar (orthoclase) and sodium-plagioclase. Muscovite and biotite are present, as are small quantities of hornblende. Granite, of course, is well known to most of us because it has been used for centuries in the construction of buildings, statues, and monuments. It is not, however, the most abundant granitic rock. Granodiorite, a somewhat less siliceous granitic rock is more abundant. The Sierra Nevada Batholith is composed largely of granodiorite.

The more finely crystalline but compositional equivalent of granite is rhyolite. Actually, the basic aphanitic texture of rhyolite may range into the glassy condition. Many rhyolites tend to be porphyritic, with small phenocrysts of orthoclase, sodic plagioclase, quartz, and mica. Some appear to be welded tuffs. In color, rhyolites tend to be white, light gray, or tints of pink or orange.

ROCKS OF THE DIORITIC CLAN

Igneous rocks of the diorite clan include diorite itself and its aphanitic equivalent known as andesite. Diorite is a coarse- to fine-grained phaneritic rock containing less silica than granite or granodiorite, but more than gabbro. Thus, in the gradations of composition across the rock chart, it is an intermediate rock type. The most abundant minerals are plagioclases, and these are compositionally in the mid range and contain both calcium and sodium. Quartz and orthoclase are very rare or absent in diorites. Among the ferromagnesian constituents, hornblende occurs in amounts about equal to plagioclase, and biotite mica is a common accessory mineral. The color of diorite is controlled by its compositional makeup of nearly equal amounts of black ferromagnesians and grayish plagioclase. Thus, it tends to be rather drab gray or greenish gray in color.

The somber color of diorite prevails also in andesite, its aphanitic equivalent. Andesites, which were first identified in the summit volcanoes of the Andes Mountains of South America, are mostly found along the more mountainous continental borders and island arcs that surround the Pacific Ocean. In fact, geologists determine the true edge of the Pacific Basin by plotting a line, on the oceanic side of which rocks are principally basalt, and on the continental side andesite. Geologists refer to this demarcation as the andesite line.

A member of the plagioclase family known as andesine is the most abundant mineral constituent of andesite. It is a mineral that contains nearly equal proportions of calcium and

sodium. Dark minerals such as biotite, hornblende, and pyroxene are also prevalent in andesites. Andesites are intermediate between basalts and rhyolites in composition, and also intermediate in relative abundance on the earth's surface. Thus, they are more abundant than rhyolites and less abundant than basalts.

ROCKS OF THE GABBRO CLAN

In gabbro the chief mineral is labradorite plagioclase, which is darker and more calcium-rich than the plagioclase found in diorite. The typical ferromagnesian constituents are pyroxenes and olivine. Gabbros are typically coarsely crystalline plutonic rocks. One variety called anorthosite is composed mostly of intergrown calcium-rich plagioclase crystals. Anorthosite is characteristic of the lighter colored crustal areas of the moon. Varieties of gabbro are frequently polished and used as ornamental stone because of their rich dark hue and the iridescent play of colors reflected by the plagioclase crystals.

Basalt is now familiar to us as the rock name for the aphanitic equivalent of gabbro. We have previously noted its importance as the most abundant of extrusive igneous rocks. Basalts are generally darker than andesites. They are mostly very dark gray or black. In thin section, they are found to contain myriads of elongate lathlike crystals of calcic plagioclase interspersed with pyroxene and olivine. Basalts differ from andesites in that ferromagnesians like biotite or hornblende are sparse or absent.

THE ULTRAMAFIC CLAN

Ultramafic rocks are characterized by having a high density (3.3 g/cm^3), low percentage of silica (45 per cent), and a major mineral composition of pyroxenes and olivine. Peridotite, in fact, is an ultramafic rock composed of 70 to 95 per cent olivine, while pyroxenite is almost entirely an intergrowth of pyroxene crystals. The ultramafic rocks are not common near or on the surface of the earth. They are occasionally encountered in the lower parts of thick sills, laccoliths and lopoliths where dense ferromagnesian minerals accumulated by fractional crystallization and gravity settling. At several locations around the world, peridotites have pushed their way upward from great depths and penetrated near surface rocks. Geologists are keenly interested in these peridotites, for they may represent samples of the earth's mantle.

THE GLOBAL DISTRIBUTION OF GRANITIC AND BASALTIC ROCKS

One of the most interesting observations about the global occurrence of igneous rocks is that granitic plutons occur within or on the edges (or former edges) of continents, and that the crust beneath the ocean basins is practically devoid of granites and kindred intrusive rocks. This indicates that the crust of the continents and ocean basins originates by fundamentally different processes. The igneous rocks of the ocean basins are predominantly basalts that have apparently been generated by partial melting within the lower crust or

upper mantle. This is indicated by the high temperatures at which these basaltic melts are extruded and their relatively rich ferromagnesian composition. The process of building the oceanic crust is thought to be going on continuously as prodigious amounts of basalt pour out of fissures along the world-encircling network of mid-ocean ridges. These ridges are developed where tectonic plates separate and permit magma to well up and form new oceanic crust, which then moves away from the ridges at the rate of a few cm a year. Ultimately, rocks which were extruded along the ridges reach subduction zones where they, along with the cover of sediment they have accumulated, are plunged downward into the mantle and consumed. By this process, the basaltic ocean crust is being continuously renewed.

The plate tectonic model may also provide an explanation for the origin of large granitic batholiths located along some plate margins. Because of their abundant silica and aluminum and relative deficiency of iron and magnesium, it is unlikely these granitic bodies could have been derived directly from the upper mantle. They might, however, be formed from the melting of mixtures of ocean basalts and sediments. Weathering processes tend to remove iron and magnesium and concentrate silica and aluminumin sediments, and if the sedimentary materials can be melted, they may generate silica and aluminum-rich granitic rocks. A likely place for this to occur is along subduction zones where a lithospheric plate moves downward carrying with it not only basalts of the ocean floor but water saturated marine sediments as well. When these descending slabs reach the asthenosphere, partial melting occurs, and magmas of the kind that form granodiorites and andesites are produced.

Not all granitic rocks are formed by processes operating within subduction zones. Many times in the geologic past, sedimentary materials accumulated and were buried in deeply subsiding troughs called geosynclines. After these materials had accumulated, the geosynclines were compressed and the resulting heat and pressures severely metamorphosed and partially melted the deeper parts of the wedge of sediment to form the parent magmas of granites and granodiorites. Field evidence suggests that this process will occur readily at depths of about 35 km and temperatures of 600 C, provided there is ample water in the parent material.

In addition to large bodies of granitic rocks found in the interiors of continents, there are a fewer number of large gabbroic bodies. These rocks contain too much iron and magnesium and too little silica to have been generated by the melting of continental rocks and sediments. Like the basalt of the ocean basins, they appear to have been derived from melts that originated in the upper mantle or asthenosphere. In some localities, the iron and magnesium-rich, silica-poor melts (mafic melts) may have risen through fissures and rifts produced when a lithospheric plate bearing a continent broke apart. As the two plate segments moved away from each other, the gabbroic magma worked its way upward into the zone of divergence.

New Words and Expressions

1. granodiorite [ˌgrænəˈdaiəraitˌ] n. 花岗闪长岩
2. diorite [ˈdaiəraitˌ] n. 闪长岩
3. gabbro [ˈgæbrouˌ] n. 辉长岩
4. peridotite [ˌperiˈdoutaitˌ] n. 橄榄岩
5. rhyolite [ˈraiəlaitˌ] n. 流纹岩
6. andesite [ˈændizaitˌ] n. 安山岩
7. basalt [ˈbæsɔ:ltˌ] n. 玄武岩
8. rectangular [rekˈtæŋgjuləˌ] a. 矩形的；长方形的；成直角的
9. gleam [gli:m] n. 闪光；微光
10. clan [klæn] n. 宗派；族；类
11. phaneritic [ˌfænəˈritikˌ] a. 显晶质的
12. batholith [ˈbæθəliθ] n. 岩基
13. aphanitic [ˌæfəˈnitik] a. 隐晶质的；非显晶质的
14. porphyritic [ˌpɔ:fiˈritikˌ] a. 斑岩的；斑状的
15. phenocryst [ˈfi:nəkristˌ] n. 斑晶
16. sodic [ˈsəudikˌ] a. 含钠的
17. tuff [tʌf] n. 凝灰岩
18. tint [tint] n. 色彩，色泽
19. accessory mineral [ækˈsesəri ˈminərəl] 副矿物
20. drab [dræb] a. 黄褐色的
21. somber [ˈsɔmbəˌ] a. 暗淡的；浅黑的
22. demarcation [ˌdi:mɑ:ˈkeiʃən] n. 分界；界限
23. andesine [ˈændizi:nˌ] n. 中长石
24. labradorite [ˈlæbrədɔ:raitˌ] n. 拉长石
25. plutonic [plu:ˈtɔnik] a. 深成岩体的
26. anorthosite [æˈnɔ:θəsaitˌ] n. 斜长岩
27. iridescent [ˌiriˈdesnt] a. 晕彩的；虹彩的
28. extrusive [eksˈtru:siv] a. 喷出的
29. myriad [ˈmiriəd] a., n. 无数的；无数，极大数量
30. lathlike [ˈlɑ:θlaikˌ] a. 板晶的
31. intersperse [ˌintəˈspə:sˌ] v. 散布
32. sparse [spɑ:sˌ] a. 稀少的；稀疏的
33. ultramafic [ˈʌltrəˈmæfik] a. 超基性岩的
34. pyroxenite [paiˈrɔksənaitˌ] n. 辉岩
35. intergrowth [ˈintəgrouθˌ] n. 共生
36. sill [sil] n. 岩床，海底山脊
37. laccolith [ˈlækəliθˌ] n. 岩盖
38. lopolith [ˈləpəliθˌ] n. 岩盆
39. pluton [ˈplu:tənˌ] n. 深成岩体；深成火成岩
40. kindred [ˈkindrid] n., a. 宗族；类；同源的
41. extrude [eksˈtru:d] v. 使喷出
42. prodigious [prəˈdidʒəs] a. 巨大的；庞大的
43. fissure [ˈfiʃə] n. 裂缝；裂隙
44. subduction [ˌsəbˈdʌkʃənˌ] n. 俯冲
45. slab [slæb] n. 平板，厚板
46. geosyncline [dʒi:ouˈsinklainˌ] n. 地槽；地向斜
47. gabbroic [ˈgæbrɔikˌ] a. 辉长岩的
48. mafic [ˈmæfik] a. （火成岩的）镁铁质
49. rift [rift] n. 裂缝；穿隙；断裂；裂谷

Lesson Four

Text

The Study of Fossils —Paleontology

The term Fossil originally referred to any curious object obtained by digging in the earth-mineral specimens, crystals, old artifacts of humans, odd stones of any kind, and the remains of ancient plants and animals, but it is now used to mean the remains or traces of organisms preserved from the geologic past. Usually fossils are preserved in solid rock, but many specimens have been found in loose sand, in bogs, and in tar pools; some have even been found frozen in ice.

The number of fossils preserved in the earth is beyond calculation. Many common rock types, such as limestone and chalk, are composed almost entirely of countless small fossils. A pinch of diatomaceous earth contains thousands of skeletons of a small floating type of algae called a diatom. Literally cubic kilometers of sediment may be made up of animal shells and skeltons. The Great Barrier Reef of Australia is composed of the remains of billions of marine organisms; fossil reefs similar to this are found embedded in ancient sedimentary formations throughout the earth. Coal beds are accumulations of fossil plants, whereas petroleum is primarily altered material that once constituted various kinds of living organisms.

Generally, only a tiny fraction of the organisms that have lived during the geologic past have been preserved as fossils. Normally the remains of an animal or plant are totally destroyed. Under what circumstances are they preserved? Two special conditions appear to be necessary: rapid burrial and the possession of hard parts.

Usually when an organism perishes, its soft parts are quickly eaten by scavengers or decomposed by bacteria. The remaining hard parts are then weathered, eventually crumbling into dust. Occasionally, however, the remains are buried by sediment. In this situation, scavengers and weathering cannot disturb them because they have been removed from the environment where these destructive forces operate. Rapid burial following death therefore is an important condition favoring preservation.

In addition, animals and plants have a much better chance of being preserved as part of the fossil record if they have hard parts. Although traces and imprints of soft-bodied animals such as jellyfish, worms, and insects exist, they are, to say the least, rare. Flesh usually decays so rapidly that preservation is exceedingly remote. Hard parts like shells, bones, teeth, and wood predominate in the record of past life.

The scientific study of fossils is called paleontology; important subdivisions are inver

tebrate paleontology, vertebrate paleontology, paleobotany, and micropaleontology. Each of these fields has its own specialists and embraces such a vast amount of information that no one person can satisfactorily master more than a small fraction of the subject matter. Likewise, as explained in the following paragraphs, the techniques and aims of the various fields are significantly different.

Invertebrate paleontology is perhaps the oldest and the best established subdivision of paleontology. Dealing as it does with the most abundant types of fossils, it has attracted correspondingly more attention than its sister studies. Most professional paleontologists begin their studies with basic courses in this field.

Vertebrate paleontology deals with the highly organized backboned animals. Fossils of the vertebrates are relatively less common than invertebrate fossils and are restricted mainly to land deposits of the later geologic periods. Vertebrates offer scientists the most convincing and understandable evidence for organic evolution, and a major part of the study of vertebrate specimens involves establishing lines of descent and tracing adaptations to changing environments.

Paleohotany is the study of plant fossils, and a great deal of its subject material has been gathered in the great coal fields of the world. Palynology, the study of fossil spores and pollen, is a rapidly growing subdivision of paleobotany. Students of fossil plants have made important contributions to our understanding of the formation of coal and also have aided in the discovery of numerous coal beds. Plant fossils provide the paleontologist with evidence of past geographic conditions, because plants are especially sensitive to climatic influences. The plant world supports the animal world, and evolutionary advances in plants have been followed by corresponding changes in the animals that feed on them.

Micropaleontology, as the term implies, is the study of all fossils that are so small that they must be analyzed with a microscope. Practically all groups of animals and plants are represented in this field, either as specimens or as parts of complete specimens. Plant spores, pollen grains, and seeds are included, as are minute teeth, scales, and bones of vertebrates. Most of the work of the micropaleontologist, however, centers about certain shell-bearing protozoans belonging to the order Foraminifera. These small forms are found in tremendous numbers in marine rocks. Because of their small size, they are recovered intact in rock fragments brought up from wells drilled for oil or gas. More than half of all professional paleontologists are engaged in the field of micropaleontology and are employed by oil companies.

(*From Essentials of Earth History*, *pp*88 -100; *Earth Science*, *p*194)

New Words and Expressions

1. odd stone 怪石
2. remain [ri'mein] n. 遗体
3. trace [treis] n., vt. 迹；痕迹；遗迹；追踪；探索
4. bog [bɔg] n. 沼泽；沼地
5. tar [tɑ:] n. 焦油（沥青）

6. frozen ['frəuzn] a. 冰冻的；冻结的
7. a pinch of 一撮
8. diatomaceous [ˌdaiətə'meiʃəs] a. 硅藻的 ~ earth 硅藻土
9. algae ['ældʒi:]（单数 alga）n. 藻类
10. diatom ['daiətəm] n. 硅藻
11. The Great Barrier Reef 大堡礁
12. embed [im'bed] vt. 埋入；埋置
13. petroleum [pi'trəuljəm] n. 石油
14. a tiny fraction of 一小部分
15. perish ['periʃ] vi. 灭亡；腐烂
16. scavenger ['skævindʒə] n. 食腐动物
17. decompose [ˌdi:kəm'pəuz] v.（使）腐败；分解
18. crumble ['krʌmbl] v. 弄碎；破碎
19. imprint ['imprint] n. 印痕
20. soft-bodied animals 软体动物
21. jellyfish ['dʒelifiʃ] n. 水母；海蛰
22. worm [wə:m] n. 蠕虫；蚯蚓
23. paleontology [ˌpæliɔn'tɔlədʒi] n. 古生物学
24. vertebrate paleontology 古脊椎动物学
25. paleobotany [ˌpæliəu'bɔtəni] n. 古植物学
26. micropaleontology ['maikrəuˌpæliən'tɔlədʒi] n. 微体古生物学
27. embrace [im'breis] vt.，n. 拥抱；包含；包围
28. backboned animals 脊椎动物
29. decent [di'sent] n. 血统；遗传；下降
30. adaptation [ˌædæp'teiʃən] n. 适应；适应性的变化
31. palynology [ˌpæli'nɔlədʒi] n. 孢粉学
32. spore [spɔ:] n. 孢子
33. pollen ['pɔlin] n. 花粉
34. sensitive ['sensitiv] a. 敏感的
35. microscope ['maikrəskəup] n. 显微镜
36. protozoan [ˌprəutə'zəuən] n. 原生动物门
37. Foraminifera [fəˌræmi'nifərə] n. 有孔虫
the order Foramini'fera 有孔虫目
38. tremendous [tri'mendəs] a. 极大的
39. intact [in'tækt] a. 未扰动的；原状的；完整（无缺）的
40. to say the least 至少可以说

Notes to the Text

1. Each of these fields has its own specialists and embraces such a vast amount of information that no one person can satisfactorily master more than a small fraction of the subject matter. 这些（古生物学）领域的每一学科都有它自己的专家，并且每一学科包括的信息量非常之大，所以哪怕是多于该学科的一小部分内容也没有人能真正满意地掌握它。

句中的 "such…that" 引导结果从句，作 "这么…，以致" 或 "所以" 解。these fields 是指前一句提到的古生物学的几个重要分支学科。

2. Dealing as it does with the most abundant types of fossils, it has attracted correspondingly attention than its sister studies. 由于古无脊椎动物学研究的是最丰富的化石类型，所以比起它的姊妹学科来，它特别引人注目。

句首的 "Dealing…" 系分词短语作状语，其中 as it does 和分词短语连用，表示原因。it 指代前一句出现的 Invertebrate paleontology（古无脊椎动物学）。

Word Building

Prefix（前缀）（Ⅰ）

前缀是英语构词中具有一定作用的辅助词素，它加缀在词根前，同词根相结合而构成单词。前缀具有一定含义，能变更词根的意义，派生大量新词。因而在词汇学习过程中，掌握一定数量的前缀可以得到举一反三、闻一知十和触类旁通的效果，这对扩大我们的词汇量有很大的帮助。

英语前缀按构词的功能可分为基本前缀和术语前缀。

1. 基本前缀

英语的基本前缀主要是词缀法派生单词用的构词词缀。按意义相同或相近的基本前缀分类，结合地质专业词汇举例说明如下：

1）表示“否定、逆转、反对”的前缀

（1）a-，an-，dis-，in-，im-，ir-，un-，表示“非、无、不、未”的意义。例如：amorphous（非晶质的），asymmetric（不对称的），anhydrous（无水的），disorder（无序），inorganic（无生物的，无机的），insoluble（不溶的），impermeable（不渗透的），irregular（不规则的），unstratified（不成层的），unweathered（未风化的）。

（2）pseudo-，表示“虚假”的意义。例如：pseudobedding（假层理），pseudoconformity（假整合），pseudocrystal（假晶）。

（3）anti-，ant-，表示“反、抗、防、逆”等意义。例如：antidune（反沙丘），antiknock（抗震，防震），antimeridian（逆子午线）。

2）表示“空间位置、方向关系”的前缀

（1）ante-，fore-，表示“在前、在先、在前面”的意义。例如：antecedent（先成的），antetheca（前壁），foreset（前积层），foreshore（前滨），foreslope（前缘斜坡）。

（2）circum-，circu-，peri-，表示“周围、环绕、回转”的意义。例如：circulation（循环、环流），circumoceanic（环洋的），peripheral（周围的）。

（3）en-，endo-，end-，ento-，ent-，in-，intra-，表示“在内、进入”的意义。例如“enclave（包体），endogenic（内生的），enter（进入），inland（内陆），intraclast（内碎屑），intrastratal（层内的）。

（4）epi（ep）-，ex（o）-，extra-，out-，表示“外、外面、向外、外部、边缘”的意义。例如：epeiric（陆缘的），epigene（外成的），exogenic（外生的），extraclast（外来碎屑），outflow（流出），outside（外部）。

（5）hypo-，infra-，under-，表示“在…下、在下、在下部”的意义。例如：hypometamorphic（深变质的），infrastructure（下层构造），underground（地下的），underwater（水下的）。

（6）inter-，medi-，meso-，表示“在…间、中间”的意义。例如：interdeltaic（三角洲间的），mediterranean（陆间），mesosphere（中间层）。

（7）over-，super-，up，表示“在上面、向上、在…之上”的意义。例如：overlap（超复），superstrata（上覆层），superstructure（上覆构造），upwarp（上拱、隆起）。

3）表示时间、序列关系的前缀

（1）ante-，anti-，fore-，pre-，pro-，proto-，paleo（palaeo）-，表示“先、前、初、古、原始”的意义。例如：antecedent（先成的），antique（古代的），foresee（预见），preglacial（冰期前的），prototype（原始型），protozoa（原生动物），paleoecology（古生态学），paleonbotany（古植物学），paleoenvironment（古环境）。

（2）post-，表示“在后，后”的意义。例如：postglacial（冰期后的），postorogenic（造山后的），posttectonic（构造后的），postmineral（成矿后的）。

（3）ceno-，neo-，表示“新的、新近的”的意义。例如：cenophyte（新生代植物），Neocathaysian（新华夏系），neotectonic（新构造的）。

4）表示比较程度差别关系的前缀

（1）by-，hypo-，para-，sub-，表示“副、次、亚”的意义。例如：byproduct（副产品），hypotype（亚型），paratype（副型），subcycle（次旋回），subfacies（亚相）。

（2）extra-，hyper-，over-，per-，super-，ultra-，表示“超、过”的意义。例如：extraordinary（非常的），hyperhaline（超盐水），oversaturated（过饱和的），peralkaline（过碱性），supergroup（超群），ultrabasic（超基性的）。

5）表示共同、相等意义的前缀

（1）co-，com-，col-，homo-，syn-，表示“共同、一起、相互、复合”的意义。例如：coaction（相互作用），community（团体、群落），compound（复合的），collective（集合的），homogeneous（同类的），syndeposition（同沉积作用）。

（2）equi-，iso-，表示“等同”的意义。例如：equitemperature（等温的），equivalence（等价），isoclinal（等斜的），isopach（等厚线）。

6）地质专业常用的其它前缀

（1）holo-，pan-，表示“整个、完全”的意义。例如：holosymmetry（全对称），holotype（全型），pangea（联合古陆），panorama（全景、概观）。

（2）de-，dia-，dis-，se-，表示“分离、隔开”的意义。例如：decollement（脱顶构造），decompose（分解），dialysis（分离），disintegration（崩结、分裂），dispersal（分散），separability（可分离性）。

（3）trans-，表示“通过、横过、转换”的意义。例如：transection（横断面），transform（转化、转换），transition（过渡），transverse（横向的）。

（4）macro-，magni-，mega-，表示“大、巨大、宏大”的意义。例如：macrofossil（大化石），magnification（放大、扩大），megaripple（巨波纹），megaspore（大孢子）。

Exercises

1. Questions for review：

1）Wtat is a fossil?

2）What rocks are most fossil found in?

3）Under what conditions can fossils be preserved?

4) What study can help scientists to trace the organic evolution during the geologic past?

5) How many chief subdivisions is paleontology subdivided into?

6) Why is it more difficult to master every subdivision matter of paleontology?

2. Choose the proper paleontologic term listed below to complete each of these sentences:

index (or guide), fossils, petrifaction, trace fossils, impressions, remains or traces

1) The term fossil referred to the _____ of organisms preserved from the geologic past.

2) Under favorable conditions, organic materials may be replaced by mineral matter that preserves the form and structure of the original specimen by means of a process called _____.

3) Some fossils allow scientists to pinpoint the relative age of a rock, such fossils are called _____.

4) An imprint of the organism may still be left in the rock, such fossils are called _____.

5) Fossils that preserve evidence of the activities of living things are called _____.

3. Write one complete sentence in English for each term listed below:

paleontology	**Invertebrate paleontology**	**paleobotany**
Vertebrate	**paleontology**	**Micropaleontology**

4. Translating the following passage into Chinese:

Fossils are the remains of organisms of past ages. Preserved by a variety of processes, they occur in many types of sedimentary rocks. Those with hard parts, such as wood, teeth, bones, or shell are more commonly preserved than softbodied forms. The study of fossils, called paleontology, is carried on by specialists and is closely allied with biology. The chief subdivisions of the subject are invertebrate paleontology, vertebrate paleontology, paleobotany, and micropaleontology.

At first, fossils were regarded as mere curiosities, but careful collection and study eventually convinced students that they record the actual succession of life on earth. In fact, they prove that life has changed and that the change has been from simple to complex. Stages in the gradual process of change enable geologists to recognize the geologic periods by the fossils contained in the rocks. Fossils constitute the strongest evidence that organic evolution has taken place.

Although the fossil record is admittedly incomplete, the accumulation of new evidence is progressing rapidly, and the broad outlines of past biologic history are firmly established.

5. Translate the following sentences into English:

1) 化石是古代生命存在的证据。

2) 化石能提供某一地区古地理和古气候变化的线索。

3）标准化石能帮助地质工作者测定岩层的相对年代。

4）古生物学是地质学中有关古代生命研究的一个分支学科，它是以研究化石为基础的。

5）由于人们发现化石能当作时间的指示标志（time indicators），所以它成了对比不同地区相近年代岩层的最佳手段。

6）化石也是重要的环境指示标志。

Reading Materials

(A) Relation of Paleontology to Other Sciences

It is through paleontology that geology makes contact with biology. Fossils are the dead ancestors of living things, and it is assumed that when these ancestors were alive they existed as individuals and as groups in much the same ways as do their living descendants. Most fossils are distorted and incomplete, with only the hard parts represented. A fossil discouraging to contemplate, in comparison with a living breathing organism. From fossils, then, what is to be learned that cannot be learned with greater certainty from living things?

The answer in brief is that information from fossils is essential to an understanding of the complete history of life on earth. Many life forms have existed in the past that must have exploited the environment in ways that are tolally different from what is seen today. We understand how elephants live, but the life habits of dinosaurs are unknown. If we are to judge by numbers and variety, one of the most successful extinct invertebrates is the fusulinid, a protistid. How this lowly animal managed to displace larger, more complex contemporaries is a problem paleontologists are working to solve. The present world evidently does not display all the strategies and adaptations by which life has survived and progressed.

Fossils tell us practically all we know about extinction. If we had only the living world, we would never guess the true extent of past life or realize that the fate of the vast majority of created things has been extinction. The list of losers in the struggle for existence grows steadily longer. More detailed study will surely offer clues as to the role of death in the scheme of things.

Plants and animals live where they are comfortable and tend to find and remain with the conditions that are best for their existence. The correlation between organisms and their environments offers the possibility of learning much about past conditions. Fossils can tell us if certain sediments originated in fresh or salt water and if a sandstone originated in a desert or a beach.

We now perceive that living things have little control over what goes on in the physical world. As climates shift, and lands rise, sink, or shift position, their occupants must adjust accordingly. Within the last decade, much attention has been given to the ponderous forces that have split continents apart and welded them together in ever-changing aggregations. Without fossils we would be much less sure about what is going on. It is fossils that

gave us the thought that India was once in the southern hemisphere, that Africa and South America were once joined, that Antartica was once in a tropical zone, and that the rocks at the very summit of Mount Everest were formed in the bottom of an ocean 400 million years ago.

(*From Essentials of Earth History*, p105)

(B) Fossils and Correlation

Although the existence of fossils had been known for centuries, it was not until the late 1700s and early 1800s that their significance as geologic tools was made evident. During this period an English engineer and canal builder, William Smith, discovered that each rock formation in the canals contained fossils unlike those in the beds either above or below. Further, he noted that sedimentary strata in widely separated areas could be identified by their distinctive fossil content. Based upon Smith's classic obervations and the findings of many geologists who followed, one of the most important and basic principles in historical geology was formulated. Fossil organisms succeed one another in a definite and determinable order, and therefore any time period can be recognized by its fossil content. This has come to be known as the principle of faunal succession. In other words, when fossils are arranged according to their age, they do not present a random or haphazard picture. To the contrary, fossils show progressive changes from simple to complex; this is , they reveal the advancement of life through time, which we refer to as organic evolution.

Since fossils were found to be time indicators, they became the most useful means of correlating rocks of similar age in different regions. Geologists pay particular attention to certain fossils called index, or guide, fossils. Since these fossils are widespread geographically and are limited to a short span of geologic time, their presence provides an important method of matching rocks of the same age. Rock formations, however, do not always contain a specific index fossil. In such situations, groups of fossils are used to establish the age of the bed.

In addition to being important and often essential tools for correlation, fossils are also important environmental indicators. Although much can be deduced about past environments by studying the nature and characteristics of sedimentary rocks, a close examination of the fossils present can usually provide a great deal more information. For example, when the remains of certain clam shells are found in limestone, the geologist can deduce that the region was once covered by a shallow sea. Also, by using what we know of living organisms, we can conclude that fossil animals with thick shells capable of withstanding pounding and surging waves inhabited shorelines. On the other hand, animals with thin, delicate shells probably indicate deep, calm offshore waters. Hence by taking a closer look at the types of fossils, the approximate shoreline may be identified. Further, fossils can be used to indicate the former temperature of the water. Certain kinds of present-day corals must

live in warm and shallow tropical seas like those around Florida and the Bahamas. When similar types of coral are found in ancient limestones, they give a good estimate of the marine environment that must have existed when they were alive. The preceding are just a few brief examples of how fossils can help unravel the complex story of earth history.

(*From Earth Science*, pp194—198)

New Words and Expressions

1. make contact with 与…接通；与…联系起来
2. ancestor ['ænsistə] n. 祖先
3. descendant [di'sendənt] n. 子孙后代
4. distort [dis'tɔ:t] v. (使) 变形
5. fusulinid [fusu'linid] n. 纺锤虫类
6. protistid ['prəutistid] n. 始先类
7. contemporary [kən'tempərəri] n. 同时期的东西
8. strategy ['strætidʒi] n. 对策
9. perceive [pə'si:v] vt. 察觉；看出
10. occupant ['ɔkjupənt] n. 居住者
11. ponderous ['pɔndərəs] a. 沉重的
12. aggregation [ˌægri'geiʃən] n. 聚集
13. Antartica [ænt'ɑ:ktikə] n. 南极洲
14. Mount Everest 埃佛勒斯峰（珠穆朗玛峰）
15. formulate ['fɔ:mjuleit] vt. 系统阐述
16. succeed [sək'si:d] vt. 接替
17. faunal succession 动物群顺序（律）
18. come to be known as… 从此称为…
19. random ['rændəm] a. 随便的
20. haphazard ['hæp'hæzəd] a. 任意的
21. to the contrary 相反
22. index (guide) fossil 标准化石
23. deduce [di'dju:s] vt. 推断
24. clam [klæm] n. 蛤
25. withstand [wið'stænd] vt. 抵挡；经受住
26. pounding wave 击浪
27. surging wave 涌浪
28. coral ['kɔrəl] n. 珊瑚

distrain (ti) upon: (legal) seize goods to compel a person to pay money due (esp rent)
to distrain a person's ~~furniture~~ furniture for rent
distraught (of 情绪) 心烦意乱的, 精神错乱的

discourse, speech, lecture, sermon
discourse upon: (formal) talk, preach or lecture upon

Lesson Five

Text

The Geologic Time Scale

Scientists have put together geologic columns (a listing of rock layers of an area in order from oldest to youngest) from around the world. By using absolute dating methods, they have been able to find the actual age of most of the rocks in a geologic column. As a result, they have been able to piece together an outline of the history of the earth. You can see this outline in the Geologic Time Scale (Figure 1). The Geologic Time Scale divides the history of the earth into time units and lists these units in the order they occurred.

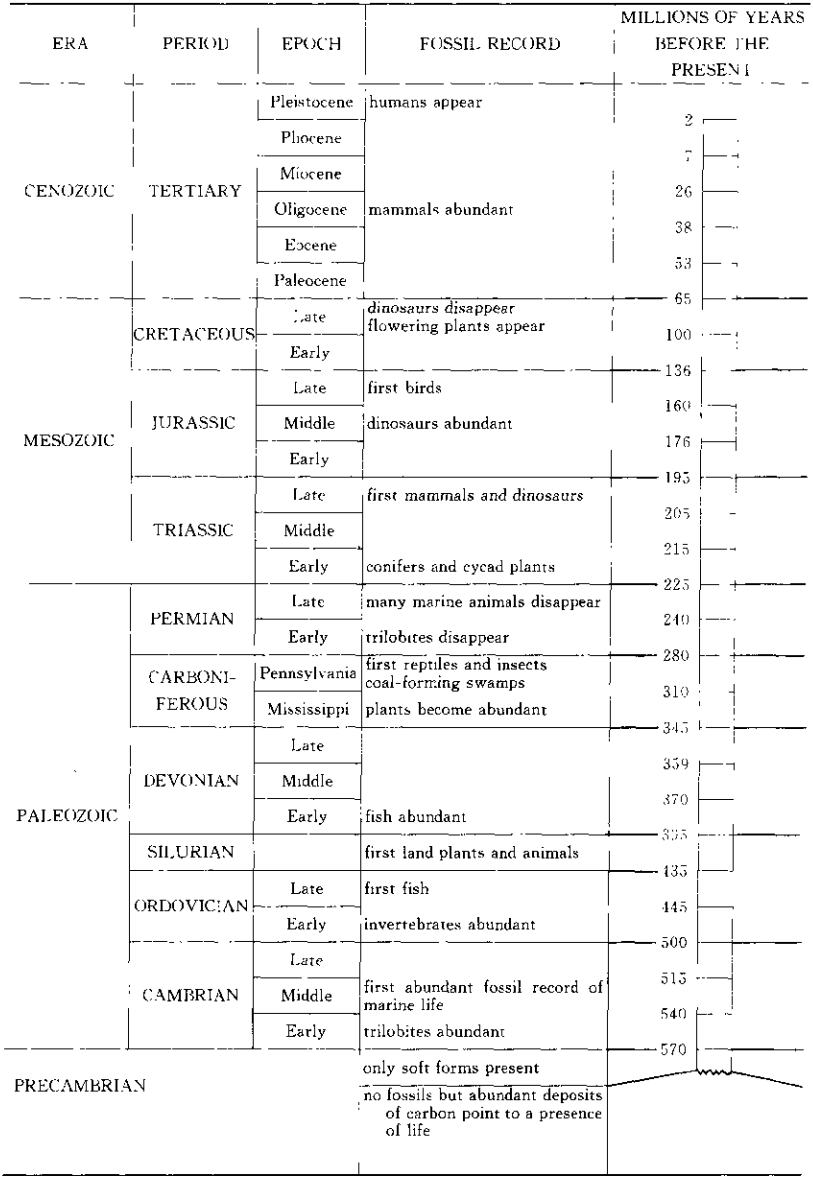
Figure 1 shows that the Geologic Time Scale is divided into four large time intervals called eras. Each era in the earth's history ended with major crustal movement. There are major differences in the fossils found in each era. Each era is divided into shorter time intervals called periods. Periods are blocks of time during which certain life forms were common. Often there is no clear break between the rock layers of one period and the next. Periods are further divided into shorter intervals called epochs.

The Precambrian Era: The Precambrian Era lasted for about 4 billion Years. It began with the formation of the earth and ended about 600 million Years ago. Very few early, Precambrian rocks still exist. Scientists believe they were worn away long ago or changed by crustal movements or volcanic activity. However, areas of late precambrian rock called shields are found on each continent. Precambrian rocks also show evidence of mountain building, volcanic activity, and glaciers. Scientists believe that many changes in the earth's surface took place during this era. Hardly any fossils are found in precambrian rocks. Only a few traces of simple ocean dwelling life forms have been found.

The Paleozoic Era: Paleozoic means ancient life. This era began about 600 million years ago and ended about 230 million years ago. Its beginning is marked by the sudden appearance of abundant fossils. Many changes took place during the Paleozoic Era. Continents moved, climates changed, and many types of life forms first appeared.

The early Paleozoic Era was a quiet time. The continents were close together. The level of the sea was high and the continents were covered by shallow seas. In these shallow seas many types of invertebrates, animals without backbones, evolved and multiplied. The early Paleozoic seas teemed with invertebrate life forms. As time went on, new life forms evolved. Refer to the Geologic Time Scale (Figure 1).

Figure 1 THE GEOLOGIC TIME SCALE



The late Paleozoic Era was a time of dramatic changes. The continents collided, producing larger land masses. Mountinents formed. Shallow seas drained into oceans. Toward the end of the era, climates became drier and colder. Rocks of the last period, the Permian, show evidence of extensive glaciers in some parts of the world. During the late Paleozoic Era, land life evolved and expanded. The first forests appeared, although they looked nothing like forests of today. The bulk of today's coal beds formed from these Paleozoic forests. Insects, amphibians, and reptiles also first appeared at this time, and increased in numbers. By the end of the Paleozoic Era, 230 million years ago, life was firmly established on land.

The Mesozoic Era: The next era was the Mesozoic, meaning "middle life". It lasted for about 160 million years. During this vast time span, great changes occurred in the earth's plants and animals.

Early in the Mesozoic Era the continents began to break apart. Shallow seas began to spread across them. The spreading of oceans and seas brought milder climates.

These conditions formed a near perfect environment for the reptiles. They flourished and became the dominant life form. The Mesozoic Era is often called the Age of Reptiles. The most widespread reptiles were the dinosaurs. Dinosaurs, whose name means "terrible lizards" were giant reptiles. Some of the largest animals that ever lived were dinosaurs.

During the Mesozoic Era, plants became better adapted to life on dry land. Towards the end of this era, flowering plants appeared. Fossils of over 30000 different plant types have been found in Mesozoic rocks. They include such familiar plants as oaks and maples.

The Mesozoic Era also saw the appearance of the first mammals and birds. Although neither group flourished during this era, they survived. Birds and mammals eventually replaced the type of reptiles that could not adapt as conditions changed.

No single event marks the end of the Mesozoic Era. But when it was over, the dinosaurs were gone. No one knows exactly why dinosaurs became extinct. But some scientists believe that they became extinct because of a change in climate. These scientists believe the climate became colder and the dinosaurs could not adapt quickly enough. Other scientists believe that mammals caused the dinosaurs to become extinct. They think that mammals were faster and smarter than dinosaurs. As a result, the dinosaurs could not compete with mammals for food.

The Cenozoic Era: The Cenozoic, meaning "recent life" began about 70 million years ago and has not yet ended. It is the era in which you live. Fossils and the rock record show that many of today's mountain ranges and plateaus were lifted up during this era. The earth has also undergone a cooling and drying trend during the Cenozoic Era. This general cooling of the earth's air has brought on at least four ice ages in recent times.

During an ice age, vast sheets of ice cover much of the land. At one point much of North America, Europe, and Asia was covered with a sheet of ice up to 3000 m thick. The ice was as thick as nine Empire State Buildings piled one on top of the other. The last ice

age ended 10000 years ago. We may now be living in an inter-glacial age, a time between ice ages.

The Cenozoic Era is often called the Age of the Mammals since mammals are its dominant life form. Mammals dominate because they have been able to adapt to the changes that have occurred.

The first mammals were small in size, they resembled modern forms only slightly. As mammals became more successful, they increased in size. New mammal types also developed. By the middle of the Cenozoic Era, many mammals resembling modern forms had appeared. Primitive dogs, cats, and horses, were common.

New Words and Expressions

1. The *Geologic* Time Scale 地质年代表
2. put together 汇合；编
3. geologic columns 地质柱状（图）
4. dating [ˈdeitiŋ] n. 年代测定
5. piece together 拼合；综合
6. outline [ˈaut-lain] n. 轮廓
7. interval [ˈintəvəl] n. （时间的）间隔
8. era [ˈiərə] n. 代；时代
9. period [ˈpiəriəd] n. 纪；时期
10. break [breik] n. 间断；断裂
11. epoch [ˈiːpɔk] n. 世；时期
12. Precambrian [ˌpriːˈkæmbriən] n., a. 前寒武纪的；前寒武系（的）
13. be worn away 被剥蚀掉
14. shield [ʃiːld] n. 地盾
15. glacier [ˈglæsjə] n. 冰川
16. dwelling [ˈdweliŋ] n. 居住；住处
17. Paleozoic [ˌpæliəuˈzəuik] n., a. 古生代（的）；古生界（的）
18. be marked by… 以…为标志；以…为特征
19. evolve [iˈvɔlv] v. （使）发展；（使）演化；（使）进化
20. multiply [ˈmʌltiplai] v. 增加；增多
21. teem with 充满，大量地出现
22. refer to 参考；涉及；关于；参见
23. collide [kəˈlaid] vi. 冲突；相撞
24. drain [drein] vt. 排水，流掉（off）
25. Permian [ˈpɔːmiən] n., a. 二叠纪（的）；二叠系（的）
26. extensive [iksˈtensiv] a. 广泛的
27. expand [ikspænd] v. 扩大；发展
28. the bulk of 大多数；大部分
29. amphibian [æmˈfibiən] n., a. 两栖动物；两栖类的
30. reptile [ˈreptail] n., a. 爬行动物（的）
31. Mesozoic [ˌmesəuˈzəuik] n., a. 中生代（的）；中生界（的）
32. span [spæn] n. 跨（度）；一段时间
33. break apart 裂开
34. spread [spred] v. 扩展；蔓延
35. flourish [ˈflʌriʃ] vi. 繁荣；兴旺
36. dinosaur [ˈdainəsɔː] n. 恐龙
37. lizard [ˈlizəd] n. 蜥蜴
38. oak [əuk] n. 橡树；栎树
39. maple [ˈmeipl] n. 枫树
40. mammal [ˈmæməl] n. 哺乳动物
41. survive [səˈvaiv] v. 幸免于；幸存
42. extinct [iksˈtiŋkt] a. 灭绝的
43. smart [smɑːt] a. 灵巧的
44. Cenozoic [ˌsiːnəˈzəuik] n., a. 新生代（的）；新生界（的）
45. plateau [ˈplætəu] n. 高原
46. trend [trend] n. 趋势；倾向
47. bring on 引起
48. ice age 冰期
49. Empire State Buildings 帝国大厦
50. inter-glacial age 间冰期
51. primitive [ˈprimitiv] a. 原始的

Notes to the Text

1. Fossils of over 30，000 different plant types have been found in Mesozoic rocks. They include such familiar plants as oaks and maples. 在中生代地层中，已发现三万多种不同类型的植物化石，它们包括有（象）栎树和枫树这类植物。
   句中 such 作 plants 的定语，as 引导省略了 are 的定语从句。如：
   Our plant produces such chemicals as gasoline，kerosene，vaseline，and paraffin. 我厂生产（象）汽油、煤油、凡士林和石腊等（那样的）化工产品。
2. The ice was as thick as nine Empire State Buildings piled one on top of the other. 冰的厚度就象把九个帝国大厦叠起来那么厚。
   此句含比拟状语从句，这里 "as…+as+所比拟的事物" 其含义为 "如…一样"。
   It is as white as snow. 其白如雪。

Word Building

Prefix（前缀）（Ⅱ）

2. 英语术语前缀

英语的术语前缀不仅是词缀法派生单词用的构词词缀，而且主要是合词法中的结合型所合成的结合词词头，或称之为词头成分。它的特点就是这类词头本身是词根，可以和各个不同意义的词根结合成各类术语。在地质专业术语中，这类词头也很多，现仅把最常见者列举如下：

（1）aer（o）-（希腊语 aer=air）含义是 "空气、空中" 的意思。例如：aeration（通风、通气），aerobe（需氧微生物），aerogeology（航空地质学），aerosphere（气圈）。

（2）astr-（希腊语 astra=star）含义是 "星、天体、宇宙" 的意思。例如：astrogeology（天体地质学），astronautics（宇宙航行学），astronomy（天文学）。

（3）atmo-（希腊语 atmos=smoke，vapor）含义是 "烟雾、大气、水蒸气" 的意思。例如：atmoclast（大气碎屑），atmolith（气成岩），atmosphere（大气圈）。

（4）bathy-（希腊语 bathys=deep）含义是 "深" 的意思。例如：bathydermal（深壳的），bathymetric（等深的），bathypelagic（海洋深层的）。

（5）bio（希腊语 bios=life）含义是 "生命、生物" 的意思。例如：biochemical（生物化学的），biochronology（生物年代学），bioecology（生态学），biofacies（生物相），biogenic（生物成因的），biostrata（生物层）。

（6）chron-（希腊语 chronos=time）含义是 "时、时间、时代" 的意思。例如：chronolith（年代地层单位），chronostratigraphy（年代地层学），chronozone（年代带）。

（7）carb-，carbon-（拉丁语 carbo，carbonis=coal）含义是 "碳" 的意思。例如：carbonatite（碳酸盐岩），carboniferous（含碳的、石炭纪），carbonization（碳化作用），carbonification（煤化作用），carbonite（天然焦）。

（8）crystall-（拉丁语 crystallum=crystal）含义是 "晶体、结晶" 的意思。例如：crystallin-

ty（结晶度），crystallization（结晶作用），crystallographic（结晶的）。

（9）electr-（希腊语electron＝amber）原义是“琥珀”，而转义为“电”的意思。例如：electro.og（电测井），electrolytic（电解的），electromagnet（电磁铁）。

（10）ge-（希腊语ge＝earth）含义是“地球、大地”的意思。例如：geochemistry（地球化学），geochronology（地质年代学），geography（地理学），geohydrology（水文地质学），geomorphy（地貌学），geotectonics（大地构造学）。

（11）hydr-（希腊语hydor，hydros＝water）含义是“水、流体、氢”的意思。例如：hydrocarbon（碳氢化合物），hydrodynamics（流体动力学），hydrogenic（水成的），hydrogeology（水文地质学），hydroxide（氢氧化物），hydromica（水云母）。

（12）lith-（希腊语lithos＝stone）含义是“石、岩石”的意思。例如：lithification（石化作用），lithoclast（岩屑），lithofacies（岩相），lithogenesis（成岩作用），lithosphere（岩石圈），lithostratigraphy（岩石地层学）。

3. 英语前缀的合成

在英语构词中，往往出现许多前缀重叠组合的复杂结构，这种组合型式叫做前缀的合成。这些合成的前缀组合在构词的过程中已经溶化成不可分割的整体。合成的前缀之间往往存在某种意义上的联系，有的是加强词义，有的恰恰相反，构成词义的对立。

前缀的重叠组合型式常分为以下三种：

（1）双重前缀——由两个前缀重叠使用所构成的组合型式。例如：irreversible（不可逆的），disassociate（离解），decompress（排除压力），correspond（符合、对应）等词中的irre-，disas-，decom-，corre-，都是双重前缀。

（2）多重前缀——由三个以上的前缀重叠使用所构成的组合型式。例如：indecomposable（不可分的）中的indecom-就是由三个前缀重叠组合而成。

（3）隐藏前缀——前缀的最后一个字母在构词过程中和词根或词干同化的现象。例如：cover（掩盖）一词的前缀“co-”，在合成时“o”被同化了。

Exercises

1. Questions for review:

1) What is the geologic column?

2) How many eras is the Geologic Time Scale divided into? Write their terms.

3) How long does the Precambrian Era last for?

4) When does the Paleozoic Era begin and end?

5) What are the largest animals that ever lived during the Mesozoic age?

6) Why the Cenozoic Era is often called the Age of the Mammals?

2. Select the letter of the answer that best completes each of the following:

1) Most fossils are found in _____.

a. sedimentary rocks　　b. igneous rocks

c. metamorphic rocks　　d. all of the above

2) In order to form a fossil the remains of a living thing must _____.

a. decay　　b. be eaten by other living things

c. be buried soon after it dies　　d. be trapped in molten rock

3) The parts of living things most often preserved as fossils are _____.

a. soft, fleshy parts　　b. hard parts

c. hair　　d. blood

4) You presently live in the _____.

a. Precambrian Era　　b. Mesozoic Era

c. Paleozoic Era　　d. Cenozoic Era

5) The Geologic Time Scale is divided into _____.

a. eras, periods, and epochs

b. years, months, days

c. igneous, metamorphic, and sedimentary rocks

d. mountains, oceans, and swamps

3. Complete the Following:

1) Eras are subdivided into _____.

2) Fossils provide clues about ancient _____.

3) The earth's rock layer are arranged in relative-age order in the geologic _____.

4) When correlation between widely separated areas or between continents is the objective, the geologist must rely upon _____.

5) The term system refers to rocks formed during a _____.

6) Finding the relative age of rock layers and the events they represent is called _____.

4. Translating the following passage into Chinese:

In order to develop a geologic calendar that is applicable to the whole earth, rocks of similar age in different regions must be matched up. Such a task is referred to as correlation. Within a limited area there are several methods of correlating the rocks of one locality with those of another. A bed or series of beds may be traced simply by walking along the outcropping edges. However this may not be possible when the continuity of the bed is interrupted. Correlation over short distances is often achieved by noting the place of a bed in a sequence of strata, or a bed may be identified in another location if it is composed of very distinctive or uncommon minerals. By correlating the rocks from one place to another, a more comprehensive view of the geologic history of a region is possible. No single locale contains a complete sequence, but correlation reveals the total extent of sedimentary rocks.

5. Translate the following sentences into English:

1) 每一个代中发现的化石有较大差异。

2) 古生代时期发生了许多变化，如，大陆移动、气候改变、许多生物种类大量出现。

3) 世界一些地区的二叠纪岩层中显示有大面积冰川分布的证据。

4) 一些科学家认为气候变冷导致恐龙灭绝。

5) 到新生代中期，许多类似于现代的哺乳动物出现了。

6) 前寒武纪延续了大约 40 亿年。

7) 晚古生代地层中含有大量煤层。

Reading Material

Sequence Stratigraphy

As the search for oil and gas becomes more sophisticated and producing basins and fields become more intensely developed, geoscientists need correspondingly more accurate techniques for stratigraphic analysis. To achieve this accuracy, companies are shooting higher resolution seismic lines, acquiring 3-D seismic surveys over fields, and coring more to quantify reservoir properties. Exploration and production staff, provided with these more accurate but expensive data, often under-utilize the well log. In basins or fields with a sufficient density of well control, the coupling of conventional well logs and cores with the techniques of sequence stratigraphy results in an ultra-high-resolution chronostratigraphic framework for subsurface correlation. Where integrated with seismic and biostratigraphic data, well-log cross sections, interpreted using sequence and parasequence concepts, provide a state-of-the art framework for analyzing reservoir, source, and seal distribution, whether on a regional or a field-reservoir scale.

Sequence stratigraphy is the study of genetically related facies within a framework of chronostratigraphically significant surfaces. The sequence is the fundamental stratal unit for sequence-stratigraphic analysis. The sequence is defined as a relatively conformable, genetically related succession of strata bounded by unconformities or their correlative conformities. Sequence boundaries form in an increase in water depth. Parasequences and parasequence sets are building blocks of sequences. A parasequence is defined as a relatively conformable, genetically related succession of beds or bedsets bounded by marine-flooding surfaces or their correlative surfaces.

A parasequence set is defined as a succession of genetically related parasequences that form a distinctive stacking pattern, bounded, in many cases, by major marine-flooding surfaces and their correlative surfaces. Parasequence and parasequence set boundaries form in response to an increase in water depth. Under certain depositional conditions, parasequence and parasequence set boundaries may coincide with sequence boundaries. Parasequences are composed of bedsets, beds, laminasets, and laminae.

These stratal units, ranging from the sequence down to the lamina, are the building blocks of sedimentary rocks; they form a stratigraphic hierarchy and share two fundamental properties: (1) each stratal unit, with the exception of the lamina, is a genetically related succession of strata bounded by chronostratigraphically significant surfaces, and (2) each surface is a single, physical boundary that everywhere separates all of the strata above

from all of the strata below over the extent of the surface.

Because of these properties, bounding surfaces that are correlated using well logs, cores, or outcrops, provide a high-resolution chronostratigraphic framework for facies analysis. Vertical facies analysis must be done within conformable stratal packages to accurately interpret coeval, lateral facies relationships along a single depositional surface. Parasequence, parasequence set, and sequence boundaries, occurring with a high frequence in siliciclastic sections, are significant depositional discontinuities; in most places, the facies above these boundaries have no physical or temporal relationship to the facies below. Because of this decoupling of facies across these boundaries, vertical facies analysis should be done within the context of parasequences parasequence sets, and sequences to interpret lateral facies relationships accurately.

Using well logs, cores, or outcrops, each sequence can be subdivided into stratal units called systems tracts, based on their positions within the sequence, the distribution of parasequence sets, and facies associations. Systems tracts are defined as a "linkage of contemporaneous depositional systems". Systems tracts provide a high degree of facies predictability within the chronostratigraphic framework of sequence boundaries. This predictability is especially important for the analysis of reservoir, source, and seal facies within a basin or a field.

New Words and Expressions

1. Sequence Stratigraphy 层序地层学
2. sophisticate [sə'fistikeit] v. 改进；采用先进技术
3. accuracy ['ækjurəsi] n. 精确；准确度
4. shoot [ʃu:t] v. 发（射）出；提出
5. higher-resolution 较高分辨(率)；较高清晰度
6. 3-D seismic surveys 三维地震勘查
7. quantify ['kwɔntifai] vt. 确定（表示）…的数量；定量表示；利用；应用；发现…的用途
   under-utilize 利用不足
8. well log 测井曲线；钻井（剖面）记录
9. coupling ['kʌpliŋ] n. 结合；匹配；联接
10. ultra-high-resolution 超高分辨（率）
11. chronostratigraphic [krɔnəstrætigræfik] a. 年代地层的
12. integrate ['intigreit] v. （使）结（综；总）合（成整体）
    ~ with 使…与…结合…
13. parasequence ['pærə'si:kwəns] n. 副层序，似层序
    ~ sets 副层序组
14. reservoir ['rezəvwɑ:] n. 储集层；油储
15. seal [si:l] n. 隔离层
16. conformable [kən'fɔ:məbl] a. 一致的；相似的；（地层）整合的
17. bound by 以…为界；受…限制
18. unconformity ['ʌnkən'fɔ:miti] n. 不整合
19. conformity [kən'fɔ:miti] n. 整合
20. block [blɔk] n. 块；断块；岩块；块段；地块
21. bedsets ['bed'sets] n. 岩层组
22. stacking ['stækiŋ] n. 叠加
    ~ pattern 叠加型式
23. laminasets ['læminə'sets] n. 细（纹）层组
24. laminae ['læmini:] n. 薄层；细层（单数 lamina）
25. hierarchy ['haiərɑ:ki] n. 体系；系统；层次；阶层
26. package ['pækidʒ] n. 组；单元
27. coeval [kəu'i:vəl] a. 同时代的；同时期的
28. discontinuity [dis,kɔnti'nju:iti] n. 间断（面）；不连续性

29. temporal ['tempərəl] a. 暂时的；短暂的
30. decoupling [di'kʌpliŋ] n. 不匹配；分离
31. systems tracts 系统域
32. facies associations 相组合
33. linkage ['liŋkidʒ] n. 连接；交连；耦合；连合；接合
34. contemporaneous [kən,tempə'reinjəs] a. 同时的；同生的
35. predictability [pridiktə'biliti] n. 可预测性

Lesson Six

Text

Faults

We defined faults as fractures along which adjacent rock masses have slipped past one another in response to tension, compression, or shearing stress. The various categories of faults are named according to the relative directions in which the slippage occurs. It is not always an easy matter to identify the direction of movement, especially in faults that have been inactive for perhaps tens of millions of years. Geologists depend primarily on offsets in strata, veins, or other geologic structures in order to determine the character of ancient faults. For those faults that have experienced recent movements, small escarpments (fault scarps) may show where one segment of the surface moved upward relative to the other. There may also be displacements of physiographic features such as ridges and stream channels.

The plane of dislocation along which movements occur during faulting is called the fault plane. As rock masses grind past one another along the fault plane, they produce polished surfaces with parallel scratches called slickensides, and pulverized rock material known as fault breccia. Sometimes, the rock is ground to a clayey mass named fault gouge. For geologists attempting to recognize deeply buried faults by examining well samples, these clues to faulting can be of great value.

Fault planes are permeable zones along which hot mineralized water solutions can penetrate and may, in relatively rare instances, deposit valuable ores. Long ago, miners tunneling along sloping fault planes helped to provide a nomenclature that even today serves to identify certain kinds of faults. The side of the fault on which the miners stood was appropriately dubbed the footwall. Above their heads was the hanging wall. These terms are put to work in the definition of two major categories of faults; namely, normal and reverse faults. In a normal fault the hanging wall appears to have moved downward relative to the footwall. Normal faulting occurs most frequently in rocks that have been subjected to tensional forces—that is, forces that tend to stretch the earth's crust. A system of normal faults with parallel fault planes may have topographic expression as linear uplands separated by troughlike valleys, somewhat like a piano keyboard in which some of the keys are depressed. The topographically depressed down-faulted segments that are bounded by normal faults are termed grabens after the German word for grave, and the high-standing blocks that generally stand above the grabens are called horsts.

In reverse faults, the hanging wall appears to have moved upward relative to the foot

well. If one holds two blocks of wood cut, then it is easy to visualize that they may be pushed together or compressed in order to cause reverse faulting. Similarly, regions of earth's crust containing numerous reverse faults (and folded strata as well) are likely to have experienced compression.

Reverse faults in which the fault plane is inclined 45° or less from the horizontal plane are termed thrust faults. In other words, thrust faults are simply low-angle reverse faults. They may have displacements of many kilometers. Such thrusting may carry immense slabs of older crustal rocks great distances, so that they come to rest on younger rocks that lie beneath the fault plane. Erosion may remove most of the overthrust sheet, leaving behind isolated erosional remnants called klippen (singular klippe). In some thrusts, the upper plate is thin and composed of relatively flat rocks. Other thrusts are formed during extreme folding, in the course of which the lower limb of an overturned fold breaks and the fold is pushed out as a thrust fault. In the Alps and Himalayas such overthrust folds occur on a spectacular scale.

Another type of faulting involves primarily horizontal movements along the strike of the fault plane. Such features are called strike-slip faults, although the informal term lateral fault is also sometimes applied. The fault plane in a strike-slip fault is usually nearly vertical, and the displacement along the fault planes may be tens or even hundreds of kilometers. The San Andreas fault is a lateral fault. It is over 1000 km long, and the total lateral movement along the fault has been estimated by geologists to be over 500 km.

Strike-slip faults are designated as either "right lateral" or "left lateral." In order to decide which kind is being observed, one simply must look across the fault zone to see if the opposite block moved to the right or left. The San Andreas is a right lateral fault. Of course, there is nothing in nature that restricts fault movements to either a purely vertical or horizontal direction, and so there are many faults that are formed as a result of oblique and rotational movements. For example, an oblique-slip fault exhibits displacement obliquely across the fault plane. Rotational faults occur where one of the fault blocks turns or rotates in a scissor-like motion against the other.

(*From Contemporary Physical Geology: Geologic Structure*, *pp*275-- 279)

New Words and Expressions

1. fault [fɔ:lt] n. 断层
   ~ plane 断层面；normal ~ 正断层；reverse ~ 逆断层；thrust ~ 逆掩断层；strike-slip ~ 走向滑动断层
2. slippage ['slipidʒ] n. 滑动
3. offset ['ɔ(:)fset] n. 水平断错
4. escarpment [is'kɑ:pmənt] n. 悬崖；急斜面
5. physiographic [fiziəg'ræfik] a. 自然地理的
6. dislocation [dislə'keiʃən] n. 断层；断错
7. slickenside ['slikənsaid] n. 擦痕面；断层擦面
8. pulverize ['pʌlvəraiz] vt. 研磨；使成粉末
9. breccia ['bretʃə] n. 角砾岩
10. clayey ['klei] a. 粘土的；粘土似的
11. gouge ['gaudʒ] n. 断层泥
    fault ~ 断层泥
12. permeable ['pə:mjəbl] a. 可渗透的；具渗透性

的

13. dub [dʌb] vt. 授予；给…起名（绰号）
14. footwall ['futwɔ:l] n. 下盘
15. hanging ['hæŋiŋ] n. 悬；垂
~ wall 上盘；顶壁
16. upland ['ʌpləndˌ] n. 高地；山地
17. troughlike ['trɔ (:) flaik a. 槽形的
18. graben ['grɑ:bən] n. 地堑
19. grave [greiv] n. 坟墓
20. horst [hɔ:st] n. 地垒
21. fold ['fould] n. 褶皱
22. oblique [ə'bli:k] a. 斜的；倾斜的
~ slip faults 倾斜滑动断层
23. San Andreas [sænˌændrəs] n. 圣安德列斯
24. scissor ['sizə] n. 剪刀
~ like 剪刀状的
25. lateral ['lætərəl] a. 侧面的；旁边的
26. nomenclature [nou'menklətʃə] n. 名称；术语
27. mineralize ['minərəlaiz] vt. 使矿化；使矿物化

Notes to the Text

Sometimes, the rock is ground to a clayey mass named fault gouge. 有时，岩石被研磨成粘土状的断层泥。

ground 为 grind 的过去分词。

Word Building

Suffix（后缀）

1. 后缀的构成

后缀是加缀在词干或词根后的词缀。后缀一般不改变其含义，只转变其词类；作用与前缀恰好相反。比较 work（vt. 工作，劳动）；worker（n. 工人）；workable（a. 可加工的）；working（n. 劳动），这说明加了不同的后缀，可以分别出不同的词类。

一个词根加了不同的后缀，也会引伸出不同的含义。比较 human（有人情的）- humanistic（人性研究的）；electoral（有关选举的）——elective（选举产生的）。

后缀在构词中也具有一定的作用和含义，懂得了后缀的含义，就容易了解由后缀和词根结合而成为单词的意义。所以说，后缀不仅是构成新词的分子，而且也是形成各种词类的手段。

2. 半后缀

有一部分词根或词干在构成合成词时，实际上起着后缀的作用，但从形态上来说，不完全是后缀的型式，这种作为合成词词类的构词词缀叫做半后缀(semi-suffix). 例如：-man 有“…员；…家”之意，seaman（海员）；airman（飞行员）；fireman（救火员）。land：(a) 接在某些种族之后表示国名或地名；Scotland（苏格兰）；Finland（芬兰）；England（英格兰）；Greenland（格陵兰）；(b) 表示本土，祖国之意；homeland（故国，本国）；fatherland（祖国）。

3. 后缀派生词

后缀派生词是由加后缀派生法所构成的派生词。它可以分成派生名词、派生形容词、派生动词、派生副词等。下面主要介绍几个具有同一后缀的地质类名词：

(a) logy 表示"…学；…论"，学科名称的意思，例如：geology（地质学）；geomorphology（地貌学）；hydrology（水文学）；petrology（岩石学）；mineralogy（矿物学）；paleontology（古生物学）；seismology（地震学）；

(b) -ite 表示"…石；矿物；岩石；化石"，例如：cryolite（冰晶石）；oolite（鲕石）；calcite（方解石）；graphite（石墨）；granite（花岗岩）；biotite（黑云母）；pyrite（黄铁矿）；magnetite（磁铁矿）；hyalite（玻璃蛋白石）；anthracite（变质煤）；dendrolite（树木化石）；

(c) -sphere 表示"…圈；…层"，例如：hydrosphere（水圈）；biosphere（生物圈）；lithosphere（岩石圈）；magnetosphere（磁层）；ionosphere（电离层）；atmosphere（大气层）；homesphere（均质层）；heliosphere（日光层）。

Exercises

1. Questions for review:

(1) What are faults?

(2) What are fault planes?

(3) What are the reverse faults?

(4) What are the normal faults?

(5) What are the hanging-wall block and footwall block?

(6) What are the major kinds of faults described in the text?

2. Choose the correct answer from the alternatives:

(1) Reverse faults in which the fault plane is inclined 45° or less from the horizontal plane are termed ___ ___.

a. Thrust faults　　b. Reverse faults

c. Normal faults　　d. Strike-slip faults

(2) Which of the following is not the name of an ancient continent? ___ .

a. Tethys　　b. Pangea

c. Gondwanaland　　d. Laurasia

(3) The new global tectonic theory differs from the older theory of continental drift in which of the following ways? ___.

a. It postulates different rates of ralative motion

b. It does not require the continents to move across the ocean floor

c. It uses convection currents as the driving mechanism

d. It explains orogeny at the leading edges of continents

(4) Thick, geosynclinal sequences of sediments always accumulate in which of the following situations? ___.

a. At the edges of lithosphere plates

b. At the edges of continents

c. In deep oceanic trenches

d. In interior basins, within the continents

(5) Many important phenomena cannot, at present, be explained in terms of plate tectonics, which of the following has been explained under this theory? _____.

a. Gradual subsidence of broad area within the continents

b. Gradual subsidence of the ocean floor as it moves away from an actively spreading ridge

c. Extensive flood basalts away from the plate margins

d. Substantial earthquakes thousands of kilometers from plate margins

3. Put the verbs in brackets into either the infinitive or the-ing form as required:

1) It is sometimes difficult _____ (tell) the difference of the three major kinds of faults.

2) A good student enjoys _____ (try) _____ solve difficult problems.

3) We have not yet got used to _____ (use) the sea as a major source of minerals.

4) The geologist helped the engineer _____ (calculate) the stability of the building by _____ (give) an accurate description of the soil.

5) Hydrogen combines with oxygen _____ (form) water.

6) Minerals in rocks sometimes decompose _____ (form) other minerals.

4. Give the Chinese/English equivalents for the following:

1) for descriptive purposes
2) with respect to that fault
3) to be parallel with the strike of the fault
4) a classification of fault displacements
5) to offset for many miles
6) 走向滑动断层
7) 正断层
8) 逆断层
9) 地质构造
10) 上盘

5. Translate the following passage into Chinese:

Faults are classified on the basis of the relative movement of two formerly adjacent points. Should movement occur in the horizontal direction and parallel to the plane of the fault, the fault is referred to as a strike-slip fault. Strike-slip faults can further be divided into right and left-slip faults, depending on the direction of offset. If the opposite side of the fracture appears to the observer to have moved toward the left, the fault is a left slip fault; in a right-slip fault, movement appears to have been toward the right.

6. Translate the following sentences into English:

1) 这个断层把这座山分为两部分。

2) 人们认为地震与断层有关。

3) 断层面可能是由垂直到水平的任何位置。

4) 逆断层中，上盘相对下盘向上运动。

5) 走向滑动断层可以分为右侧滑动和左测滑动。

Reading Material

Crustal Plates in Motion

Perhaps more than other scientists, geologists are accustomed to viewing the earth in its entirety. It is their task to assemble the multitude of observations about minerals, earthquakes, and landforms and then to weave them into a coherent view of the whole earth. Recently, a theory has been developed that provides a marvelous base for associating a great variety of geologic information. As noted earlier, the concept is plate tectonics, and it has taken on the dimensions of a scientific revolution. The idea of plate tectonics was late in coming. Perhaps the most important reason for its tardy arrival was simply that, until recently, there were large regions of the globe that could not be adequately studied. This was particularly true of the vast realms beneath the oceans. For two centuries, the continents, which constitute only about 30 per cent of the earth's surface, received most of the attention. Technologic problems and formidable costs so limited exploration of the ocean floors that oceanographic research was possible only for relatively few earth scientists.

The lack of adequate information about the ocean floors began to be corrected in the years following World War II. Research related to naval operations produced submarine detection devices that also proved useful in measuring magnetic properties of rocks. In the mid 1940s to late 1950s the need to monitor atomic explosions resulted in the establishment of a worldwide network of seismometers. This network provided the precise information about earthquake locations required in order to produce seismic maps such as that shown in Figure 8-36. The magnetic field over large portions of the seafloor was soon to be charted by the use of newly developed and delicate magnetometers. Other technologic advances ultimatelly permitted scientists to examine rock that had been carefully dated by radiometric methods and then to determine the nature of the earth' s magnetic field at the time those rocks had formed. Geologically recent reversals of the magnetic field were soon detected, correlated, and accurately dated. A massive federally funded program to map the bottom of the oceans was launched, and depth information from improved echo depth sounding devices poured into data collecting rooms to be translated into maps and charts. A new picture of the ocean floor began to emerge. It was at once awesome, alien, and majestic. Great chasms, flat-topped submerged mountains, broad abyssal plains, and imposing volcanic ranges appeared on the new maps and begged an explanation. How did the volcanic mid-oceanic ridges and deep sea trenches originate? Why were both so prone to earthquake activity? Why was the Atlantic Ridge so nicely centered and parallel to the coastlines of the continents on either side? As the topographic, magnetic, and geochronologic data accumulated, the relationship of these questions became apparent. An old theory called continental drift was re examined, and the new, more encompassing theory of plate

tectonics was formulated. It was an idea whose time had come.

CONTINENTAL DRIFT

It requires only a brief examination of the world map to notice the remarkable parallelism of the continental shorelines on either side of the Atlantic Ocean, If the continents were pieces of a jigsaw puzzle, it would seem easy to fit the great "nose" of Brazil into the reentrant of the African coastline. Similarly, Greenland might be inserted between North America and northwestern Europe. It is not surprising, therefore, that earlier generations of mapgazers also noticed the fit and formulated theories involving the break-up of an an cient supercontinent.

In 1858 there appeared a work titled La Création et ses Mystères Devoilés. Its author, A. Snider, postulated that before the time of Noah and the biblical flood, there existed a great region of dry land. This antique land developed great cracks encrusted with volcanoes, and during the great Deluge, a portion separated at a north-south trending crack and drifted westward. Thus, North America came into existence. Near the close of the 19th century, the Austrian scientist Eduard Suess became particularly intrigued by the many geologic similarities shared by India, Africa, and South America. He formulated a more complete theory of a supercontinent that drifted apart following fragmentation. Suess called that great land mass Gondwanaland after Gondwana, a geologic province in east-central India.

The next serious effort to convince the scientific community of the validity of these ideas was made in the early decades of the twentieth century by the energetic German meteorologist Alfred Wegener. His book, Die Enstehung der Kontinente und Ozeane ("The Origin of the Continents and Oceans"), is considered a milestone in the historical development of the concept of continental drift.

Wegener's hypothesis was quite straight forward. Building on the earlier notions of Eduard Suess, he argued again for the existence in the past of a supercontinent that he dubbed Pangaea. That portion of Pangaea that was to separate and form North America and Eurasia came to be known as Laurasia, whereas the southern portion retained the earlier designation of Gondwanaland. According to Wegener's perception, Pangaea was surrounded by a universal ocean named Panthalassa, which opened to receive the shifting continents when they began to split apart some 200 million years ago. The fragments of Pangaea drifted along like great stony rafts on the denser material below. In Wegener's view, the bulldozing forward edge of the slab might be expected to crumple and produce mountain ranges like the Andes.

(*From Contemporary Physical Geology: Crustal Deformation and Global Tectonics*, *pp*288—289)

New Words and Expressions

1. entirety [in'taiəti] n. 整体；总体；全部；全面 | 2. multitude [mʌl'titju:d] n. 众多；大量

3. landform [lændfɔ:m] n. 地形
4. coherent [kou'hiərənt] a. 紧凑的；连贯的；表达清楚的
5. marvelous ['mɑ:viləs] a. 奇异的；奇迹般的；惊人的；不可思议的
6. dimension [di'menʃən] n. 范围；方面
7. tardy ['tɑ:di] a. 慢的；行动缓慢的；迟的；迟到的
8. formidable ['fɔ:midəbl] a. 可怕的；令人生畏的；难对付的；难克服的
9. oceanographic [ouʃjənou'græfik] a. 海洋学的
10. naval ['neivəl] a. 海军的；军舰的
11. seismometer [saiz'mɔmitə] n. 测震表
12. chart [tʃɑ:t] vt. 用图表表示
13. delicate ['delikit] a. 灵敏的；精密的
14. magnetometer [mægni'tɔmitə] n. 地磁仪；磁强计
15. radiometric [reidiə'metrik] a. 辐射仪的
16. federally ['fedərəli] ad. 在全联邦范围的
17. launch [lɔ:ntʃ] vt. 着手进行；开始
18. echo ['ekou] n. 回声；反响
19. alien ['eiljən] a. 相异的；不相容的
20. majestic [mə'dʒestik] a. 庄严的；威严的；崇高的
21. chasm ['kæzəm] n. 断层；裂口；峪谷；深渊
22. submerge [səb'mə:dʒ] vt. 浸没；淹没
23. imposing [im'pouziŋ] a. 给人深刻印象的
24. reentrant [ri:'entrənt] a. 凹入的
25. mapgazer [mæp'geizə] n. 凝视地图者
26. supercontinent [sju:pə'kɔntinənt] n. 超大陆
27. Noah ['nouə] n. 挪亚
28. biblical ['biblikəl] a. 圣经的；出于圣经的
29. antique [æn'ti:k] a. 自古就有的；古时的
30. encrust [in'krʌst] vt. 包外壳于
31. deluge ['delju:dʒ] n. 洪水；大雨；暴雨
32. fragmentation [frægmenteiʃən] n. 分裂；裂成碎片
33. Gondwanaland 冈瓦纳大陆
34. energetic [enə'dʒetik] a. 精力旺盛的
35. Pangaea n. 泛大陆；联合古陆
36. Laurasia n. 劳亚古陆
37. perception [pə'sepʃən] n. 感觉；理解
38. raft [rɑ:ft] n. 木筏；木排
39. bulldozing ['buldouziŋ] n. 推土
40. crumple [krʌmpl] vt. 把…弄皱；扭弯
41. Panthalassa 泛古洋
42. Andes ['ændiz] n. 安第斯山脉（南美洲）

Lesson Seven

Text

Coal-Forming Environments

For a mat of dead vegetation to be preserved as peat, which is ultimately transformed into coal, the area must be protected from detrital influx, and the water table must remain at or near the ground surface, with no pronounced seasonal lowering. Ideally, the water table should rise slowly and continuously as the area subsides to keep pace with vertical growth of the peat mat. Vegetable matter is rapidly oxidized on exposure, whereas prolonged submergence terminates peat accumulation. A low pH of the peatswamp waters is critical; total degradation results at values higher than 5.0. Even a temporary decrease in acidity may degrade the peat surface to the extent that inorganic constituents of the cellular structure of swamp vegetation are preferentially concentrated on the surface, subsequently to be preserved in coal seams as ash bands. Similar authigenic partings in seams may also arise from burning or emergence oxidation of the peat surface. Prolonged marine incursion is another factor that significantly reduces the preservation potential of a peat.

Conditions favorable for peat accumulation prevail in paralic coal-forming environments of humid coastal plains as southern New Guinea, parts of West Africa, and the Gulf and Atlantic coastal plains of the United States. According to Diessel over 90 percent of all coals formed in a paralic setting. The other broad category of coal-forming environments, limnic, is represented by alluviated interior basins such as the upper Nile and Amazon, and infilled lake systems such as the Okavango of Botswana.

The bulk of the peat mat tends to be provided by collapse and decay of the plant cover, but this is augmented in some areas by driftwood and floating leaves. Rate of peat accumulation largely depends upon climate, being some four times more rapid in tropical forests than in swamps with lower rainfall. Open marshes tend to be dominated by reeds and other herbaceous plants and accumulate large quantities of fungal spores. Marshes, by definition, are devoid of trees, so the resulting peat has no woody material. Swamps contain a variable amount of woody vegetation which increases in proportion in forest swamps and drier forests with dense stands of large trees. Aquatic and semiaquatic plants contribute material to abandoned river channels, ponds and lake floors, which commonly also receive transported debris. These lake floor accumulations include the degradation products of pre existing peat beds, to which are added algae and spores.

All of these different plant communities give rise to distinct maceral types in coal. For example, stunted herbaceous plants and grasses produce inertinite-rich coal, whereas an

abundance of large trees gives rise to a high vitrinite content. But maceral content is also influenced by factors of hydrochemistry and level of the water table.

Most vegetated coastal lowlands show a parallel zonation of plant communities, reflecting differences in maturity, substrate consistency, salinity, and groundwater level. The groundwater level affects not only the living community, but also controls the biochemical environment in which the dead vegetal matter accumulates and is preserved. In modern tropical areas, mangroves extend to the limits of aeration corresponding approximately to neap high water. Mangroves commonly show a well-defined zonation depending upon frequency of tidal inundation, and merge landward into dense fresh-water swamps; marshes are conspicuously absent. Away from the tropics, mangroves gradually give way to a belt of marsh in the most youthful, seaward portions of a prograding lowland; this merges inland into treebearing swamps. Where riverine discharge is large and unconfined, fresh-water marsh may extend to the water's edge. More commonly, however, a belt of saline marsh forms along the zone affected by tidal incursion, and is succeeded inland by a transitional zone of brackish marsh followed by fresh-water marsh and swamp. Brackish and salt marshes are generally not areas of significant peat accumulation, Where present, these thin, marine-influenced peats tend to have a high H_2S content, giving rise to pyritic, high-sulfur coals.

Fresh-water marsh is a more important coal-forming environment. Large areas can be dominated by vegetation floating in shallow, stagnant pools. These floating marsh peats thus accumulate on a root-free underclay and could be mistaken for allochthonous coals in the rock record. In other fresh-water marshes the rootmat of living plants is very thick, with roots commonly penetrating to depths of a meter or more. The marshes grade landward into more stable swamps, which may extend vast distances up alluvial lowlands toward the continental interior. Many of the thickest peats accumulate in these fresh water swamps, and most economically important coal seams were probably of similar swamp origin.

Raised bogs may be locally important as a peat-forming environment, and account for some exceptionally thick seams. These bogs are related to perched water tables, and vary from moss swamps in humid temperate regions to forests comprising a limited number of tree species in the tropics. Raised bogs of Borneo carry dense forests with one or two tree species dominant. The peat surface is typically convex upward, with steep slopes near the margins of the peat domes. Toward the rivers and coast the number of tree and shrub species increases before passing into coastal mangroves.

Peat growth may evolve through several stages before becoming a peat bog. Initial peat accumulation from allochthonous material, or as a partially floating mat forms an island that diverts flow across progressively narrower areas of the basin. The peat becomes less frequently inundated as a consequence, with additional water being supplied by direct precipitation or by local drainage into the depression. The rising peat surface develops its

own water table and can therefore accumulate to considerable thickness. In the case of a 33 m seam in Queensland, Australia, Smyth suggests that the final stage of peatbog formation was rapidly attained, and that most of the seam accumulated in a peatbog environment. This mode of accumulation also accounts for the very low detrital mineral content and the high-inertinite composition.

Although often difficult to reconstruct because of poor preservation and mixing, the paleoecological relationships of some ancient coal-forming plant communities have been established. These reflect a zonation into open water, marsh and swamp environments not unlike those of today, although spanning a narrower range of adaptations. The fernlike floras of the Northern Hemisphere Carboniferous are poorly represented in Gondwana deposits, which characteristically show evidence of autumnal leaf accumulations.

(*From Terrigenous Clastic Depositional Systems*, *pp*255—258)

New Words and Expressions

1. peat [pi:t] n. 泥炭
2. detrital [di'traitəl] a. 碎屑的
3. influx ['inflʌks] n. 流入量；流入；河口
4. peatswamp ['pi:t'swɔmp] n. 泥炭沼泽
5. cellular ['seljulə] a. 细胞状的；多孔的；蜂窝状的
6. authigenic [ɔ:θi'dʒenik] a. 自生的
7. incursion [in'kə:ʃən] n. 进入；流入
8. paralic [pə'rælik] a. 近海的；海陆交互的
9. limnic ['limnik] a. 湖沼的
10. alluviate [ə'lu:vieit] v. 冲积
11. augment [ɔ:g'ment] v. 增长；增加；扩大
12. marsh [mɑ:ʃ] n. 沼泽
13. reed [ri:d] n. 芦苇
14. herbaceous [hə:'beiʃəs] a. 草本的；草质的
15. fungal ['fʌŋgəl] a. 如真菌的；真菌的
16. aquatic [ə'kwætik] a. 水生的；水的
17. semiaquatic ['semiə'kwætik] a. 半水生的；近水生的；半水栖的
18. maceral ['mæsərəl] n. 煤岩显微组分
19. stunt [stʌnt] v. 使发育不良
20. inertinite [i'nə:tinait] n. 惰性组
21. vitrinite ['vitrinait] n. 镜质组；镜质体
22. substrate ['sʌbstreit] n. 基质；基层
23. salinity [sə'liniti] n. 盐度；含盐量
24. mangrove ['mæŋgrəuv] n. （热带沿海生长的）红树林
25. aeration [eiə'reiʃən] n. 通风；通气；充气
26. neap [ni:p] n. 最低潮
27. inundation [inʌn'deiʃən] n. 泛滥；海侵
28. pyritic [pai'raitik] a. 黄铁矿的
29. pyrite ['pairait] n. 黄铁矿
30. stagnant ['stægnənt] a. 停滞的；不流动的
31. underclay ['ʌndəklei] n. 底粘土层（煤层下）
32. allochthonous [ə'lɔkθənəs] a. 外来的；移置的
33. alluvial [ə'lu:viəl] a. 冲积的
34. perched water table 上层滞水位
35. shrub [ʃrʌb] n. 灌木；灌丛
36. inundate ['inʌndeit] v. 淹没；泛滥；使充满
37. paleoecological [pæliəui:kələdʒikəl] a. 古生态学的
38. fernlike ['fə:nlaik] a. 像蕨类植物的
39. flora ['flɔ:rə] n. 植物群；植物区系

Notes to the Text

1. For a mat of dead vegetation to be preserved as peat, which is ultimately transformed into coal, the area must be protected from detrital influx, … with no pronounced sea-

sonal lowering. 要使一层植物遗体以泥炭的形式保存下来，并最终转化成煤，那么这个地区就不能有碎屑物注入，潜水面也要维持在地表或近地表，不能有显著的季节性下降。句中 For …into coal 为不定式短语作状语，在该不定式短语中，还包含有一个非限定性定语从句。

2. Rate of peat accumulation largely depends upon climate, being some four times more rapid in tropical forests than in swamps with lower rainfall. 泥炭堆积的速度主要取决于气候因素，在热带森林中的堆积速度要比在降雨量较少的沼泽中快四倍左右。

句中 being … rainfall 为分词短语做状语，该短语中的 some 为副词，意思是“大约”。如 The belt pulleys are some sixty in all. 皮带轮总共约为60件。

3. Raised bogs may be locally important as a peat-forming environment, and account for some exceptionally thick seams. 高位沼泽作为一种泥炭形成环境，在某些地区是很重要的，它可以解释一些特厚煤层的成因。

Translation Guide
翻译的标准和过程

一、翻译标准

对于翻译的标准，比较一致的看法有两条——准确、通顺。“准确”是指要忠实于原作的内容，对原作所述的内容不予增添和删改，同时还要尽量保持原作的文体风格。“通顺”是指译文必须通顺易懂，符合译文语言习惯。这里需要指出的是，“准确”并不是要照搬原文形式，逐字死译，而“通顺”也不是可以随意发挥，忠实于原作和译文通顺两者是统一的。

对于科技作品来说，其特点是叙述事理、传授知识、探讨问题，语言往往简洁明了，结构严谨，逻辑性强，公式、数据和专业术语多。所以对科技作品的翻译必须做到概念清楚，语言通顺，专业术语正确。

举例说明：

例1 This mineral is no harder than that one.

［误］这种矿物没有那种矿物硬。

［正］这种矿物和那种矿物一样软。

可以看出，“准确”是第一位的，译文“准确”对科技作品的翻译来说非常重要。然而，在译文准确的基础上，还应注意译文的通顺。

例2 What is large and what is small is relative.

［不好］什么是大的和什么是小的是相对的。

［较好］大和小是相对的。

二、翻译过程

翻译过程大体上可以概括为理解和表达两个阶段，理解是指对原作内容要正确地理解，表达是指在译文语言中寻找和挑选恰当的表达方式。

1. 在理解上，最大的问题恐怕是长难句的理解。一般说来，长难句中难点的形成有以下几个方面：

1）词汇难点：英语中一个词往往可以分属几个词类，在不同的场合或与不同的词搭配时，意义也不相同。因此，在翻译时，首先必须正确选择词义。

2）语法难点：有的句子除了有主语和谓语外，还有复杂的次要成分，如宾语、定语、状语、独立成分以及各种从句。有的句子有并列成分和几个分句，而分句又带从句，从句本身又带从句。有的句子省略一些成分或者成分倒装，有的有词语分割，不易看出词与词或句与句之间的关系。

2. 在表达上，其难点也不外乎是词汇和语法两方面的。

1）词汇难点：在翻译过程中，常常会遇到一些词或词组无法直接搬用辞典中的释义，如果勉强按照词典所给的意义译出，译文就会令人费解。在这种情况下，就要在弄清原文词义的基础上根据上下文的逻辑关系以及译文语言的习惯对词义加以引伸，以更确切地表达原文的思想内容。

2）语法难点：英语和汉语的结构不同，两者不能在形式上相互照搬，尤其在翻译长句时，要按照汉语的习惯，把长句译成短句，并安排好各短句之间的次序。

举例说明：

例1 The proof that magmatic emanations have passed into such waters is found in the presence in them of such substances as sulphur, arsenic, boric acid, etc, in quantities and under conditions which show that they could not have been leached out from the original rocks of the country.

分析：句中有两个连接词 that，第一个 that 引出同位语从句，把主句 The proof … is found … under conditions 分开，说明 proof；第二个 that 引导的是一个宾语从句。句中 which 代表前面的复数名词，所以谓语用 show。

译文：该水体含有大量的硫、砷、硼酸等物质，而这些物质不可能是由该区基岩里淋滤出来的，由此证明岩浆喷出物进入水体。

例2 The belief that all unconformities are significant punctuation marks in geologic time scale was severely discredited when stratigraphic studies expand into regions where no great breaks are present between systems and where major unconformities are present within previously established systems.

分析：that 引出的同位语从句 "that all … time scale" 说明主语 belief 的具体内容，把主句中的主语 belief 同谓语 was discredited 分开。when 引出的时间状语从句又带有两个以 where 引出的定语从句，这两个并列的定语从句用连接词 and 连接起来，用来修饰时间状语从句的名词 regions。从词义上来说，punctuation marks 指标点符号，这里不能直译为标点符号，这样会令人费解，应结合上下文加以引申，译为"分界标志"。同时，break 在这里也要引申为沉积间断。

译文：传统的观念认为所有的不整合都是地质历史上的重要分界标志，而当地层研究延伸到这样一些地区——系与系之间并没有大的沉积间断，但在已确立的系的内部却出现了大的不整合时，这种观念就大大的动摇了。

另外，在翻译的过程中，除了词法、句法外，还要具备一定的专业知识。例如：

例3 The main thing to notice is that sediments, which once were muds, terminate abruptly against limestone, which once was the main body of the reef.

译文1：应该注意的一个要点是：过去曾经是淤泥的沉积物，接触到过去曾经是生物礁主体的灰岩时便突然终止了。

分析："接触到…便突然终止了"这个译文是很难理解的，原因是译文中对 terminate abruptly against 在该句中的确切含义理解不深，缺乏专业知识。这个短语的意思在句中应译为"和…为突变接触"。

译文2：应该注意的一个要点是，泥质沉积物和由生物礁体形成的灰岩之间为突变接触

Exercises

1. Questions for review:
   1) What is the difference between marshes and swamps?
   2) What are the conditions favorable for peat accumulation?
   3) Name the factors by which the maceral content is influenced.
   4) What is meant by allochthonous coals?
   5) What does the rate of peat accumulation largely depend upon?
2. Fill in the blanks with correct terms given below:

   vitrinite-rich, marshes, fresh-water, inertinite-rich, swamps, raised bogs, allochthonous, pyritic

   1) Herbaceous plants and grasses produce _____ coal.
   2) _____ are dominated by reeds and other herbaceous plant, and devoid of trees.
   3) An abundance of large trees gives rise to a high _____ coal.
   4) _____ contain a variable amount of woody vegetation, compared with marshes.
   5) The marine-influenced peats tend to have a high H_2S content and produce _____ coals.
   6) Some peat and even coals may be reworked and redeposited in a fluvial system and are called _____ in origin.
   7) _____ are related to perched water tables.
   8) _____ marsh is not affected by sea water.
3. Give the Chinese/English equivalents for the following:

1) authigenic partings	6) 成煤环境
2) plant communities	7) 森林沼泽
3) brackish and salt marshes	8) 草本植物
4) root free underclay	9) 废弃河道
5) riverine discharge	10) 海水侵入

4. Choose the correct terms to complete the statements:
   1) The peatswamps must be protected from _____ in order to preserve a mat of dead vegetation as peat, which is finally transformed into coal.
      a. fresh-water b. salt water c. detrital influx
   2) Environments conducive to peat accumulation are _____ areas.

a. paralic b. desert c. glacial

3) The marshes can be distinguished on the basis of _____ into three types: salt, brackish, and fresh-water marshes.

a. climate b. vegetation c. salinity

4) The climate favorable for peat accumulation is _____.

a. arid b. warm c. frigid

5) Water table must remain _____ the ground surface to form thick peat beds.

a. much higher than b. much lower than c. near

5. Translate the following paragraphs into Chinese:

Substantial coal seams trending approximately parallel to depositional dip are associated with birdfoot-type or elongate river-dominated deltas, accumulating along levees and infilled bays. Coals capping the thick, upward-coarsening delta-front and interdistributary bay sequences are extensive but seldom attain significant thicknesses. These seams are relatively free of washouts because of the limited number of distributaries, which remain stable while extending their courses basinward.

Coals of lobate deltas accumulate during both the constructive and destructive phases of deltaic sedimention. During the constructive phase the detla plain is traversed by numerous distributary channels. Peat formation is restricted to the interdistributary tracts, which in many cases are of limited extent. The coals are therefore characterized by "wants" corresponding to the positions of the active distributary channels. Ash content can be high because low levees allow frequent inundation of the marsh. In contrast, blanket peatswamps originating during abandonment of lobate deltas can be thick and remarkably widespread. The seaward edge of the abandoned delta lobe is attacked by shallow, brackish bays. Peat accumulates on the more slowly subsiding delta platform landward of the maximum marine influence. Blanket peats of the Mississippi delta plain cover areas of up to 190mi^2 (500km^2). As transgression progresses, the peats are likely to he subject to marine influence, which impairs the chemical quality of the coal, at least in its upper parts.

Tertiary lignites of the Gulf Coastal Plain originated partly as thick blanket peats formed in a variety of inactive delta-plain environments. The lateral extent of these peats was determined by the size of the underlying platform, which in places may have comprised several adjacent, inactive delta lobes. In other coal basins, too, the most persistent delta-plain seams probably originated as similar blanket peats. These seams are readily distinguished from the far more numerous but laterally more restricted seams representing peat accumulation during the active delta phase.

6. Translate the following into English:

1) 世界煤炭资源的40%产于上石炭统和二叠系。

2) 如果没有古代丰富的植物，煤是不可能形成的。

3) 泥炭的广泛堆积是随着志留纪裸蕨植物 (Psilophyte) 的出现而开始的。

4）古代的许多沼泽和现代的沼泽相比是非常大的。

5）当植物死亡以后，它们会暴露在空气中并氧化分解。

Reading Material

Application of Depositional Models

Once a depositional model has been established for a particular coal deposit, it can be used to predict the distribution of coal seams in the region, and thus delineate the areas most suitable for further exploration. At a different scale, such a model can also be used to improve the understanding of thickness and quality variations in an individual seam over a colliery holding, as well as variations in the nature of the roof or floor strata, and thus be of invaluable assistance in mine planning operations.

The three-dimensional shape or geometry of coal bodies is affected directly by the depositional setting in which the sequence accumulated. Many of the sedimentary environments that precede coal swamp formation act to shape the topography on which the swamp develops. This topography in turn influences the thickness pattern of the resulting seam, and, to a lesser extent, the lateral continuity of the coal bed. The environments that coexist with the peat swamp in adjacent areas, together with internal swamp processes such as plant growth, plant decay, fires and water flow, affect these features, particularly seam continuity, as well. Post-depositional processes, such as channeling, may cause further variations (e. g. washouts), while compaction associated with burial must also be considered in many areas.

The shape of a coal seam may also be influenced, to some extent, by the tectonic structure of the sedimentary basin in which it is developed. Variations in thickness may be associated in the field with fold axes or fault zones possibly reflecting differential subsidence of the basement materials.

A summary of the depositional controls on the shape of coal bodies, based mainly on the Appalachian model, is given below. These factors may be used to guide the design and implementation of a broad-scale exploration programme, including such aspects as the selection of the most appropriate drilling sites. However, they may also be of vital significance in the more detailed studies associated with the planning and operation of coal mines, and a number of examples of the use of such data in this way are given by Horne et al.

BACK-BARRIER DEPOSITS

Swamps in a back-barrier environment form due to infilling of lagoons behind the barriers. Coals formed in these areas tend to occur as elongate podshaped bodies, oriented parallel to the trends in the associated barrier systems and, most commonly, parallel to deposition-

al strike. The shape of the resulting peat bed may be modified in part, however, by contemporaneous and post-depositional tidal channel activity.

LOWER DELTA PLAIN DEPOSITS

The swamps in a river-dominated lower delta-plain develop on the levees along the distributary channels, which are generally straight and oriented perpendicular to depositional strike. The resulting coal seams are usually relatively thin and split by numerous crevasse-splay deposits. They tend to be relatively continuous along the direction of depositional dip, but are often discontinuous parallel to depositional strike, with coal being replaced in places by interdistributary bay-fill material.

UPPER DELTA-PLAIN AND FLUVIAL DEPOSITS

In an upper delta or alluvial environment, peat generally builds up as pod-shaped bodies on the low-lying parts of the flood plain adjacent to the meandering stream channels. The resulting seams tend to be oriented parallel to depositional dip, but are less continuous than those of the lower delta-plain facies. Because of the less regular course followed by the river channels, the seams may vary greatly in thickness over relatively short distances, and numerous splits may be developed in association with the contemporaneous levee bank deposits. The shape of the seams may also be considerably modified by washout development at a later stage of their depositional history.

TRANSITIONAL DEPOSITS

The transition between upper and lower delta-plain environments is marked by extensive swamp development on almost completely filled interdistributary bays. Coal seams are generally quite extensive with a tendency to be slightly elongate parallel to depositional strike. Like the coals of the upper delta-plain, they may contain splits in areas near contemporaneous channels, and washouts due to subsequent channel activity.

The formation of pyrite and related minerals in coal by bacterial reduction of sulphate in peat waters is discussed Probably because the supply of sulphate is greater in sea water than river water, this reaction appears to take place most readily in coals that are associated with marine conditions. Pyritic material especially that occurring in framboidal form, is most abundant in seams that are directly overlain by marine strata and for this reason is thought to develop mainly in areas where the swamp was transgressed by a marine or brackish environment shortly after peat accumulation. If, however, a sufficient thickness of sediment is deposited above the peat early enough to shield it from the effects of this transgression, the amount of pyritic sulphur in the seam is significantly reduced.

Because of the role played by this trangressive process the depositional environments that produce the sediments above the coal are more important to the distribution of the type and amount of sulphur in the coal than the environments within which the coal itself

was deposited. Seams that accumulated in areas of marine influence, such as back-barrier environments or lower delta-plains are more likely to be overlain by marine to brackish sediments than are those of an upper delta-plain or fluvial environment, and thus contain higher proportions of framboidal pyrite. Most of the pyritic sulphur of upper delta-plain coals, at least in the Appalachian region, appears to be of secondary origin in the form of massive plant replacements and cleat infillings.

An example of the role of the depositional environment in determining the distribution of sulphur in coal seams can be seen in the Illinois Basin of the U. S. A. Most of the seams in this area are directly overlain by dark grey marine shale reflecting widespread marine transgressions throughout the region. Several of the coal beds, however, are cut in places by long belts of contemporaneous channel-fill sandstone, and overlain along the flanks of these structures by crevasse-splay deposits of light grey terrestrial shale, siltstone and sandstone. Coal is generally absent within the channels and often thin or split by shale beds immediately adjacent to them. However, the major seams thicken considerably in a wide belt along the channel beyond this zone.

In the areas where the crevasse-splay roof deposits are developed, the total sulphur content of the seam (represented largely by pyritic sulphur) is considerably less than it is in the remainder of the region. The terrestrial sediments, and possibly the associated hydrologic systems, apparently acted to protect the peat from the ingress of sulphate rich sea waters while marine transgression was in progress and thus cut off the pyrite-producing process from a large part of its sulphur supply. Because of the better quality of the coal in these areas, as well as the general development of a thicker working section, a large part of the mining activity in the basin is concentrated along sides of these channel systems.

The three dimensional arrangement of the non-coal strata in the sequence, especially those occurring above the seam, can be an important factor in the stability and safety of open-cut and underground mining operations. Rock types and lithofacies respond in different ways to the mining process, reflecting a combination of the sediment's grain size distribution, cementing materials, bedding characteristics and depositional structures, as well as post-depositional features such as compaction effects and the joint or fault pattern.

Problems may be encountered with roof falls in underground mines or slope failure in open-out excavations due to unfavourable combinations of these factors. However, in some cases the nature of the noncoal strata can also cause difficulties with effective stripping of overburden, or controlled caving of roof material if the beds involved are excessively strong.

(From Coal Geology and Coal Technology, pp174- 176)

New Words and Expressions

1. delineate [di'linieit] v. 叙述；描写
2. colliery ['kɔliəri] n. 煤矿
3. topography [tə'pɔgrəfi] n. 地形；地势；地形学
4. coexist [ˌkəuig'zist] v. 共存；共处

5. washout ['wɔʃaut] n. 冲刷；冲蚀；冲刷沟
6. back-barrier ['bæk 'bæriə] n. 坝后
7. lagoon [lə'gu:n] n. 泻湖
8. levee ['levɪ] n. 天然堤
9. distributary [dis'tribjutəri] a. 分流的；支流的
10. interdistributary [intə'dis'tribjutərɪ] a. 分流间的
11. meander [mi'ændə] n. 河曲；曲流
12. framboidal ['fræmbɔɪdəl] a. （草）莓状结核的
13. transgression [træns'greʃən] n. 海侵；海进
14. brackish ['brækiʃ] a. 稍咸的
15. cleat [kli:t] n. 割理（煤层）；内生裂隙
16. flank [flæŋk] n. 翼；侧
17. crevasse-splay [kri'væs-spleɪ] n. 决口扇（决川）；决口扇形滩
18. ingress ['ingres] n. 侵入；海侵
19. lithofacies [liθə'feɪʃi:z] n. 岩相（沉积岩）
20. excavation [ekskə'veiʃən] n. 掘进；挖掘

Lesson Eight

Text

Coal Basins

Tectonic setting influences the number, thickness, continuity, and quality of seams, and determines their attitudes, degree of disruption, and present depth. This in turn determines their mineability. Coal basins that have been subjected to tectonic deformation, with folding and faulting over a broad area, are the most important economically. Over 90 percent of the world's coal production comes from regions affected by late Paleozoic and end Mesozoic-Tertiary tectonism, with only a small amount from the vast, stable intracontinental basins such as the Moscow Basin.

COAL BASINS RELATED TO SUBDUCTION

Orogenic foredeeps and back-arc basins undergo locally tight folding, thrusting, and, where oblique collision is involved, major strike-slip faulting. Rapid subsidence through high geothermal gradients produces coals of subbituminous to anthracite rank. In areas of maximum subsidence, coals may be thick and numerous but contain large detrital splits. Further, the seams commonly show a very complex three-dimensional geometry.

A modern example of a subduction-related coal basin is the southwestern foredeep of New Guinea, which is underlain by as much as 13,000 m of Cenozoic sediments containing abundant coal seams. The Permian Sydney Basin of Australia is remarkably similar to the New Guinea foredeep basin in geometry and inferred origin.

Coals in these orogenic basins are rapidly covered with sediment, and therefore tend to be bright. Although deeply buried during tectonic subsidence, subsequent basin-edge tilting and erosion, or the onset of later tectonic uplift, elevates many seams to levels at which they can be mined without difficulty.

COAL BASINS RELATED TO EPEIROGENY

Intracontinental rift grabens and strike-slip pull-apart basins can involve large vertical displacement, but deformation is less intense than is the case in orogenic basins. However, except in areas of persistent block faulting, even the most tectonically active intracontinental basins are generally subject to only moderate tectonic subsidence. Thus, the total coal-bearing succession tends to be thinner. The number of seams is limited, but their geometry and thickness are highly variable. Patterns of splitting are less complex than in the deposits of subsiding continental margins, and the seams contain a greater proportion of dull bands

because of slow burial. Many of the more rapidly subsiding epeirogenic basins tend to fill with conglomeratic sediments devoid of coal. Significant exceptions include the Cantabrian coal basins of Spain, where peats accumulated during quiescent episodes. Lignites of Victoria, Australia, occupy a Cenozoic aulacogen which opened to the sea, these seams are among the thickest known.

STABLE CRATONIC COAL BASINS

Coal-bearing successions of cratonic basins are normally thin and comparatively uniform, with few seams. Individual seams may, however, attain considerable thickness, and some cover vast areas of 4000mi^2 (10,000km^2) and more; other seams are restricted to paleotopographic depressions, terminating abruptly against basement highs.

Smyth (1980) has shown that most Australian coals thicker than 15m (50ft) accumulated in small, stable intracratonic basins subject to very gradual subsidence.

Coal-bearing successions in the intracratonic Karoo Basin change in response to elongate downwarps in the regionally stable basement platform of Precambrian rocks. Coals are more numerous in the downwarps, within which regressive deltaic sequences are more abundant than they are on the adjacent stable platform. Individual seams commonly split in the direction of downwarped areas. This simple pattern of interfingering contrasts with the complex splits in orogenic coal basins.

Coals of cratonic downwarps are predominantly of low to medium rank because of low geothermal gradients and limited depths of burial. The Cooper Basin of Australia, with a radioactive crystalline basement in parts, provides an exception. High temperatures associated with igneous intrusion produce pockets of high-rank coal unrelated to depth. Burned coal, or natural coke, forms at the intrusive contact. The generally dull nature of epeirogenic basin coals reflects prolonged exposure, responsible for the high inertinite basin and ash content.

PASSIVE-MARGIN COAL BASINS

Terrigenous clastic wedges that prograde over a progressively deepening shelf, for example the northern Gulf Coast Basin, commonly contain major coal deposits in the updip facies. The coal bearing succession can show evidence of listric growth faulting, but the coal-bearing strata do not as a rule display the dramatic expansion characteristic of the hydrocarbon bearing facies farther basinward.

EFFECTS OF CONTEMPORANEOUS TECTONISM ON COAL

Contemporaneous tectonism produces dramatic changes in coal-seam thickness and petrography. Displacement may be related to synclinal warping, graben development, or growth faulting. In parts of the Appalachian Basin subsidence appears to have limited peat accumulation on the downthrown block, whereas thick coals are located along the edge of the up

thrown block, which provided a platform for peat accumulation. Elsewhere in the Appalachian Basin the coals may thin or merge onto the upthrown block, and some coals are preserved only on the downthrown block, where they survived the destructive effects of oxidation at higher levels. Subtle differences in elevation of peatswamps subject to minor tectonism might be reflected in the microlithotypes, chemistry, or ash content of the coal.

CHANGES IN TECTONIC SETTING OF COAL BASINS

Coal-forming paralic environments, in which the bulk of the world's coal resources originated, commonly precede limnic environments during coal-basin evolution. For example, the Late Carboniferous foredeep north of the Variscan highlands of Europe first contained large paralic coal basins along the prograding fluvio-deltaic margin, followed by the limnic coals of intermontane basins. Similarly, in the classical thick and relatively undeformed clastic wedges that result from asymmetric basin filling, there may be a gradual vertical and updip progression from distal paralic to proximal limnic coals.

(*From Terrigenous Clastic Depositional Systems*, *pp*262 264)

New Words and Expressions

1. mineability [ˌmaɪnəbiliti] n. 可采性
2. intracontinental [ˌintrə kɔntiˈnent] a. 陆间的
3. foredeep [ˈfɔːdiːp] n. 前渊；陆外渊；狭窄深海槽
4. epeirogenic [i pairəuˈdʒenik] a. 造陆的
5. conglomeratic [kɔnˈgləməˈrætik] a. 砾岩状；含砾的
6. quiescent [kwaiˈesnt] a. 不动的；静止的
7. episode [ˈepisəud] n. 幕；期
8. aulacogen [ˈɔːləkədʒən] n. 断陷槽
9. cratonic [ˈkreɪtɔnik] a. 克拉通（稳定地块）的
10. paleotopographic [pælɪəu tɔpəˈgræfik] a. 古地形的
11. downwarp [daunˈwɔːp] v. 向下弯曲；下沉
12. regressive [riˈgresiv] a. 海退的；后退的
13. interfinger [intəˈfiŋgə] v. 指状交错
14. terrigenous [teˈridʒinəs] a. 陆源的；陆生的
15. prograde [ˈprəugreid] v. 推进；延伸
16. updip [ˈʌpdip] a. 上倾的
17. listric [ˈlistrik] a. 铲状的
18. synclinal [sinˈklainl] a. 向斜的
19. warp [wɔːp] v. 弯曲；翘曲
20. microlithotype [ˈmaikrəuˈliθətaip] n. 显微煤岩类型
21. fluvial-deltaic [ˈfluːviəl-delˈteɪik] a. 河流三角洲的
22. intermontane [intəˈməntein] a. 山间的
23. asymmetric [æsɪˈmetrik] a. 不对称的
24. proximal [ˈprɔksiməl] a. 最近的；近似的

Notes to the Text

1. Orogenic foredeeps and back-arc basins undergo locally tight folding, thrusting, and, where oblique collision is involved, major strike-slip faulting. 造山带前渊和弧后盆地在局部地方会遭受紧密褶皱作用和逆冲断层作用，而且在有俯冲碰撞的部位，还会遭受大规模的平移断层作用。

句中的三个动名词短语皆为动词 undergo 的宾语，在最后一个动名词短语 major strike-

slip faulting 之前，有一个以 where 引导的状语从句修饰该短语。

2. Coals in these orogenic basins are rapidly covered with sediment, and therefore tend to be bright. 在这些由造山作用形成的盆地中，煤能够被沉积物迅速地掩埋，因此这些煤往往是光亮型的。

句中的 bright 是指煤的岩石类型，即“光亮型的”。例如：bright coal 亮煤。

3. Coal-forming paralic environments, in which the bulk of the world's coal resources originated, commonly precede limnic environments during coal-basin evolution. 世界上的大部分煤炭资源形成于近海成煤环境，这种近海成煤环境在聚煤盆地的演化过程中常常可以转化成湖沼型环境。

句中 in which … originated 为非限制性定语从句，修饰 coal-forming paralic environments. 句中 precede 的原意是“在…之前”、“先于”，在此处可以结合上下文转译为“转化成”。

Translation Guide
翻译过程中常见的错误

在翻译过程中常见的错误可以分为两类，即词法和句法两个方面的错误。

1. 词法方面的翻译错误举例

汉英两种语言中一词多义和一词多用现象都很普遍，而英语中某个词与汉语中相应的词之间在使用范围和搭配上又有许多差别。因此，在翻译过程中常见的错误之一是词义选择和理解方面的错误。例如：

1) The research groups constantly had to develop new articles which had never before been produced in the world.

[误] 研究组必须不断发表世界上过去不曾发表过的论文。

[正] 研究组必须不断研制出世界上过去从未制造过的物品。

2) But for water and air living things could not exist.

[误] 但是生物不可能为了水和空气而生存。

[正] 如果没有空气和水，生物就不能生存。

3) Lending my dictionary to others is the last thing I want to do.

[误] 借字典给别人是我要做的最后一桩事。

[正] 借字典给别人是我最不愿意的事。

上述例句中的错误是因对 article，but for 和 the last thing 的意义未能正确理解造成的。

4) 墙上有个洞。

[误] There is a hole on the wall.

[正] There is a hole in the wall.

5) 墙上有一幅世界地图。

[误] There is a map of the world above the wall.

[正] There is a map of the world on the wall.

6）一架梯子靠在墙上。

[误] A ladder is leaning above the wall.

[正] A ladder is leaning against the wall.

汉语表达“在墙上”可以有上述三种不同的英语表达方法。例句4）中，是因为洞在墙内，所以用 in the wall。例句5）中，是指挂在墙上，直接接触，所以要用 on the wall。例句6）中，是指倚靠在墙上，要用 against。

2. 句法方面的翻译错误举例

1) Contrary to what is often thought, the earth does not move round in the empty space.

[误] 与通常的想法相反，地球在空无一物的空间是不运转的。

[正] 与通常的想法相反，地球并不是在空无一物的空间运转的。

2) This theory of convection currents within the earth is not yet accepted by all geologists.

[误] 所有的地质学家都不赞同这个地球内部存在着对流运动的理论。

[正] 并非所有的地质学家都赞同这个地球内部存在着对流运动的理论。

以上两个例句是由于不了解英汉两种语言表达否定方式的不同而造成的。在英语中否定谓语，译成汉语应否定状语，等等。

3）看到这张地形图时，她的心往下一沉，简直站不住了。

[误] When she looked at the topographic map, her heart sank and could harldy stand.

[正] When she looked at the topographic map, her heart sank and she could hardly stand.

在例句中，her heart 可以做 sank 的主语，但不能做 could hardly stand 的主语，因此必须在连接词 and 后加主语 she，才符合逻辑。

Exercises

1. Questions for review:
   1) Coals of cratonic downwarps are predominantly of low to medium rank. why?
   2) What do orogenic foredeeps and back-arc basins undergo locally?
   3) What is meant by the terms continuity, attitudes, and quality, as applied to coal seams?
   4) Explain the changes in tectonic setting of coal basins.
   5) Give an example of stable cratonic coal basins in China.
2. Fill in the blanks with correct terms given below:

   listric growth faulting, limnic, subduction, cratonic basins, epeirogeny

   1) Orogenic foredeep and back-arc basins are involved with _____.
   2) Intracontinental rift grabens and strike-slip pull-apart basins are related to _____.
   3) According to the text, the coal-bearing succession of passive-margin coal basins can

show evidence of ____.

4) The paralic environments are often followed by ____ environments during coal basin evolution.

5) Coal-bearing successions of ____ are comparatively thin and uniform.

3. Give the Chinese English equivalents for the following:

1) 同生断层	6) downwarps
2) 上升盆	7) listric growth faulting
3) 块断作用	8) continuity of seams
4) 山间盆地	9) pull-apart basins
5) 地热梯度	10) downthrown blocks

4. Fill in the blanks with the words below:

in **under** **of** **and**
during **for** **through** **which**

Stable crustal plates with basins of accumulation within or a trailing-edge margin will be characterized by low relief and widespread, blanket-type accumulations of sediment such as are present along the southeastern Atlantic Coastal Plain and adjacent continental margin today. Similar conditions were present ( )the midwestern United States ( ) early Paleozoic times. These accumulations are dominated by sand size quartz and carbonates with some muds. The terrigenous sediment is supplied by previously existing sediments and sedimentary rocks. Long-term quiescence may permit erosion to continue down ( ) the metamorphic layer and into the plutonic rocks. ( ) the most part this will not greatly affect the composition of sediments accumulating on the stable shelf because of prolonged weathering and transport. Some potassium feldspar may persist, however, as has been observed ( ) Cambro Ordovician rocks of the upper Mississippi valley. Stable tectonic conditions ideally produce sediments ( ) are texturally and compositionally mature or supermature.

Modest tectonic activity such as would be brought about by nonviolent plate collision produces folding, thrusting, and metamorphism as well as at least a modest amount of relief. The relatively rapid erosion of both sedimentary ( ) metamorphic source rocks produces sediments which are less mature both physically and chemically than ( ) quiescent conditions. These fluvial, deltaic, and shelf sediments will contain a significant amount ( ) rock fragments and some mud. The geometry of these deposits is somewhat lenticular.

5. Translate the following into Chinese:

Basins can be simple, with only a single source and few depositional environments, or they may be quite complex, with numerous sources, polycyclic sediments, and many varied depositional environments. Regardless of the size, complexity, or tectonic setting of the basin under consideration, it is important to conduct its analysis in a systematic fashion. Some general models for basin development and for basin

analysis have been developed by F. J. Pettijohn and P. E. Potter together with some of their students and colleagues and they are briefly summarized here.

Probably the simplest general basin model is one involving direct sediment contribution from distinct and geographically separated sources. Here sediment body geometry, mineralogy, and paleocurrent indicators are likely to be straightforward and permit reconstruction of the system without difficulty. Some perturbations on this general model are possible depending on the positions of the source rocks and the amount of mixing of sediments during transportation and deposition. For example, although separated geographically, the sediments produced from the source rocks may be thoroughly mixed in the depositional basin or they may remain somewhat separated. Another variation on this theme is caused by the different source rocks being layered at one location. If they are horizontal, erosion should proceed from the topmost unit downward and resulting deposition in the basin should reverse the stratigraphic order of the source rocks. Strongly tilted source rocks could provide all three source types to the basin simultaneously and produce a mixed population of sediment.

6. Translate the following sentences into English:

1) 不同类型的聚煤盆地可以根据构造背景，几何形态以及充填方式这些特征的组合进行划分。

2) 海相碳酸盐岩，泥岩和石英砂岩常常沉积于浅而稳定的地台型盆地中。

3) 在广阔的克拉通内盆地 (intracratonic basins) 中，占主导地位的是冲积三角洲体系。

4) 流速缓慢的河流，其规模不管有多大，只能搬运不大于粉砂的物质。

5) 无烟煤通常是在褶皱山区被找到，而烟煤则是在岩层平坦的地区被发现。

Reading Material

Basin Analysis

SEDIMENT BODY GEOMETRY

The size and shape of sediment bodies is probably the most fundamental type of data utilized in basin analysis; however, it is commonly overlooked. There is value in determining the overall dimensions of the entire basin as well as the size and shape of each of the lithostratigraphic units it contains. Such data are obtained through field mapping and measurement of stratigraphic sections, logging of cores or other subsurface samples, or from geophysical data.

It is not uncommon for the stratigraphic sequence in a given basin to be incomplete. That is, unconformities may be present, signifying the removal of a certain part of the rock record. These situations may cause the geologists's job of determining the true geometry of sediment bodies to be quite difficult.

Large-scale sedimentary sequences are grossly wedge shaped regardless of composi-

tion or location. Within this overall wedge-shaped prism of sedimentary rocks there may be several lithostratigraphic entities each of which may have its own characteristic shape. Let us consider some general size and shape aspects of sediment bodies from various environments. At this stage in the analysis only the gross lithology and the geometry will be considered.

Probably the best example to use is that of quartz arenite with at least moderate sorting. At least four or five major depositional environments may fall within this general lithology. A tabular or blanket sand body could indicate the shoreface or an inland dune field. Linear sand bodies may represent barriers if they are straight or gently curved. Anastomosing patterns suggest the fluvial system. Branching or bifurcating linear sand bodies could develop as a tributary or distributary system; paleocurrent direction would determine which one was present.

This is but one example of how sediment body geometry may be useful. In most cases additional data beyond size and shape are necessary to accurately establish the particular depositional system of the sediment body in question. Certainly, however, a knowledge of the size and shape of the unit will permit the geologist to exclude certain depositional systems from consideration and thereby enable better utilization of time in analyzing the sediment body.

PROVENANCE

Basin analysis includes more than interpreting the environment of deposition of various facies. To gain a comprehensive understanding of the basin it is also necessary to know where the sediments came from, that is, their source rock type and location. The subject of this section, the provenance of the basin sediments, covers just those points. Because the basic thrust of this book is at the megascopic scale, emphasis will be on those provenance characteristics that can be seen in the field with the unaided eye or the hand lens. The reader should know that detailed provenance studies require at least petrographic studies, and in some cases detailed mineralogy or trace element composition is required in order to trace the origin of some sediments.

For proper recognition of sediment particles that might be indicative of provenance, at least coarse sand is necessary. Typically, pebbles and cobbles form the basis for most provenance information in the field or at the hand lens scale. Because great detail, such as quartz types or specific mineral composition, cannot be determined at this level of observation, one must look for readily identifiable and traceable detrital particles. Examples are various rock fragment types, chert varieties, particles containing recognizable fossils, and any metallic ores in large clasts. Any of these particle types is exotic enough to be traceable to a source rock.

One of the primary techniques that has been utilized in determining direction of ice movement by Pleistocene glaciers is through the presence of exotic rock particles which can

be tied to a known source. Large clasts of basaltic rock with native copper have been found in glacial drift in southern Illinois. The only source for this copper is the Keewenaw Peninsula of Michigan. This information not only establishes the source rock type but also provides general paleocurrent direction from the source to its present location.

Coarse conglomerates characterize the Cambrian section in the vicinity of the Baraboo syncline in south central Wisconsin. The major rock unit that forms the syncline is a red to maroon Precambrian quartzite. The clasts which are included in the basal Cambrian strata are clearly derived from this Baraboo Quartzite. These distinctive quartzite pebbles have been found in Cambro Ordovician strata 85km to the south, near Madison.

TRENDS IN TEXTURE OF SEDIMENT PARTICLES

The distribution of particle size and shape through time and space can provide substantial information that is useful in basin analysis. In general, the attempt is made to establish the existence of certain trends in the texture of particles, both geographically and stratigraphically. It is not textural properties of the entire rock on which attention is focused but attributes of the individual particles, such as roundness and size.

The geographic variation in grain size has received important consideration by geologists since the 1920s. Much effort has been directed toward grain size patterns in glacial drift and alluvial fans. Students of F. J. Pettijohn at Johns Hopkins University have done comprehensive basin analyses in the Paleozoic strata of the Central Appalachians.

Typical efforts involve the measurement and mapping of maximum particle size and roundness, although mean pebble size may also be utilized. Increase in roundness and decrease in particle size indicates increasing distance from the source. Such trends also provide paleocurrent direction.

Stratigraphic trends in similar parameters are also useful in basin analysis. A decrease upward in maximum clast size implies that relief in the source area is decreasing, thereby decreasing the erosive power and competence of streams. On the other hand, an increase in particle size, particularly one that is abrupt stratigraphically, suggests that the source area has been rejuvenated; it is tectonically active.

PALEOCURRENTS

A large number of sedimentary structures has directional, or at least orientational properties. These structures serve as the fundamental basis for paleocurrent determinations. Actually, any feature that indicates direction of transport is a paleocurrent indicator.

Features such as cross-stratification and bottom marks serve as the best and most abundant structures for paleocurrent determinations. Regardless of the particular directional feature (s) being used, it is necessary for the investigator to measure the spatial orientations of many examples. It is not uncommon for paleocurrent studies to include at least several hundred directional measurements. The field geologist must remember to adjust any

directional measurements to accommodate any structural movement of the strata involved; this is particularly critical in foldbelt areas such as the Appalachians.

Typically, paleocurrent data are portrayed graphically, generally in the form of a rose diagram. This type of diagram is simply a histogram plotted in such a way that direction is shown. Rather than plot the actual number of observations, it is preferable to plot percentages. This allows for comparisons and does not cause problems of large diagrams for some sites and small ones for others; however, one must record wide ranges in the number of observations from locality to locality. The modal class or classes can easily be recognized in a rose diagram or current rose, as it is frequently called. A mean direction may also be calculated and shown on the diagram. It is appropriate to categorize directional data for purposes of rose diagrams by stratigraphic level as well as by geographic location. Paleocurrent directions may vary with time and therefore stratigraphic horizon, as well as with space.

(*From Depositional Systems* pp127-130)

New Words and Expressions

1. lithostratigraphic [ˌliθəˌstrætiˈgræfik] a. 岩石地层的
2. logging [ˈlɔgiŋ] n. 记录；测井
3. geophysical [ˌdʒiːəuˈfizikəl] a. 地球物理的
4. arenite [ˈærənait] n. 砂岩
5. sorting [ˈsɔːtiŋ] n. 分选性；分选作用
6. dune [djuːn] n. 沙丘
7. anastomose [əˈnæstəməuz] v. 网结
8. bifurcate [ˈbaifəˈkeit] v. 分流；分叉；分枝
9. paleocurrent [ˌpæləuˈkʌrənt] n. 古流向
10. provenance [ˈprɔvinəns] n. 起源；物源区
11. megascopic [ˌmegəˈskɔpik] a. 肉眼识别的
12. cobble [ˈkɔbl] n. 大砾
13. clast [klæst] n. 碎屑
14. exotic [igˈzɔtik] a. 外来的
15. conglomerate [kənˈglɔmərit] n. 砾岩
16. syncline [ˈsiŋklain] n. 向斜
17. maroon [məˈruːn] a. 栗色的；酱紫色的
18. roundness [ˈraundnis] n. 圆度
19. rejuvenate [riˈdʒuːvineit] v. 复活；回春
20. spatial [ˈspeiʃəl] a. 空间的
21. foldbelt [ˈfəuldbelt] n. 褶皱带；造山带
22. histogram [ˈhistəgræm] n. 直方图

Lesson Nine

Text

Coal (I)

There is no doubt that coal is of vegetable origin because coals not only contain recognizable plant remains, but transitions can be found between obvious accumulations of vegetable matter, e. g. peat, through lignites or brown coals, into true coals and on into anthracite. This series, from peat, through lignite, into the humic coals and finally anthracite is called the "coal series". The position of a coal in the series is termed its "rank". Thus lignite is a very low-rank coal, while at the other extreme, anthracite is a very high-rank coal. Physical appearance, physical properties and chemical composition of coals change with rank as do their utilization characteristics, e. g. calorific value, coking properties and gas generation potential. Thus knowledge of the rank of a coal can be a guide to its utilization.

The changes that vegetable matter undergoes in the course of alteration to coal are termed maturation or coalification. Maturation takes place in two stages; the peat stage and the burial stage. In the peat stage the plant material suffers a measure of biochemical degradation, and, when it is buried, progressive increase in both overburden load and temperature bring about dynamothermal maturation that slowly turns the peat into coal. The peat stage is an essential prerequisite for the formation of coal.

Under normal circumstances when plants die, they are exposed to air and are broken down primarily by oxidation and also by various organisms, particularly the fungi and aerobic bacteria. Where plant remains accumulate in swamp or bog environments, however, they become water saturated. Aerobic decay soon depletes the water of oxygen, the aerobic organisms die off and anaerobic bacteria take over. The anaerobic bacteria operate without oxygen but they are equally as capable of breaking down organic matter as the aerobic forms. Because of the stagnant nature of swamps and bogs, however, the waste products of the bacteria are not flushed away, but build up in interstitial waters and ultimately render the environment sterile. Bacterial activity is thus curtailed and the partially decomposed plant material remains in a state of arrested decay. In this state the material is peat. If the peat is drained the toxic materials are flushed out, decomposition sets in again and the peat may ultimately be destroyed. If the peat is not drained, however, but is buried under relatively impermeable sediments, its geological preservation becomes possible.

These conditions are generally met with in certain continental environments. Coal formation is especially characteristic of deltas, but may also take place in lakes, on alluvial

flood plains and in coastal lagoons. Detailed environmental analysis is essential to the economic exploitation of coals.

Chemically, coals comprise the three elements carbon, hydrogen and oxygen with minor proportions of sulphur and nitrogen and mineral impurities. The latter remain as ash after the coal has been burnt and, clearly, high ash content is undesirable. Inherent sulphur is normally present in a very small amount and was probably derived from sulphur proteins in the original plants. Some coals have a high sulphur content due to the presence of disseminated pyrites; this is deleterious because it generates sulphurous fumes on combustion of the coal. Although the nitrogen content of coal is small, it was economically important in the production of ammonia as a by-product of the coal-gas industry.

Dynamothermal diagenesis of coal on burial is expressed by the changes in carbon, hydrogen and oxygen contents that accompany maturation. If the elemental composition of coal is plotted in terms of these three elements it will be seen that the coals lie within a narrow zone, called the coal belt. Carbon content increases progressively with increase in rank, but the proportion of hydrogen remains fairly constant at between 5 and 7% in the humic coals before it falls rapidly in the semianthracites and anthracites. Oxygen decreases with increase in rank.

The chemical changes that accompany maturation or coalification are not well understood but they no doubt involve production of gaseous carbon dioxide and methane. Some occurrences of natural gas, e. g. that in the Permian Rotliegendes of Holland and the southern parts of the North Sea appear to have been derived from devolatilization of underlying Westphalian coals.

In general terms the rank of coals tends to increase with age, in the sense that most lignites or brown coals are Tertiary or Mesozoic in age whereas the Upper Palaeozoic occurrences are true coals. Age is only coincidental, however, and the prime control appears to be thermal, which is generally related to depth of burial. In any normal vertical succession of humic coals the carbon content, i. e. the rank, increases with depth. This relationship is called Hilt's law, and it is likely that increase in temperature with burial is an important factor in maturation.

There is debate about the causes of the change from coal into anthracite. In some instances it may be the natural continuation of thermal maturation, but in many occurrences coals change laterally into anthracites as they approach zones of tectonic deformation. The latter relationship is found in the South Wales coalfield where the coals pass westwards into anthracite as they enter the zone of shearing associated with the Ammonford compression. Similarly in North America the Pennsylvanian coals pass laterally into anthracites as they enter the Appalachian fold belt. Coals may be devolatized by thermal metamorphism where they are cut by igneous intrusions. Examples of this are seen where Tertiary dykes cut Westphalian coal measures in north-east England. Although the physical appearance of the coals is only affected for a few feet on either side of the intrusions, devolatization as ex

pressed by increase in carbon content spreads out regionally.

Most brown coals or lignites are obviously woody, lustreless, and not well-jointed; humic coals on the other hand do not normally show a woody appearance in hand specimen. They are well-bedded and display various degrees of lustre from bright to dull. On the basis of lustre and physical appearance, the humic coals are divided into four "rock" types: vitrain, clarain, durain and fusain. Vitrains are the bright coals which have a vitreous lustre. Clarains are less bright with a silky appearance, while the durains are dull, and matt. Fusain is sooty black and very friable so that, unlike vitrain, clarain and durain, it readily soils the hands like charcoal. It is important to distinguish between coal type and rank. Coal type is the expression of the composition of the original plant materials, whereas rank is a measure of the extent of maturation or diagenesis that the vegetable matter has undergone. Some coal seams consist mainly of one rock type, but many are composite and comprise alternations of layers of vitrain, clarain, durain and fusain of varying thicknesses.

Most coal seams appear to have been of *in situ* origin; that is to say the coal-forming peat accumulated where the plants lived and died. Some coal appears to be of "drift" origin, and the plant remains were transported, e. g. as log rafts, to the site of deposition. An in situ origin is demonstrated by the presence of roots and rootlets that lead down from the coal into an underlying fossil soil or "seat earth". Seat earths are of interest in their own right, by virtue of their refractory properties. Clayey seat earths, termed fire clays, consist mainly of kaolin minerals (disordered kaolinite) and are of value for manufacture of refractory bricks. Sandy seat earths, "ganisters", are almost pure quartz rocks and are used for producing silica fire bricks. There can be little doubt that the seat earths were deposited as normal clays and sands, but that they were leached of alkali metals and reconstituted by humic acids from the overlying peats.

(*From An Introduction to Sedimentology*, *pp*144—148)

New Words and Expressions

1. lignite ['lignait] n. 褐煤
2. anthracite ['ænθrəsait] n. 无烟煤
3. humic ['hju:mik] a. 腐殖的
4. maturation [mætju'reiʃən] n. 成熟
5. coalification [kəulifi'keiʃən] n. 煤化作用
6. dynamothermal [dainəməu'θə:ml] a. 热动力的
7. aerobic [ɛə'rəubik] a. 喜氧的
8. anaerobic [ə nɛiə'rəbik] a. 厌氧的
9. interstitial [intə'stiʃəl] a. 空隙的；填隙的
10. curtail [kə:'teil] v. 削减；削弱
11. impermeable [im'pə:mjəbl] a. 不渗透的；不透水的
12. deleterious [deli'tiəriəs] a. 有害的；有毒的
13. fume [fju:m] n. 烟；气
14. ammonia [ə'məuniə] n. 氨
15. methane ['mi:θein] n. 甲烷；沼气
16. Hilt's law 希尔特定律
17. dyke [daik] n. 岩墙
18. intrusion [in'tru:ʒən] n. 侵入；侵入体
19. vitrain ['vitrein] n. 镜煤
20. clarian ['klærin] n. 亮煤
21. durain ['djuərein] n. 暗煤
22. fusian ['fju:zein] n. 丝炭
23. matt [mæt] a. 无光泽的
24. sooty ['suti] a. 烟灰的；乌黑的
25. rootlet ['ru:tlit] n. 小根；枝根

26. refractory [ri'fræktəri] a. 耐火的；耐熔的
27. clayey ['klei] n., a. 亚粘土；粘土质的
28. kaolinite ['keiəlinait] n. 高岭石
29. kaolin ['keiəlin] n. 高岭土
30. ganister ['gænistə] n. 致密硅岩

Note to the Text

There is no doubt that coal is of vegetable origin because coals not only contain recognizable plant remains, but transitions can be found between obvious accumulations of vegetable matter, e. g. peat, through lignites or brown coals, into true coals and on into anthracite. 毫无疑问，煤是由植物形成的，这不仅因为煤中包含了可辨的植物残留体，而且在泥炭、褐煤直到无烟煤这样的渐变类型中，也发现了明显的植物聚集体。

句中 no doubt 之后有一个以 that 引导的同位语从句。on into anthracite 中的 on 为副词，意思是“继续下去”，“向前去”。

Exercises

1. Questions for review:
   1) Define the term coalification.
   2) Why is coal of vegetable origin?
   3) Name the "rock" types of humic coals.
   4) How is the dynamothermal diagenesis of coal expressed?
   5) What is the difference between lignites and humic coals according to the text?
2. Fill in the blanks with correct terms given below:
   Hilt's law, refractory, low-rank, coalification, vitrains, high-rank
   1) The changes that vegetable matter undergoes in the course of alteration to coal are termed _____.
   2) The normal increase of carbon content, i. e. rank, with depth, which is well known and described by the term _____, is caused by rising temperature with depth.
   3) Lignite is a very _____ coal, while anthracite is a very _____ coal.
   4) Clayey seat earths, termed fire clays, are of value for manufacture of _____ bricks.
   5) _____ are the bright coals which have a vitreous lustre.
3. Give the Chinese/English equivalents for the following:
   1) coal series
   2) coking properties
   3) gas generation potential
   4) dynamothermal maturation
   5) well-jointed
   6) 侵染状黄铁矿
   7) 腐殖酸
   8) 厌氧细菌
   9) 原地生成
   10) 耐火粘土
4. Translate the following into Chinese:

   Coal is brownish-black to black, carbon-rich combustible material that forms in

beds from a few centimeters to many meters in thickness and is interbedded with shales, sandstones, and limestones. It was formed long ago as the result of the accumulation of dead vegetation in an environment that favored the concentration of carbon. Swamps and bogs in mild temperate to subtropical climates are among the places that favor the initiation of coal forming processes. Such environments are characterized by an abundance of plants, and as the plants die and fall away, they are often covered by water. Submergence prevents dry rot, a form of oxidation in which the carbon combines with oxygen to form carbon-dioxide, which is liberated into the atmosphere. In the oxygen deficient environment, decay is enhanced by the action of anaerobic bacteria. These bacteria secure the oxygen they need by extracting it from plant tissue. For example, the common plant tissue cellulose consists of carbon, hydrogen, and oxygen. When anaerobic bacteria extract oxygen from cellulose, they release hydrogen, and the carbon is left behind to accumulate. The mass of decaying debris is then buried under additional sediment, further compressed, and altered until it becomes coal.

Clearly, coal could not have developed in the past without an abundance of land plants. The fossil record of land plants begins about 400 million years ago, and thus coal occurs in rocks of post-Devonian Age. The Carboniferous Systems (Mississippian and Pennsylvanian) are well known for their abundance of coal. Lesser amounts of coal are also found in rocks of the Permian, Triassic, and Jurassic Systems. The geologic system second only to the Carboniferous as a source of coal is the Cretaceous. There are, for example, extensive coal beds in Cretaceous stratigraphic sequences of western North America and central Europe. The Tertiary yields mostly soft varieties of coal.

5. Translate the following sentences into English:

1) 各种煤都是从腐烂的植物变来的。

2) 从泥炭到无烟煤的整个演化过程称为煤化作用。

3) 由植物成煤的第一步是生物化学分解。

4) 烟煤含有80%的碳和10%的氢，其比重也要比褐煤大一些。

5) 当前世界上的主要能源是石油、天然气、煤和铀。

Reading Materials

(A) Coal (Ⅱ)

Coal-forming environments have existed since mid-Paleozoic time in areas where substantial quantities of vegetal matter are accumulating and being preserved. Widespread peat accumulation only became possible with the appearance of psilophyte vegetation during the Silurian, which accounts for the first Devonian coals and then the extensive Carboniferous seams. Evolving Mesozoic and Tertiary vegetation occupied an ever expanding range of environments. Today tropical swamps and marshes are undergoing the most rapid accumulation of peat, with rates in Borneo of 17m in 4000 years, but peats are also forming in tem

perate and even polar regions, and at high altitudes. The same geographic diversity is apparent in the origin of coal. The majority of early seams were laid down in humid tropical regions, but in Permian and later times coal formation shifted to temperate and polar regions. The lower proportion of coals between the 15-and 30 degree latitudes results from the warm, arid conditions that prevail.

Many ancient swamps and marshes were very large by comparison with those of today and represented prolonged adjustment to equilibrium conditions. Modern swamps, in contrast, are still adjusting to the unstable conditions that characterized much of the Quaternary, and are therefore rather anomalous. Furthermore, vigorous clastic influx from the unusually elevated terrain of today, in comparison with the subdued landmasses of much of the geologic past, has the effect of limiting the areas of swamp lands. Drainage systems in many ancient coal basins were substantially smaller, and the deltas would have been more intensely reworked by waves, creating widespread barriers conducive to development and preservation of broad peat blankets. Most modern peatswamps therefore provide incomplete analogues for coal seams. However, studies of sedimentary processes operating in these swamps and in adjacent clastic environments allow interpretation of most coals in terms of their depositional setting.

Most coals formed from predominantly in situ organic precursors with subordinate transported components, but the proportions vary widely even within individual seams. An in situ, or autochthonous, origin is accepted for most Northern Hemisphere coals, but some authors consider the Permian Gondwana coals to have a larger proportion of transported, or allochthonous material. Certainly there are pronounced differences in petrography and substrate characteristics of Gondwana and Upper Paleozoic Northern Hemisphere coals, but factors of climate and vegetation were also important along with possible differences in emplacement of the dead vegetation.

The striking similarities in coal bearing deposits of the various continents and of various ages demonstrate that many paleoenvironmental concepts and models have broad application in coal exploration, extraction, and reserve estimates. Regional differences may very often be regarded as variants of the general models. Application of the depositional systems concept tends further to reduce the confusion that may be introduced by a multiplicity of minor facies viewed as disparate elements, and eliminates the need for elaborate stratigraphic nomenclature.

Of the total volume of sediments in the Earth's crust, only about 4 percent is potentially coal bearing. About 40 percent of the world's coal resources are in Upper Carboniferous and permian rocks, with about 50 percent in Upper Cretaceous and Tertiary rocks, in the United States the figures are about 37 and 54 percent, respectively. Coal is therefore concentrated in rocks that represent a restricted range of depositional environments with specific conditions favoring organic preservation, and is confined to a narrow geologic time span.

Coal seams range in thickness from centimeters to over 300 ft (100m) in exceptional cases, attaining a maximum of 765 ft (233m) in Tertiary lignites of Victoria, Australia. Generally, a thickness of 2-3 ft (70-100cm) is the lower limit for both open-cut and underground mining. In most coalfields, open-cut mining is limited to depths of less than 300 ft (100m) because of potential ground-water, slope-stability, and environmental problems. The maximum ratio of overburden to coal in these mines usually ranges between 8 to 1 and 25 to 1. With increased coal prices and improving technology, several open-cut mines are extending to greater depths, with 1000 ft (300m) planned for some Australian mines, and 1650 ft (500m) being considered in Europe. Open-cut mining removes some 90 percent of a coal seam, with a small proportion frequently left in the floor. Only in the United States is auger mining of any consequence, providing a very small proportion of the total coal mined.

Underground mining accounts for around 60 percent of world coal production. In many older mines, bord and pillar (room and pillar) methods are employed. This method leaves the pillars to support the roof, but today usually involves two stages in extraction, first from the stalls or tunnels and later from the supporting pillars. Depending on the coal thickness, roof and floor strength, and mining procedure, between 10 and 90 percent of the coal is left in the ground in bord and pillar mining. The more modern technique of longwall mining utilizes hydraulic jacks which support the roof and are moved forward as coal is removed from the face. Longwall mining has been increasingly mechanized but still results in coal losses in some mines of as much as 50 percent. The world's deepest coal mines are around 5000 ft (1500m), but few exceed 3300 ft (1000m) because of problems associated with high temperature and rock stress.

Coal at even greater depths is potentially recoverable using remote-mining methods. In hydromechanical extraction, coal is loosened by higt-pressure jets and brought to the surface by water flow. In underground coal gasification the seams are partially burned and the gaseous products piped to the surface.

Exploitation of coal is being restricted in places by environmental considerations such as land disfiguration, acid mine drainage and other forms of water contamination, air pollution, and waste disposal. Remote mining poses the threat of ground-water contamination and land subsidence. Labor unrest and the voluminous and often conflicting regulations of governmental agencies continually burden the coal industry in several countries despite calls for increased production.

The largest coal resources are in the U. S. S. R, United States, People's Republic of China, and Australia. Most coal is used as metallurgical coke in blast furnaces and as steam coal in electricity generation. Coal's importance as a fuel is being further extended by its use in the production of synthetic liquid fuels. Production of gasoline and diesel fuel using Fischer-Tropsch synthesis has been a commercial operation in South Africa since the 1950s. Higher efficiency second-generation coal liquefaction and gasification have not yet

reached the commercial stage.

The organic properties of coal that govern its use fall into two categories: type and rank. Coal type depends upon the basic plant constituents, or macerals, which are comparable to the mineral constituents in other rocks. Rank expresses the level of maturity or degree of coalification. Inorganic constituents, or ash, together with chemical precipitates, may severely restrict coal use. But improved beneficiation methods have permitted the mining of increasingly dirty coal. For example, in the Ruhr Field of West Germany an ash content of up to 13 percent was acceptable in 1935, but this had risen to 40.3 percent in 1973. Furthermore, coals with a high pyrite content, which may be unsuited to combustion because of emission problems, may be excellent for liquefaction purposes since the conversion of pyrite to pyrrhotite early in the process is thought to catalyze the reaction.

'From Terrigenous Clastic Depositional Systems, pp253 -255)

New Words and Expressions

1. psilophyte ['psailəufait] n. 裸蕨植物
2. autochthonous [ɔ:'tɔkθənəs] a. 原地的
3. paleoenvironmental [pælɪəu'invaiən'mentl] a. 古环境的
4. disparate ['dispərit] a. 根本不相同的；无联系的
5. auger ['ɔ:gə] n. 麻花钻；螺旋钻
6. bord and pillar method 房柱采矿法
7. longwall mining 长壁式开采
8. hydromechanical ['haidrəumi'kænikəl] a. 流体力学的
9. gasification [gæsifi'keiʃən] n. 气化作用
10. disfiguration [disfigə'reiʃən] n. 毁形；变形
11. metallurgical [metə'lə:dʒikəl] a. 冶金的
12. liquefaction [likwi'fækʃən] n. 液化作用
13. pyrrhotite ['pirətait] n. 磁黄铁矿
14. catalyze ['kætəlaiz] v. 催化

(B) Coalification

Once a layer of peat is covered by detrital sediments and buried to progressively greater depths, it is compressed, thermally insulated, and converted through a series of increasing coal ranks from lignite (brown coal) through subbituminous and bituminous coal, to semianthracite and anthracite. Biological, physical, and chemical changes are involved in this coalification sequence. Conversion to lignite rank is accomplished mainly by biological activity, whereas upgrading to bituminous coal and anthracite involves a combination of physical and chemical processes.

Gradual increase in geothermal energy with burial is the most important factor in coalification, which can be accelerated by an anomalously high heat flow associated with tectonism or igneous intrusion. The increase in coal rank with depth was shown by Hilt in 1873 to result from increase in carbon and decrease in volatile content. Geothermal gradient varies markedly with the structural setting The relationship between coal rank and depth is strongest in young continental margin basins, whereas intracratonic basins of lower heat

flow may show only a minor increase in coal rank with depth.

Lithostatic pressure is relatively unimportant during conversion of peat to subbituminous coal, apart from its role in expelling moisture by compaction. At higher rank, pressure may even retard coalification, and may account for unusually low coal ranks below certain thrust sheets. Frictional heating associated with tectonic deformation does produce locally elevated coal rank, but is generally of little significance. Variable pressure conditions can, however, influence the partial pressures of volatile products of coalification, thereby providing anomalies in coal rank and organic maturation indicators.

Time is an important factor in coalification only if the temperature is above a critical minimum. For example, Carboniferous coals in the Moscow Basin have only reached lignite rank. This is because of a very low geothermal gradient and a temperature at the depth of the coals of only 50 to 60°C. Upper Miocene coals of Louisiana have reached the rank of high-volatile bituminous coal, whereas some Carboniferous coals at comparable depths in Europe have less than half the volatile matter of their Louisiana counterparts.

Increase in rank is generally accompanied by progressive darkening and increased opacity, calorific value, and vitrinite reflectance. Solubility, together with oxygen, volatile, and moisture content decrease concomitantly. Reversals in some of these trends are apparent at the coalification break at the level when the volatile content of vitrinite falls below 30 percent. At this stage, there is an abrupt change in various parameters of coalification. Both calorific value and hydrogen content decrease, and the volume of methane suddenly increases before expulsion as coalification progresses. As a consequence, this threshold is an important consideration in the assessment of underground mining hazards.

Peat stage is achieved by surficial biochemical diagenesis which extends to a depth of around 30 ft (10m), where purely chemical processes become dominant. Decomposition of dead plant material is accomplished largely by micro-organisms. Cellulose and protein are decomposed, progressively concentrating lignin and humic acids, and increasing the carbon content to between 50 and 60 percent. Plant material is transformed into peat by massive removal of both organic and inorganic components of the plant debris. Of the latter oxalates and alkali and alkali-earth elements are almost totally removed. Clay minerals form rapidly in situ presumably from amorphous inorganic material in woody plant tissue. The activities of aerobic bacteria, fungi, and actinomycetes in the surface layers are replaced downward by anaerobic bacteria.

Lignite (brown coal) stage is normally attained at depths of 650-1300 ft (200-400m) as a result of compaction and associated reduction in moisture content. Some of the giant brown coal seams of Victoria, Australia, still contain 67 percent moisture. Most lignites are Cenozoic in age, but a few are as old as Carboniferous. Plant remains tend to be still recognizable thus providing the opportunity to compare them with modern plant communities. For example in the Tertiary lignites of Germany coals of coniferous and angiosperm forests can be distinguished.

Increase in rank through the lignite stage is reflected in progressively higher carbon content and calorific value, and continued reduction in moisture content. During this process the humic acids condense into larger molecules forming humines, and the coal gradually becomes black and lustrous as it is transformed to bituminous rank by vitrinization.

Bituminous stage generally requires burial to depths of 1500-4000m depending on geothermal gradient. By this stage humic acids have been totally transformed into humines. In contrast to the very gradual transition from lignite to bituminous coal, there is a very abrupt coalification break at the boundary between high-volatile and medium volatile bituminous coal. This break corresponds to a carbon content of about 87 percent and a volatile content of around 29.5 percent. Bituminous rank increases by removal of alicyclic and aliphatic groups and aromatization of humic complexes. Vitrinite reflectance rises accordingly to a level of around 1.0.

Anthracite rank is marked by a strong increase in reflectance and optical anisotropy. Hydrogen content is dramatically diluted by release of methane and water. Many coal basins of predominantly bituminous rank for example the Karoo coalfields of South Africa contain anthracites in the contact aureole of igneous intrusions. Larger plutons and laccoliths convert greater volumes of coal to anthracite rank.

Coal rank is strongly influenced by the tectonic behavior of a basin. Because coal is carried down to deep crustal levels of high geothermal energy, coal rank increases laterally in the direction of maximum deformation and heat flow. For example, Upper Permian coals of Queensland, Australia originated in a foredeep plain west of the main orogenic axis. The east-central part of the basin was severely deformed during Late Triassic orogeny and this area of maximum heat flow now contains semianthracites. These high-rank coals grade into bituminous and sub-bituminous coals toward the stable craton. The same changes are evident between the anthracite and bituminous coal regions of the eastern United States. Local hot spots in orogenic terranes may be sensitively recorded by coals of higher rank, as may be uranium-rich granitoid platforms.

(*From Terrigenous Clastic Depositional Systems*, *pp*258—259)

New Words and Expressions

1. anomalously [ə'nɔmələsli] ad. 异常地
2. tectonism [tek'tənizm] n. 构造作用
3. volatile ['vɔlətail] a., n. 挥发的；挥发物
4. lithostatic [liθəst'ætik] a. 地压的
5. anomaly [ə'nɔməli] n. 异常
6. opacity [ou'pæsiti] n. 不透光；不透明
7. calorific [kælə'rifik] a. 热量的；生热的
8. concomitantly [kən'kɔmitəntli] ad. 相伴地
9. surficial [sə:'fiʃəl] a. 表面的；地表的
10. oxalate ['ɔksəleit] n. 草酸盐
11. actinomycete [æktinou'maisi:t] n. 放线菌类
12. coniferous [kou'nifərəs] a. 针叶树的
13. angiosperm ['ændʒiəuspə:m] n. 被子植物
14. humin ['hju:min] n. 腐殖酸等不溶性物质
15. vitrinization [vitrinai'zeiʃən] n. 镜煤化
16. alicyclic [æli'saiklik] a. 脂环族的

17. aliphatic [ælɪ'fætɪk] a. 脂肪族的
18. aromatization [ə,rəʊmətaɪ'zeɪʃən] n. 芳香化
19. optical ['ɒptɪkəl] a. 光学的；光的
20. [illegible]
21. aureole ['ɔːrɪəʊl] n. 接触变质带
22. granitoid ['grænɪtɔɪd] a. 花岗质的；花岗状
23. [illegible]
24. [illegible]
25. [illegible]
26. [illegible]
27. [illegible]
28. [illegible]
29. anisotropy [,ænaɪ'sɒtrəpɪ] n. 各向异性

Lesson Ten

Text

Macerals of Coal

Coal is not a homogeneous substance but consists of various constituents. In the same way as inorganic rocks are composed of minerals -- for example granite is made up of feldspar, quartz and mica -- coals consist of macerals. But there is a difference. Whereas a mineral is characterized by a fairly well defined chemical composition, by the uniformity of its substance, and by the fact that most minerals are crystalline, a maceral of coal varies widely in its chemical composition and physical properties and is not crystalline.

The heterogeneous structure of coal is perceptible to the naked eye when examining a coal face or a sample, but only the microscope reveals the details of the constitution of coal. The main constituents of low-rank bituminous coals are the bright constituents, the exinites or liptinitic constituents and fusinitic constituents. By maceration which involves the solution of the bright constituents, the fusinitic and the exinitic constituents can be separated and recovered. The words 'maceration' and to 'macerate' are derived from the Latin verb 'macerare' which means 'to soften', and it was STOPES (1935) who first used the term 'macerals' for the constituent of coal isolated by maceration.

As used at present, the term 'maceral' describes at the same time both the shape and the nature of the microscopically recognizable constituents of the coal. In order to distinguish the different individual macerals under the microscope it is necessary to choose parameters which can be determined during microscopic examination, such as reflectance, colour, shape and relief or polishing hardness. To exclude any ambiguity of the definitions of the different macerals, the ICCP has established standard rules for petrographic microscopy which provide that the description of macerals shall correspond to their appearance in incident light using oil immersion objectives with 25 to 50x magnification. This is to say that the definition of macerals is based on morphology. Studies on pure maceral concentrates have made it possible in many cases to determine the chemical and physical properties of the macerals. In addition, palaeobotanists have succeeded in establishing correlations between many microscopically observed shapes and structures of macerals and certain plant organisms or tissues.

All macerals have the suffix 'inite', and are classified in three groups: vitrinite, exinite (or liptinite) and inertinite. This subdivision is conventional and represents a simplification which is useful in practice. Each group includes a series of macerals which can be regarded as belonging together, either because of similar origin (such as exinite) or because of the

mode of conservation (vitrinite and inertinite).

The three maceral groups are to a certain degree characterized by their chemical composition. If one compares isometamorphic maceral groups, i. e. groups of the same rank, the vitrinite contains relatively more oxygen, the exinite more hydrogen and the inertinite more carbon. In isometamorphic maceral groups whose vitrinite contains say 81 C, the hydrogen content would be 7% in the exinite, 5.5% in the vitrinite and 3.9% in the inertinite. The volatile-matter yield also is highest in the exinite, amounting in a particular coal to 66.7% as against 35.2% in the vitrinite and 22.9% in the inertinite. On the low-rank side of the 'coalification jump' (which occurs when the vitrinite has a volatile-matter yield of 29%), the hydrogen content of a coal increases with the proportion of the exinite and the carbon content with the proportion of the inertinite.

With increasing rank the macerals vary in the way their chemical, physical and technological properties alter. Coal petrologists and coal chemists have established the existence of a distinct relation between the reflectance of a maceral and its carbon or volatile-matter yield. this means that the rank of a coal can be determined exactly by measuring its reflectance on a polished surface. With increasing rank the individual macerals become less and less different in reflectance so that it becomes more and more difficult to differentiate between them under the microscope. When examining a polished surface of an anthracite, special techniques are required to differentiate between the individual macerals.

It should be underlined that strictly speaking the macerals ought to be free from mineral inclusions. However, they may contain inorganic components of submicroscopic size which were already present in the original plant material or which formed during the first stage of the coalification process as complex compounds of organic and inorganic matter. These inorganic admixtures are grouped under the term 'inherent ash'. In German coals of the Carboniferous the proportion of inherent ash amounts to some tenths of one per cent at the most; in German Tertiary lignites it may reach several per cent, because these coals fairly commonly contain alkali or metallic humates which cannot he recognized microscopically. In many cases it is possible to detect these inorganic constituents within macerals in the submicroscopic size range by means of an electron microprobe, sometimes also by electron microscopy. Microscopically visible minerals (also called 'adventitious ash') are not, however, looked upon as part of the macerals and are recorded separately in microscopic analyses.

Macerals of one and the same maceral group differ from one another in morphology and structure rather than in reflectance. This is to say that there are only slight differences in volatile-matter yield, elementary composition and technological properties amongst macerals belonging to the same group. If certain forms or structures of macerals can be ascribed without any doubt to a certain plant organ or plant tissue, e. g. to a woody or a parenchyma tissue as in the case of telinite, the term 'maceral variety' is used (e. g. xylotelinite or parenchymotelinite). By contrast, if differences in the origin of a maceral can be deduced

from its shape or structure (in the example of fusinite, well-preserved cellular structures originating from charcoal or poorly preserved cellular structures originating from degraded wood), they are classified as maceral types (pyrofusinite, oxyfusinite).

(*From Coal Petrology*, *pp*87 - 89)

New words and Expressions

1. homogeneous [ˌhɔməˈdʒiːnjəs] a. 均质的；均匀的
2. heterogeneous [ˌhetərəuˈdʒiːnjəs] a. 非均质的
3. perceptible [pəˈseptəbl] a. 看得出的；察觉到的
4. exinite [ˈeksinait] n. 壳质组
5. liptinitic [ˌliptiˈnitik] a. 壳质组的
6. fusinitic [ˌfjuːziˈnitik] a. 丝质体的
7. ambiguity [ˌæmbiˈgjuiti] n. 多义性；二重性
8. ICCP (international committee for coal petrology) 国际煤岩学委员会
9. morphology [mɔːˈfɔlədʒi] n. 形态学
10. paleobotanist [ˌpæliəuˈbɔtənist] n. 古植物学家
11. isometamorphic [ˌaisəumetəˈmɔːfik] a. 等变质的
12. coalification jump 煤化作用跃变
13. reflectance [riˈflektəns] n. 反射率
14. admixture [ədˈmikstʃə] n. 混合；混合物
15. humate [ˈhjuːmeit] n. 腐殖酸盐（脂）
16. adventitious [ˌædvenˈtiʃəs] a. 外来的；不定的
17. parenchyma [pəˈreŋkimə] n. 薄壁组织
18. telinite [ˈtelinait] n. 结构镜质体
19. xylotelinite [zailəˈtelinait] n. 木质结构镜质体
20. parenchymotelinite [pərenkiməˈtelinait] n. 薄壁结构镜质体
21. pyrofusinite [paiərəuˈfjuːznait] n. 火焚丝质体
22. oxyfusinite [ɔksiˈfjuːznait] n. 氧化丝质体

Notes to the Text

In the same way as inorganic rocks are composed of minerals——for example granite is made up of feldspar, quartz and mica——coals consist of macerals. 煤是由显微组分组成的，正像无机岩是由矿物组成的那样，例如花岗岩是由长石、石英和云母组成的。

Exercises

1. Questions for review:
   1) Is a maceral of coal characterized by a fairly well-defined chemical composition?
   2) What does the term 'maceration' mean?
   3) Name the maceral groups of coal.
   4) Explain how the three maceral groups are to a certain degree characterized by their chemical compositions.
   5) How do the chemical, physical and technological properties alter with increasing rank?
2. Fill in each blank with the correct terms given below:

   isometamorphic, macerals, crystalline, reflectance, liptinite

   1) The rank of coal can be determined by measuring its _____ on a polished surface.

2) Coal consists of various constituents, termed _____, distinguishable by their optical properties.

3) A maceral of coal varies widely in its chemical composition and physical properties and is not _____.

4) Exinite, or _____, is one of the three maceral groups.

5) Those maceral groups are of the same rank, that is to say they are _____.

3. Give the Chinese/English equivalents for the following:

1) volatile-matter yield	6) 肉眼可分辨的
2) inherent ash	7) 固定的化学成分
3) polishing hardness	8) 采煤工作面
4) relief and colour	9) 煤化学
5) mineral inclusions	10) 煤岩学

4. Translate the following into Chinese:

As with most other rocks, the "rock" types of coal are each composed of a series of discrete components, termed macerals (the prefix "mac-" implying that they are macerated plant remains, and the termination "-erals" indicating that they are analogous to minerals). Macerals are named with the suffix "-inite", to distinguish them from the rock type of degradation products that have been modified chemically by diagenetic processes, i. e. by maturation. The common ones include: vitrinite, the main constituent of the coal type vitrain, and there are two varieties; tellinite and collinite. Under the microscope, tellinite shows compressed cellular structure of what was formerly woody tissue or xylem, whereas collinite which has similar optical properties is structureless. Suberinite, cutinite and exinite are macerals formed by coalification of bark, leaf cuticles and spore jackets respectively. Fusinite stands apart from other macerals in that it is nearly pure carbon. It often shows cellular structure under the microscope. The cell walls are usually preserved as a mass of broken fragments. This contrasts markedly with cellular tissues that are preserved as tellinite, where the cell walls have been deformed but not broken by compaction. It appears therefore that where cellular tissues are preserved as fusinite, the alteration must have taken place very early in the maturation history, certainly before significant compaction due to overburden load. It has been suggested that fusinite may have formed during the peat stage by a process analogous to "dry rot", or by forest fires. Micrinite is the general term applied to aggregates of very fine-grained macerated plant materials most of which are too small to be identified.

5. Translate the following sentences into English:

1) 镜质组在薄片中呈半透明状，颜色为深浅不同的红色、橙色和褐色。

2) 惰性组与具有相同煤级的其它煤岩组分相比，其特点是反射率高、碳含量高、氢含量低。

3) 壳质组和与其共生的镜质组相比，在反射光下显得更暗。

4) 镜质组的反射率是随着煤级的增加而增加的。

5) 各种煤岩组分在煤中的含量比例直接影响煤的工业用途。

Reading Materials

(A) Origin of Macerals and Coal Lithotypes

The factors that influence the abundance and structure of the constituents in coals of varying type are so interrelated that it is difficult to identify a completely independent set of controls. Factors that can have a bearing on the constitution of a peat deposit include the following:

(a) The nature of the plant community. The type of plants and the relative abundance of each form is an obvious control, depending in turn on the geologic age of the deposit, the physiographic setting, the climate and the supply of nutrients;

(b) The climate prevailing in and around the depositional site. The temperature and humidity, as well as any seasonal fluctuations in these factors, influence the nature of the plant community, the extent of peat build-up and decay, and the rate and products of weathering in the swamp hinterland;

(c) The extent of plant decomposition. This in turn depends on the nature of the plants themselves, on the climate and on the Eh and pH conditions in the swamp waters;

(d) The tectonic setting of the deposit. This is a major factor in controlling subsidence rates and in determining the physiographic setting, the rate of nutrient supply and the extent of plant decay;

(e) The physiographic setting, palaeogeography or depositional milieu of the deposit. These represent a combination of factors including the depth and movement of waters, the shape and areal extent of the peat swamp and the chemistry, including Eh and pH, of the swamp waters.

Vitrinite has long been regarded as the result of deposition of ligno-cellulosic tissues (wood, bark etc.) in stagnant, highly toxic waters that protected the organic material from extensive biochemical decay. Raistrick and Marshall (1939) have noted that the great majority of vitrain sheets in Carboniferous coals, which are usually about 6 mm thick, represent the bark shells of lycopods, although the wood of gymnosperms and cycads was another important source of this type of material.

On the basis of detailed petrographic and palynologic profiles through a number of coal seams, Smith (1968) suggests that the vitrinite-rich layers in humic coals were most likely to have been deposited in areas that underwent greater subsidence than the surrounding regions. In studies of Australian coal measures, Shibaoka and Smyth (1975) have shown that coals deposited in the thicker sections of troughs (i. e. areas of greater relative subsidence) are rich in bright lithotypes, and that these are more likely to be associated with mineral partings than the duller, vitrinite-poor seams of the more stable shelf areas.

Shibaoka and Smyth (1975) and Cook (1975) noted that the lower seams of the Australian Newcastle Coal Measures and the Triassic Ipswich Coal Measures, which are 'deep basin type' deposits, are rich in vitrinite, whereas the Illawarra Coal Measures, deposited with steady, slow subsidence, contained seams typically very poor in vitrinite. Other 'shallow basin type' coals deposited on stable shelves or basement rocks, like the Blair Athol, Leigh Creek and Callide coals, also are vitrinite-poor.

The fine-grained type of vitrinite, desmocollinite, such as is commonly found in clarain, is generally assumed to have originated either from smaller plant organs, such as leaves, or from finer fragments of larger tissues that have been partly degraded. Desmocollinite usually has a lower reflectance than the telocollinite (i. e. coarse vitrinite) in the same coal, and this has been attributed to either admixture with fine liptinitic detritus or to the adsorption of 'bitumen', possibly lipoid substances derived in part from liptinite, into the maceral's structure. Some desmocollinite also exhibits fluorescence characteristics, probably also reflecting the presence of 'bitumen' impregnations. A similar explanation would account for the unusual fluorescence, reflectance and chemical characteristics of some 'jet', vitrain lenses derived from coniferous wood and found in marine sediments with a high lipid content.

Another hypothesis for the higher reflectance of telocollinite (or vitrinite A, 'pseudovitrinite', band vitrinite) is that the plant material has undergone oxidation, probably during the early stages of its development. Koch (1970), however, suggests that it is due to the nature of the original plant material involved, noting that, in the Jurassic coals of Afghanistan, this maceral type had the characteristics of coniferous tissues. Cook has suggested that any chemical differences between band vitrinite and vitrinite in attrital layers may have been imposed by differences in the chemistry of the original plant materials, with the tissues that gave rise to the band vitrinite being hydrogen deficient and therefore oxygen-rich. Such material would have decomposed more rapidly than the hydrogen-rich tissues, and thus band vitrinite would have been preserved only under rapid burial conditions.

The inertinite macerals are generally regarded as having been derived from the same types of plant debris as vitrinite, but have undergone chemical changes due to processes such as charring, oxidation, mouldering and fungal attack at an early stage of their depositional history. Fusinite, for example, is thought to have originated in many cases as plant fragments that have suffered partial combustion in forest fires. Such material, known as 'pyrofusinite' usually has a high reflectance, appearing yellow or white under oil immersion, and with distinct cell wall margins. Another form, called 'degradofusinite', is characterized by indistinct cell walls and a lower, semifusinitic reflectance. This material is thought by Teichmüller to result from dehydration, oxidation and biochemical alteration of plant debris. However, Given has challenged the possibility that degradofusinite might be the product of biochemical decay. It is a characteristically abundant constituent of the Permian coals of Gondwanaland. Other fusinite may be of primary origin, derived directly from

certain pigmented plant tissues.

Semifusinite, in general, is regarded as representing ligno-cellulosic plant debris that has suffered a lesser degree of degradation than fusinite. Fragments of both fusinite and semifusinite, often forming discrete inertodetrinite particles, can also be transported some distance from their place of formation, accumulating in quiet, sub-aquatic conditions with other particles such as spores or algae and possibly fine mineral matter.

Sclerotioids (secretion sclerotinite or carbonized resin bodies) are also thought to result from oxidizing conditions in the peat swamp, although such materials may also be transported from an oxidizing environment nearby. True sclerotinite represents fungal material and is also formed in relatively dry oxygenated peat layers.

Micrinite may possibly be formed in two ways. It may represent a by-product of the coalification of liptinite macerals, including bituminite and exudatinite. The suggestion is supported by its frequent association with sporinite. Although Teichmüller indicates that micrinite is not normally found in peats or brown coals, others have reported it in such materials. Together with the fact that it frequently occurs as cell fillings in higher rank coal, this suggests that some micrinite may also be formed by the breakdown of cell wall substances.

The origin of macrinite, a relatively rare component of most coals, is not well understood. At least some of it may, however, result from the oxidation (or fusinization) of organic gels formed during peat accumulation.

Because they are made up mainly of fine inertinite debris and have a relative abundance of spore material, the black durains of many humic coals are classically regarded as sub-aquatic ooze deposits, forming in deeper water environments than the bright, vitrain rich lithotypes. Hacquebard et al (1967) have generally indicated support for these concepts, interpreting the high telinite (bright coal) contents of some Canadian seams as representing forest moor environments, typical of the central part of a flood plain. The duller intervals of those seams, with relatively high liptinite and mineral contents, are thought to be the product of an open moor environment with a generally higher water table. As an alternative, however, Smith (1968) has suggested that black durains, rich in macrinite and thick-walled crassispores, were formed in a raised, well-drained peat swamp environment. Tenuidurains, in which thin-walled spore types are typically associated with semifusinite and a high proportion of mineral matter, are interpreted by Stach et al (1975) as representing a horizon of peat oxidation above the water table. Smith (1968) on the other hand interprets them as representing a sub-aquatic 'incursion phase' due to flooding of the peat swamp.

The presence of a large amount of mineral matter in a coal may also reflect the development of deep-water conditions. However, some workers suggest that such concentrations could also result from sub-aerial ablation of peat, or from excessive peat decay in swamp waters of pH greater than 4.5. Unlike the ligno-cellulosic materials that make up vitrinite,

the liptinite constituents are largely resistant to degradation and to the gelification or similar processes generally associated with peat formation. They do, however, exhibit a number of significant changes during coalification or rank advance.

Cannel coals are believed to be derived from the more resistant components of decayed plants, especially spore remains, that were washed into ponds, lakes and lagoons to accumulate as fine grained, anaerobic bottom muds. Boghead coals or torbanites, on the other hand, are thought to represent circumstances in which clear, aerated surface waters, free of humic matter, allowed algal colonies to flourish. After death, the remains of these colonies accumulated in euxinic bottom oozes, eventually to become masses of alginite or bituminite.

(*From Coal Geology and Coal Technology*, *pp*105--107)

New Words and Expressions

1. milieu [ˈmiljə:] n. 环境；周围
2. ligno-cellulosic [ˈlignəu seljuˈləusik] a. 木质纤维素的
3. lycopod [ˈlaikəpɔd] n. 石松
4. gymnosperm [ˈdʒimnəuspə:m] n. 裸子植物
5. cycad [ˈsaikæd] n. 苏铁（科）
6. palynologic [pælinəˈlɔdʒik] a. 孢粉学的
7. desmocollinite [dezməˈkɔlinait] n. 基质镜质体
8. telocollinite [teləˈkɔlinait] n. 均质镜质体
9. lipoid [ˈlipɔid] a., n. 类脂的；类脂物
10. attrital layers 杂质层
11. degradofusinite [ˈdigreidəuˈfju zinait] n. 氧化丝质体
12. semifusinite [ˈsemiˈfju zinaitik] a. 半丝质体的
13. dehydration [di:haiˈdreiʃən] n. 脱水作用
14. inertodetrinite [inəːtəˈdetrinait] n. 碎屑惰性体
15. sclerotinite [skliəˈrɔtinait] n. 菌类体
16. sclerotioid [skliəˈrɔtiɔid] n. 似菌类体
17. micrinite [ˈmaikrinait] n. 微粒体
18. bituminite [biˈtju:minait] n. 沥青质体
19. exudatinite [eksjudəˈtinait] n. 渗出沥青体
20. sporinite [spɔ:rinait] n. 孢子体
21. macrinite [mækrinait] n. 粗粒体
22. crassispore [kræsiˈspɔ:] n. 厚壁孢子
23. tenuidurain [tenjuːiˈdjuərein] n. 薄壁孢子暗煤
24. gelifiction [dʒilifiˈkeiʃən] n. 胶凝作用
25. sapropelic [sæprəˈpelik] a. 腐泥的
26. cannel [ˈkænl] n. 烛煤
27. boghead [ˈbɔghed] n. 藻煤
28. torbanite [tɔbænait] n. 托班藻煤
29. euxinic [juːkˈsinik] a. 静海的
30. alginite [ˈælginait] n. 藻类体

(B) Minerals in Coal

Depending on the nature of the coal sample involved, the mineral matter present may be derived from a number of different sources. Bulk samples taken from the coal as mined, for example, normally contain mineralogical contaminants due to the presence of intra-seam bands of non coal material, as well as possibly debris from the adjacent roof and floor strata. However, individually selected specimens, or plies and seam composites free of these materials, usually contain a distinctive suite of minerals.

QUARTZ

Quartz is common in most coals, but seldom as a major constituent. It often occurs as angular grains in clay-rich bands, suggesting a detrital origin. However, it may also occur as a chemical precipitate, possibly originally in the form of chalcedony, infilling cell cavities in the coal macerals or as veins cutting across the coal structure.

KAOLINITE

Although often a minor constituent or even completely absent from the associated non coal lutites, kaolinite is found in a large number of hituminous coals. It is usually very well crystallized and in some cases is the only clay mineral that can be identified even by detailed X-ray diffraction. Some of it may occur as petrifactions or cell-cavity infillings, suggesting an authigenic origin in the original peat. The mineral also occurs as bands, pellets or vermicular aggregates, and as an infilling of cleat fractures. The origin of this material is discussed by Rao and Gluskoter (1973), Ward (1977, 1978), and Gaigher (1980).

OTHER CLAY MINERALS

Well crystallized illite is a common constituent of coal from some areas, but may be completely absent in others. Montmorillonite, chlorite and regular to irregular mixed-layer clay minerals are also found in many coals throughout the world. The assemblage of these is usually similar, but not identical to that found in the associated non-coal lutites. It is likely that they mostly represent detrital contaminants of the original peat, modified to a variable extent by early or late diagenetic processes.

SULPHIDE MINERALS

Pyrite is a common constituent of many coals, particularly those closely associated with marine strata, Together with small amounts of sphalerite, marcasite, galena and other species, it occurs as lenticular masses, euhedral crystals, framboidal aggregates, cell infillings, as veins and on cleat surfaces. These minerals probably represent the result of bacterial reduction of sulphate-rich peat waters during early diagenesis, but later remobilization is also likely in some cases as well.

CARBONATE MINERALS

The carbonate minerals found in most bituminous coals are siderite, calcite and dolomite or ankerite. Siderite commonly occurs as spheroidal nodules within the coal, and was apparently formed by chemical precipitation during early diagenesis. It is most abundant in coals with a low pyrite content, and probably represents the interaction of iron with dissolved CO_2 in peat waters where sulphate concentrations were too low for pyrite production. Calcite, dolomite and ankerite are mostly late-stage accumulations in bituminous coals, occur-

areas where dense vegetation obscures the ground, the aerial photographs may need to be taken using infrared techniques.

The topographic data may also be processed to give a 'digital terrain model' of the land surface. This can be of great value if computer-based methods are used for the assessment of coal reserves and planning of mine development, especially in open-cut mine situations.

Geological mapping, at a scale appropriate to the aims of the project, is a necessary starting point for the field work of nearly all exploration programmes. The principal objects of such a study are to determine the location, attitude and extent of the coal-bearing strata, if not of the coal seams themselves, and the relation of these beds to other rock units in the area. Field mapping can also be used to reveal the nature and location of any igneous intrusions, faults or other features that may affect seam continuity and mining conditions.

The techniques used in such a study clearly depend on the nature of the area under investigation. Where the area has already been reliably mapped in detail, it may be sufficient to compile all existing data on to the base map, and use field work only to check on inconsistencies or points of detail. In other cases, however, a significant amount of outcrop mapping and aerial photograph interpretation may be necessary to gain an adequate understanding of the geological framework of coal occurrence. Only with concealed coalfields, where the seams are blanketed by unrelated deposits of younger strata, is field mapping likely to be of limited value as an exploration tool.

Recognition and tracing of marker beds is an important component of a mapping programme. Such markers may be beds of distinctive lithology, such as tuff, limestone or flint clay horizons, or alternatively zones of unusual diagenesis or weathering characteristics. Palaeontological zones, derived from detailed study of bivalves, forminifera, spores, pollens or other organisms may also be useful in some cases. If these markers are concordant with the coal-bearing strata, their distribution and attitude may serve to correlate coal seams, elucidate facies patterns and delineate the structural features of the area. This information can then be used to guide future surface and subsurface investigations.

Wherever possible, detailed stratigraphic sections should be measured. These give information similar to that obtained from exploratory drilling, but for a fraction of the cost. Such sections may be obtained from cliff exposures, road cuttings, river banks or creek beds, using aids such as tacheometry and barometric levelling where required.

Outcrops of coal seams are subject to the most intensive investigation. Detailed sections should be measured, and, if the coal is fresh, channel or strip samples may be taken. Sampling is less useful in weathered coals, but partly oxidized debris can still provide material suitable for limited petrographic analysis. Even if no sampling is possible, the measured sections can still be used to give an indication of mineable thickness and the amount of contamination in the seam by bands of non-coal material. The exact location and reduced level

of seam outcrops can also aid the interpretation of subsequent bore hole data.

In areas where the coal seams are mantled by a thick soil cover, it may be necessary to excavate pits, trenches or costeans to provide surface exposures. These excavations may range from small operations using hand-held equipment to openings made by large-scale earth-moving machinery. Because of their cost and greater environmental impact, however, the larger types of excavations are more likely to be introduced at a later stage, integrated with the mine development programme.

(*From Coal Geology and Coal Technology*, *pp*179 -180)

New Words and Expressions

1. base map 底图；工作草图
2. aerial ['ɛəriəl] a. 航空的；空气的
   ~ photograph 航摄照片
3. photogrammetric [fəutəgrə'metrik] a. 摄影测量的
4. topographic [tɔpə'græfik] a. 地形的，地形测量的
5. coal-bearing ['kəul'bɛəriŋ] a. 含煤的
6. inconsistency [inkən'sistənsi] n. 不一致；矛盾
7. marker ['mɑ:kə] n. 标记；标示物
   ~ bed 标准层；标志层
8. bivalve ['baivælv] n. 双壳类动物
9. concordant [kən'kɔ:dənt] a. 一致的；协调的；整合的
10. elucidate [i'lju:sideit] v. 阐明；解释
11. tacheometry [tæ'kimitri] n. 视距测量法
12. barometric [bærə'metrik] a. 气压（计）的
13. leveling ['levəliŋ] n. 水准测量
    barometric ~ 气压测高；气压高程测量
14. costean ['kɔstiːn] n. 探槽

(B) Coalfield Exploration

The number and location of drill sites needed to give adequate data for each stage of the exploration programe, and the depth, inclination etc. of the holes at each site, depend on the geology of the area under investigation, the mining method likely to be used and the amount of information available from other sources. A drilling programme for a regional study, such as one to delineate areas for closer investigation within an extensive sedimentary basin, may make use of holes many kilometres apart. Areas of essentially flat lying strata, with little geological complexity due to faults, washouts, splits etc. , may, on the other hand, need a pattern of holes at a spacing of 1-2 km to provide sufficient data for the design and initial development of an underground mine. For a major open-cut operation, the proving of reserves may require holes spaced at intervals of less than 100 m, with still more holes in places to delineate the actual location of the seam outcrop or the limit of near-surface oxidation before mining can commence.

Although known coal-barren intervals may be penetrated without coring, preliminary evaluation of a previously unexplored area or stratigraphic unit commonly requires a core to be taken throughout the entire coal-bearing part of the succession. As well as providing details on the structure, thickness and quality of the major seams present, such a pro-

gramme can be used to obtain data on inferior seams, which could possibly be worked under different economic circumstances. Fully cored holes can also be used in this situation to supply the geological data needed to draw up a sedimenary model of the sequence as a guide to future exploration.

In drilling to prospect for and design an underground mine, cores are generally taken at least over a significant interval of the roof and floor of the seam, as well as the actual coal seam (or seams) under investigation. This is necessary to provide data on the detailed stratigraphy and mechanical properties of these beds, as well as samples of coal for quality evaluation. Non cored holes through coal seams are more common in areas intended for open cut operations, where most of the drilling is directed towards establishing only the variations in thickness of coal and overburden materials. Suitably located cored holes are also needed in such programmes, however, to provide samples for testing of coal quality, and to allow the mechanical behaviour of the strata in the overburden and floor of the mine to be assessed.

Many commercial exploration programmes employ independent drilling teams on a contract basis. Such contractors are generally required to provide the necessary equipment and transport it to the drilling site. They are also responsible for the provision of skilled labour, accommodation, maintenance and safety while the work is in progress, and for leaving the site in an acceptable condition when the holes have been completed.

Most drilling contracts list the rates of payment for non-core and core drilling per unit length drilled, possibly with different amounts for various depth ranges or geological conditions. Other costs to be considered include the mobilization and demobilization of equipment and personnel to the area, especially in remote regions, and the transport of the drill from one site to the next. The cost of 'stand-by time', when the drill crew is required to wait for a geological inspection, for the arrival of geophysical logging equipment or for other reasons under the control of the geologist should also be specified.

It is common in core drilling for a contract to allow payment, especially when drilling zones of interest only if a certain percentage of the possible core is recovered. Modern equipment can attain recoveries of over 90% in favourable geological conditions, and a penalty is sometimes imposed on the driller's remuneration if less than a reasonable value is achieved.

Checking and approving claims for payment made by the driller requires a thorough knowledge of the drilling contract, as well as complete records of the progress and core recovery. Keeping of lithologic logging up to date also enables the geologist to advise the driller on the conditions that may be expected at greater depth, indicates when unproductive holes should be terminated, and allows the programme to be rearranged if required as new data comes to hand.

As well as the facilities for the actual drilling operation, a surveying team is required to determine the exact location and reduced level of each hole, so that it can be properly lo

cated even on large-scale mine plans. Arrangements for any geophysical logging or groundwater testing must also be made, and scheduled to fit most efficiently into the drilling operation. Sufficient receptacles, such as core boxes, are also required to accommodate the number and type of samples being taken.

Because of the great expense involved in obtaining them, and the wide range of information that they can yield, core samples of coal seams and the adjacent non-coal strata should be examined in as much detail as possible. Especially with coal seams, but also with overburden or mine roof and floor rocks, the collection of a complete core, with as little disturbance as possible, is vital to the success of this examination.

If a triple tube core barrel is used, the split inner tube is laid horizontally and the top half removed to expose the core. The geologist may, if necessary, log the core as soon as it is exposed in this way, while drilling is continued with a second core barrel. Alternatively, the core may be transferred by the driller to a segmented core box or other receptacle before logging is commenced.

The depth of the hole when the core is withdrawn at the end of each drilling run is indicated on a marker placed by the driller at an appropriate point in the core box. Great care should be taken in relating these markers to the depths and thicknesses of the strata actually penetrated. A certain amount of core may, for example, slip through the core lifter as the barrel is withdrawn, so that the base of the section recovered is unknowingly taken from a shallower depth than had been anticipated. The dropped core may be recovered, at least in part, by the next drilling run, in which case, provided no slippage occurred at the base of this interval, the thickness of strata between adjacent markers will be greater than the distance indicated by the two depth values involved.

Correction of measured depths and thicknesses to take account of such factors, as well as any actual core losses that may have occurred, is an integral part of the logging process. It may be aided by evidence such as the presence of grooves on core that has slipped through the core lifter, or by indications, that a certain length of core has been ground by the drill during a second penetration. Variations in drilling rate, or the lithology of cuttings recovered from the hole may also be significant, but the depths at which major lithological changes are identified by geophysical logs, if these are run on the hole, are probably the most reliable basis for final adjustment of the geological record.

Cores of non-coal strata are logged as systematically as possible to record their sedimentological and geomechanical properites. The way in which these data are actually recorded may vary considerably, and as well as logs compiled by manual methods, it is common practice in many areas for data to be processed by computer-based techniques. In such instances, recording directly on specially printed coding sheets may be preferred.

Where a relatively small number of rock types is present in the sequence under investigation, greater consistency and ease of logging may be achieved with the aid of photographic reproductions of selected reference specimens. Comprehensive assessment of the litholog-

ic variation in the area is first carried out, to establish the significant rock types and sedimentary structures that should be noted. Typical specimens are then photographed and compiled in book form to assist their identification in the field.

Such 'photo books' are very useful in situations where persons with only limited geological knowledge are involved in core logging. However, they can also assist in providing a standard to impro the consistency between logs of bores in the same area prepared by different professional geologists. Such a reference can allow a smaller number of lithological terms to be used in core logging, and assist in the assimilation of large amounts of geologic data by computer-based systems.

Systematic recording of the core's sedimentological features is essential for reliable stratigraphic correlation throughout the study area. Detailed lithologic data may also be used to construct a depositional model of the coal-bearing sequence, giving a more complete understanding of the distribution of the various sedimentary facies in the field. This may in turn help in the location of further coal deposits elsewhere in the region.

Geological description of coal seams, even those that are not of commerical value, is usually much more detailed than that required for non-coal strata. Thin 'dirt' bands and partings are usually recorded individually, as these may represent significant contaminants or may be useful markers in mining operations. The coal itself is logged in relatively small units, using macropetrographic or lithotype terminology. Special attention is paid to changes in coal type, especially with coals of coking or liquefaction potential, and to the occurrence of shaley coal or other impure materials. Any mineral matter visible in the coal, or on cleats and fractures is also noted.

The geomechanical properties of both coal and non-coal strata, including factors such as their strength, the orientation and spacing of any joints or fractures and the depth to which weathering or oxidation has extended, are essential considerations in the mine design phase of a coal evaluation project. A comprehensive geotechnical investigation, at least for critical parts of the area, is normally incorporated into this type of operation, but many of the fundamental decisions on the viability of extraction methods are nevertheless made at a stage when the only geological data available are from boreholes sunk for preliminary exploration.

As much geotechnical data as possible should be obtained when logging cores from all classes of exploration bores. Many of the properties involved may alter to some extent during storage, and thus, even if the core is available for re-inspection or testing at a later date, the results obtained at that time may be misleading. Systematic recording of quantitative geotechnical data, in a manner such as outlined by the Geological Society Engineering Group Working Party (1970), may be incorporated into the logging process for all boreholes if the necessary resources are available. This may include measuring the degree of fracturing of the core in a systematic way, such as determining the Rock Quality Designation (R. Q. D.), an index that can be used as a general guide to the strength of the various

rock types recovered. A number of simple field tests may also be carried out on representative core samples, such as the point-load strength index, the Schmidt rebound hammer test and others such as those suggested by Johnson (1977). Some samples may even be submitted for laboratory testing of geomechanical properties.

If such quantitative data are not obtained, the geological log should at least include general notes on the relative strength and hardness of each rock type, the nature of its fracture surface and the durability or resistance of the rock to weathering. Rocks that are unduly fragmented by drilling, or those that disintegrate readily when exposed at the surface are most significant, as they may give rise to instability of roof, floor or overburden materials in the mining operation.

Other geological features that need to be noted include the relative degree and depth of weathering in the sequence, the position of the water table (standing water level), and the location of any zones of jointing or indications of faulting. Intervals of the hole where excessive loss or inflow of water took place, or where any caving was encountered should also be recorded, together with the means by which these difficulties were ultimately remedied in the drilling process.

(*From Coal Geology and Coal Technology*, *pp*193 197)

New Words and Expressions

1. inclination [inkli'neiʃən] n. 倾斜；倾角
2. flat-lying ['flæt'laiŋ] a. 平的；平伏的
3. split [split] n. 分叉
4. overburden [əuvə'bə:dn] n. 风化层；表土；浮土
5. remuneration [rimju:nə'reiʃən] n. 报酬；酬劳
6. receptacle [ri'septəkl] n. 容器；贮藏器
7. geomechanical [dʒiəumi'kænikəl] a. 地质力学的
8. assimilation [ə simi'leiʃən] n. 吸收；同化；融合
9. parting ['pɑ:tiŋ] n. 夹层；夹矸层；裂理
10. contaminant [kən'tæminənt] n. 污染物
11. macropetrographic [mækrəu'petrəgræfik] a. 宏观岩石学的
12. viability [vaiə'biliti] n. 可行性
13. point-load 集中载荷
14. rebound ['ribəund] n. 回跳
15. durability [djuərə'biliti] n. 持久性；耐久性
16. unduly ['ʌn'dju:li] ad. 过分地；不适当地
17. disintegrate [dis'intigreit] v. 使瓦解；使分裂
18. instability [instə'biliti] n. 不稳定性
19. inflow ['infləu] n. 进水量；入流

Lesson Twelve

Text 32. top: roof fall

Geological Factors in Roof Behaviour

Apart from the presence of high stress levels in relation to rock strength, strata behaviour in the roof of an underground mine is affected, to a great extent, by a number of detailed geological features in the actual beds concerned. Features that may help to cause roof failure range from small-scale irregularities such as local bedding-plane discontinuities, to large scale problems such as zones of deformation generated by basin-wide tectonic processes. Summaries of the factors that may contribute to roof problems in several different coalfield areas are given by McCulloch et al (1975), Williams and Wilson (1976), Moebbs (1977), Krause et al (1979) and Shepherd and Gale (1982) and several of the more significant factors are discussed below.

PRESENCE OF WEAK OR UNCONSOLIDATED MATERIALS

One of the most fundamental factors in roof behaviour is the amount of solid rock above the seam in relation to the depth of the mine below the ground surface. A large part of the material above the seam, particularly in relatively shallow mines, may be made up of talus, glacial drift, alluvium or deeply weathered bedrock, leaving only a thin layer of consolidated strata to form the roof of the opening concerned. The weight of these surficial deposits may contribute substantially to the pressures developed at depth, but, as they usually have a relatively low inherent strength, they are unable to provide a great deal of support for the roof if they extend into the zone where failure may take place.

DETERIORATION WITH EXPOSURE

Many of the rock types that form the roof of coal seams , even though relatively strong when fresh, may deteriorate on exposure to the mine atmosphere. This deterioration may be due to wetting from groundwater seepage and the use of water sprays for dust suppression, or it may be due to excessive drying out by the moving air of the ventilation system. Such properties are not always apparent from visual inspection of the materials in bore cores or recent exposures, and simple tests such as the slake durability test may be needed to identify these materials and allow remedial action to be taken before the problem gets out of hand.

BEDDING-PLANE DISCONTINUITIES

Physical discontinuities may occur in an otherwise solid rock due to the depositional pro-

cesses under which the rock was formed. Depending on their orientation, these discontinuities can provide surfaces for bed separation or block detachment in the roof of the mine, or act as pathways for water to produce strength deterioration. The principal features of this type that may cause roof problems are

(i) fissile or laminated rock types, such as fine alternations of sandy and shaley materials and flaggy sandstone or limestone beds;

(ii) contacts between different rock types, especially where shaley sediments are overlain by water-bearing sandy or conglomeratic material;

(iii) thin films or horizons of carbonaceous or coaly materials, and individual, clay-filled partings in coal and other rock types;

(iv) foresets of cross-stratified rock types, such as occur in many sandstone beds;

(v) slickensided fractures, commonly developed in fine-grained sediments by compaction processes;

(vi) in situ fossil tree stumps or fossil logs, which commonly form bell-shaped features in the roof, surrounded by coaly films or slickensided fracture surfaces.

Detailed mapping and correlation of underground borehole observations may be necessary to build up an understanding of the distribution of these features in the mine roof, and hence determine the measures that can be taken to ameliorate any problems. The use of a sedimentary model may be of considerable assistance in this regard.

WASHOUT STRUCTURES

In areas where the coal seam or the immediate roof strata are cut by scour and fill structures or washouts, the strata surrounding the infilled palaeochannel commonly contain numerous slickensided surfaces produced by differential compaction. The largest slickensides tend to be curved features, oriented parallel to the washout line, and may be encountered in the mine workings some distance before the channel itself is reached.

The complex interplay of lateral changes in rock strength, together with the presence of bedding plane discontinuities of various types in the vicinity of these features, gives rise to a number of different processes of roof failure. Detailed mapping, aided by high resolution seismic studies and an appropriate sedimentary model may be necessary to enable the location of major washouts to be predicted and hence allowed for in mine planning operations.

JOINT AND FAULT PATTERN

Joints and small-scale faults in the roof strata provide further mechanical discontinuities in the rock mass. Depending on their orientation, they may open, slide or be squeezed tightly closed under the loads imposed by the mining process. Together with the discontinuities induced by the rock's bedding characteristics, they may help to detach blocks of varying size from the roof of the mine, and lead to unstable conditions in underground operations.

A detailed appraisal of the joint and fault pattern in a major Australian coalfield is given by Shepherd, Huntington & Creasey (1981). Linear zones of roof failure occur in several bord and pillar mines in this area, apparently associated with swarms of closely spaced joints and faults. These in turn appear to be related to basement irregularities.

The swarms have been mapped at the surface by field observation and aerial photograph interpretation, and in the mine workings beneath by detailed underground studies. Statistical analysis of the number of joints or faults per metre, in relation to the behaviour of the roof strata involved, has been used to determine the minimum spacing or maximum frequency for good mining conditions. As the width of the swarms is generally greater than that of the roof failure zone, short-range forecasts of difficult areas can be made by geological monitoring of development headings and noting the point at which the frequency of joints with a particular orientation exceeds this threshhold value. Long-range forecasts for mine planning before development takes place can be based, if necessary, on the location of fracture swarms revealed by surface studies.

As well as joints, imposed on the strata by tectonic processes, the roof rocks may also be cut by a series of more or less regular fractures induced by the stress redistribution associated with the mining process. These must also be taken into account as mechanical discontinuities in the study of roof materials.

(*From Coal Geology and Coal Technology*, *pp*255—256)

New Words and Expressions

1. bedding-plane ['bediŋ'plein] n. 层面
2. discontinuity [dis kɔnti'nju:iti] n. 不连续性；间断
3. talus ['teiləs] n. 山麓堆积；碎屑堆
4. alluvium [ə'lu:viəm] n. 冲积物；冲积层
5. bedrock ['bed'rɔk] n. 基岩
6. deterioration [di tiəriə'reiʃən] n. 损坏；恶化；变质
7. deteriorate [di'tiəriəreit] v. 使恶化；使变质
8. seepage ['si:pidʒ] n. 渗出；渗漏
9. suppression [sə'preʃən] n. 抑制；禁止
10. slake [sleik] v., n. 潮解；水解；熄灭
11. fissile [fisail] a. 易剥裂的
12. laminated ['læmineitid] a. 层纹的；页状
13. flaggy ['flægi] a. 板状的；薄层的
14. carbonaceous [kɑ:bə'neiʃəs] a. 碳质的；含碳的
15. foreset ['fɔ:set] n. 前积层
16. cross-stratified ['krɔs'strætifaid] n. 具交错层的
17. ameliorate [ə'mi:ljəreit] v. 改良；改善；变好
18. palaeochannel [pæliəu'tʃænl] n. 古河道
19. interplay [intə'plei] n., v. 相互影响；相互作用
20. swarm [swɔ:m] n., v. 群；群集
21. workings ['wə:kiŋs] n. 工作面；巷道；矿房；采场
22. redistribution ['ri:distri'bju:ʃən] n. 再分布

Notes to the Text

In areas where the coal seam or the immediate roof strata are cut by scour and fill structures or washouts, the strata surrounding the infilled palaeochannel commonly contain

numerous slickensided surfaces produced by differential compaction. 在冲刷充填构造或冲刷作用切割煤层或其直接顶板的地区，由于差异压实作用，在被充填古河道的周缘地层通常会出现大量的擦痕面。

句中 where … washouts 为定语从句修饰 areas，其中 scour and fill 的意思是冲刷充填；分词短语 surrounding the infilled palaeochannel（环绕被充填的古河道周围）修饰 the strata。

Exercises

1. Questions for review:
   1) How do the bedding-plane discontinuities affect the strata behaviour in the roof of an underground mine?
   2) What is meant by roof failure?
   3) What are the geological factors in roof behaviour?
   4) How do the washout structures affect the behaviour of the roof strata?
   5) What does the strength deterioration mean?
2. Give the Chinese/English equivalents for the following:

1) slake durability	6) 通风系统
2) rock mass	7) 沉积模式
3) high resolution	8) 抑尘
4) development headings	9) 矿山巷道
5) mine atmosphere	10) 航摄照片解译

3. Fill the blanks with the words below:

or **from** **for** **in**
of **on** **to** **at**

The process of gathering geologic data ( ) a mine area does not cease when extraction of the coal is commenced. Detailed plans of the workings are made and kept up ( ) date, as the operation progresses, by colliery surveyors employed ( ) the mine site. These plans show the location of all openings very precisely. ( ) most cases, they also show the nature, location and extent of any faults, washouts, igneous intrusions or other significant geological disturbances.

A routine programme of seam section measurement, sampling and analysis is usually also undertaken as production is carried out. This enables the trends indicated by the exploration programme to be investigated more closely, for relatively little cost, and allows up-dating of all types ( ) coal quality maps. The quality maps prepared from these data are, in general, more detailed than those prepared during earlier broad-scale exploration. Projection of the data ahead of the workings may be used to detect any irregularities ( ) quality variations before they are actually encountered in the mine, and therefore provide a valuable basis ( ) advance planning

and production scheduling. The maps also allow continued refinement of reserve estimates, ( ) which the need ( ) additional development can be assessed at any time.

4. Translate the following into Chinese:

The design and construction of a major surface mine generally takes place in three separate, but overlapping stages:

(a) Conceptual evaluation— -an assessment of the basic geologic data on the area, in conjunction with regional geographic and economic constraints, to determine the general feasibility of establishing a viable mining operation;

(b) Interim design ---an assessment of more comprehensive geologic data, including geomechanical and hydrological factors, to draw up a preliminary mine design and test in detail its economic viability. From the results of this study, a decision is normally made as to whether the capital, manpower and other resources should be committed to mine development;

(c) Final design——a refinement of the various components of the mine design as follow-up geological and other studies are completed. This stage merges, without significant break, into the construction of the on-site facilities and the commencement of regular coal production.

Each successive stage requires an increasing amount of geological data. The conceptual framework of the operation, together with a general assessment of its technical and economic viability, can usually be made from the results of the initial exploration programme. Information required for this purpose includes the number, thickness, quality and likely extent of the workable coal seams, the broad geologic structure of the sequence in relation to the topography of the area, and the general magnitude and marketablility of the available coal reserves. Should the results of this study prove sufficiently encouraging, a committment will normally be made to carry out a more comprehensive feasibility study of all or part of the area, without necessarily deciding that a mine will actually be established on the site at all.

5. Translate the following into English:

石炭纪是地史上第一次出现的重要聚煤期。从早石炭世开始聚煤作用的范围已经比泥盆纪显著扩大，中晚石炭世在世界范围内的聚煤作用达到了高潮，当时古气候湿润，植物茂密，泥炭沼泽广布，因而形成了许多大煤田，就目前所知，较重要者分布在北半球。

Reading Materials

(A) Geology in Underground Mining

The design of most large underground mines, particularly bord and pillar operations, embodies development into virgin coal at one or more separate localities. As well as coal winning, part of this development work is inherently devoted to an exploration of the seam in

untested areas. If unexpected difficulties are encountered in the mining of one area, production can be switched to another part of the mine in such cases until the problem is overcome.

Incorporation of this spare 'pit-room' in large scale, highly mechanized mines, however, involves the provision of more haulage facilities, supply lines and ventilation capacity than would otherwise be needed for efficient coal production. Detailed geological studies are often used in underground mines to reduce the need for over-capacity by establishing the natural constraints on coal extraction before any development actually takes place.

Geological work for underground mines may be directed towards one or more of the following objectives:

(a) To identify and map any mining hazards or breaks in seam continuity, such as those due to faults, dykes, joint zones or washouts, so that they can be taken into account in the overall mine design.

(b) To delineate coal thickness and quality trends from evaluation of mine and borehole samples, and relate the data to the day-to-day production requirements of the mine.

(c) To investigate the geotechnical behaviour of the seam or its roof and floor rocks in relation to roof support requirements and the likelihood of rock, coal or gas outbursts in the mine workings.

The investigations may be conducted as part of the design process before mining commences, or they may be part of an on-going programme of data acquisition carried out in conjunction with regular coal production. They may be further developed into a refined process of 'risk reduction', such as that described in detail by Elliott (1974).

This section discusses the features that are significant in selecting the mining method to be used, the features that may affect the overall mine design, and the techniques that can be applied in the delineation of detailed quality trends or the location of seam discontinuities while mining is in progress. The actual behaviour of the strata around an underground opening, however, is discussed separately.

GEOLOGICAL CONDITIONS FOR BORD AND PILLAR MINING

Bord and pillar mining, in general, is most suitable for reasonably thick, relatively shallow seams with moderately strong roof and floor strata. The cost of equipping a working face is relatively low, compared to longwall methods, but operating costs per tonne of coal are relatively high. It is, however, a flexible technique, and the equipment can be shifted more readily from one location to another should unexpected problems be encountered.

The principal geological factors to be considered for bord and pillar mining are as follows:

(a) Seam thickness

Mechanized bord and pillar equipment is available for seams down to about 0.7 m in thickness, although a working section greater than about 1.4 m is preferable in most cases. To-

gether with the width of the opening, seam thickness controls the amount of coal extracted per unit length of face advance, and thus the economic return for the cost of extending the roof support and haulage system.

However, where the thickness to be worked is greater than 3 or 4 m, difficulty may be encountered in obtaining sufficient reach with the coal-winning equipment used, or in handling the supports for the roof strata. The range of working thickness for the area to be extracted is also significant in selecting the most suitable equipment, while the cross-sectional area of the various openings must be considered when assessing ventilation requirements.

(b) Coal strength

The coal to be worked should be relatively strong in order that the pillars formed will not crush or collapse under the loads imposed on them. This is an important factor in obtaining good recovery from first workings, where the strength of the seam, along with the depth of the workings, determines the pillar size. It is also important, however, in the pillar extraction process, as larger amounts of weak coal may still need to be left in place to ensure safe working conditions.

The strength of the seam also affects the type of mining equipment that will be used at the working face. A boom miner , or possibly a cyclic conventional unit, may be necessary for particularly tough materials. In some cases, the use of high-powered equipment may give rise to excessive levels of airborne dust, necessitating increased ventilation rates to avoid endangering the health of mine personnel.

(c) Roof and floor characteristics

In areas that are to be maintained, at least for a significant time, as first workings only, the roof and floor of the seam should be relatively strong and free of creep effects. However, as it is necessary for the roof to collapse in pillar extraction, excessively strong materials can also cause problems with stress buildup and air blast at a later stage of the operation.

(d) Seam gases

Ideally the seam should not produce large quantities of explosive or noxious gas, such as methane and carbon dioxide. A large area of mine workings has to be provided with ventilation, and the air-flow rate would need to be increased to dilute these emissions. Similarly, it is preferable that the seam not be liable to spontaneous combustion, as fires are difficult to control in the extensive ventilation network.

(e) Seam dip

The dip of the seam should not be excessive, since difficulty may be obtained in providing traction for the mining equipment. Special arrangements may be possible for steeply dipping seams, by restricting the direction of development to keep gradients within reasonable limits.

(f) Seam depth

The depth of the seam below the surface determines, to a great extent, the level of stress imposed on the coal pillars. For this reason, larger pillars are usually formed in deep mines, resulting in a lower recovery of material from the first workings process. Panel and pillar operations, such as the Wongawilli system, are more effective at greater depths than a two-stage process, but if the depth exceeds about 500 m, longwall methods are usually preferred.

(g) Surface subsidence

The desirability of subsidence at the ground surface is a major factor in the environmental impact of any underground mining project, and in areas where such subsidence cannot be tolerated, such as around major surface structures, no mining may be permitted at all. At least some mining may still be possible, however, in many cases by using a bord and pillar process with development of first workings only, but pillar extraction, and of course longwall operations, generally cannot be used at all in areas affected by restrictions of this type.

GEOLOGICAL CONDITIONS FOR LONGWALL MINING

Longwall mining is able to operate under a wider range of geological conditions than bord and pillar techniques, and is preferred for deeper mines, for thin seams and for workings in steeply dipping beds, as well as where the roof strata for the seam are relatively weak. The technique also forms the basis for the extraction of coal from extremely thick seams by multi-slice and caving methods. However, longwall mining inherently involves a high rate of output from a single working face, and any interruption to production is therefore a major problem. Once an individual panel has been established, relocation of the equipment to overcome an unexpected obstacle is a difficult, and therefore costly process.

The principal geological factors that can affect the success of a longwall operation include the following:

(a) Seam thickness

Particularly if advancing techniques are employed, longwall mining can be used with seams that are somewhat thinner than might be desirable for bord and pillar methods. Hydraulic supports are also available for seams up to 3.5 or 4 m in thickness. However, as the supports used in mechanized operations can only extend or contract over a certain distance, the seam should have a working thickness, over the area to be extracted, within the range of the supports used. If the seam is too thick, a certain amount of coal may need to be left in place to ensure the success of the operation, while if it is too thin, some non-coal material may need to be taken as well as the coal. The possibility of minor irregularities in thickness, such as those due to roof or floor rolls, must also be taken into account in longwall design.

(b) Seam floor

The floor of the seam should be strong and have a relatively even surface. If the floor is

weak, or becomes plastic when wet, the props will tend to become embedded and progression of the face may be impeded. Minor irregularities, such as floor rolls, can also interfere with the forward movement of face equipment.

(c) Working roof

The strata above the seam need to form a stable roof in areas such as gate roads and at the immediate working face, but at the same time are required to collapse readily behind the mining equipment once coal extraction has been completed. With a roof that is dominated by thick layers of strong materials, such as well-cemented sandstones, excessive overhangs may develop behind the line of roof supports. The weight of this rock places additional loads on the hydraulic legs of the roof support system. If the legs are designed to yield at too low a value in these circumstances, the overhanging layers tend to pivot about a point slightly ahead of the coal face itself, and may cause fracturing in front of the roof canopy that leads to difficulties with face advance. Where stronger legs are used, however, or with weaker roof rocks, the overhangs tend to pivot mainly about the rear of the supports, and satisfactory goaf conditions are easier to maintain.

The nature of their contact with the coal seam may also be important to the design of the support system. If an uneven roof parting is likely to be developed, supports with articulated roof bars may be necessary to accommodate the irregular contact surface. Additional support from hydraulic cylinders at the tip of the roof canopy may be required in some circumstances.

(d) Strata dip

Because the operations do not depend on wheeled vehicles in the same way as bord and pillar mining, longwall faces can be used in a wider range of strata dip conditions. The layout of the workings, however, is controlled to a great extent by the dip direction or gradients involved.

(e) Seam discontinuities

The area to be worked by longwall methods should be free of any wide dykes or washouts and major splits or fault displacements. Penetration of these obstructions to seam continuity is virtually impossible over such a wide front, and working usually needs to cease until a new face is established on the other side.

The layout of individual longwall panels within the mine is generally governed by the location, orientation and extent of these discontinuities, as determined by detailed geological exploration. In retreat mining, any previously unknown features of this type may be detected in the development headings, but in the advance. technique this is not possible before the face is actually in operation. Probing ahead by various means may be necessary in longwall advance, and also be desirable in retreat mining, as many disturbances do not persist as far as the periphery of the block to be extracted.

(f) Surface subsidence

Subsidence of the ground surface must be allowable in a zone surrounding the area to be

worked by longwall methods.

(From Coal Geology and Coal Technology, pp241–245)

New Words and Expressions

1. winning ['winiŋ] n., a. 开采；准备采煤区
2. haulage ['hɔ:lidʒ] n. 运输，牵引
3. outburst ['autbə:st] n. 突出
   gas ～ 瓦斯突出
4. flexible ['fleksəbl] a. 易弯曲的；灵活的
5. boom miner 悬臂式联合掘进机
6. creep [kri:p] n. 蠕变
7. noxious ['nɔkʃəs] a. 有毒的；有害的
8. spontaneous combustion 自燃
9. panel ['pænl] n. 盘区；采区
10. surface subsidence 地表塌陷
11. caving [keiviŋ] n. 崩落；崩落采矿法
12. relocation ['ri:lou'keiʃən] n. 重新安置；位置的改变
13. advancing [əd'vɑ:nsiŋ] n., a. 前进式开采
14. roll [roul] n., v. 凸出
    roof ～ 顶板凸出
    floor ～ 底板凸出
15. prop [prɔp] n., v. 支架；支柱；加固
16. gate road 平巷；层内巷道
17. overhang ['ouvə'hæŋ] n. 悬垂物；伸出；外伸长度
18. canopy ['kænəpi] n. 顶梁，顶盖
19. goaf [gouf] n. 采空区；老塘
20. articulate [ɑ:'tikjulit] v. (用铰链) 连接
    ～ ed roof bar 铰链顶梁
21. retreat mining 后退式开采

(B) Outbursts of Rock, Coal and Gases

Sudden, violent failures of the coal face or the roof or floor of the seam are sometimes encountered in underground operations. These may range in severity from the expulsion of small fragments to the collapse of several complete coal pillars. Loss of life has resulted from such failures on many occasions, but even relatively minor occurrences may cause considerable difficulty due to lost production as well as the need to remove the expelled material and reestablish a safe mining operation.

A comprehensive review of outburst phenomena in coal mines is given by Shepherd, Rixon & Griffiths (1981). This study has grouped violent failures in underground mines into three principal categories:

ROCKBURSTS OR 'BUMPS'

These are violent failures of in situ rock as a result of overstressing on the scale of an entire mine panel. Important characteristics in this type of failure include the absence of any abnormal gas emissions from the strata concerned. Such failures can be further subdivided into those due to loads applied directly to the mine opening ('pressure bumps') and those where the load is transmitted to the opening by failure of rock some distance away ('shock bumps').

OUTBURSTS FROM ROOF OR FLOOR STRATA

These are rapid emissions of gas (usually methane and/or carbon dioxide), together with

a certain amount of rock in some cases, from the roof or floor of the worked seam. Outbursts from the floor may take place through cracks induced by strata movement, while roof outbursts of this type often occur in association with blast holes drilled during mining operations.

INSTANTANEOUS OUTBURSTS OF COAL AND GAS

Also known in some areas as 'blowouts', these are spontaneous ejections of coal and gas from the in situ material at the rib or face of the mine opening. The gas, a mixture of methane and carbon dioxide, is emitted in large quantities, but the emission rate usually decreases rapidly with time. The coal is ejected with the gas in the form of a fine powder, forming a cavity ahead or to one side of the working place, generally originating in the upper part of the working section.

Rockbursts are a different phenomenon to gas outbursts from either the seam or the adjacent strata. They are generally considered to be due to excessive loading of brittle rock and are more common in isolated pillars where large areas of the surrounding seam have been extracted. Gas outbursts, on the other hand, are more likely to occur when the workings are advancing into previously unmined strata, from which any trapped gas has had little opportunity to escape. They tend to have a greater proportion of fine particles in the expelled debris than do rockbursts, and are more likely to take place in porous fractured or cleaved material than in a non-porous, homogeneous rock mass.

Gas outbursts are the most common form of violent failure in coal mines. They are the result of a combination of a high gas content in at least part of the seam and excessive stresses due to burial or tectonic forces and to the removal of coal in the mining process. They may arise, for example, when the workings approach too close to a pocket of high pressure gas, such as might be trapped in an abnormally fractured part of the coal bed. Alternatively, the development of mining-induced fractures in a stressed enviroment ahead of the face may liberate sorbed gas from the coal and precipitate an outburst at a suitably located place of weakness.

The gases that occur in and around the seam act both to reduce the effective strength of the material in which they occur and to exert a considerable expansion pressure on the enclosing pore walls. They are probably generated for the most part during the rank advance process, particularly near the transition from high volatile to medium volatile bituminous coal. Shepherd, Rixon & Griffiths (1981) indicate that all extensively mined seams in Australia with a vitrinite reflectance greater than 1.10% (i.e. medium volatile bituminous coal or higher rank material) are outburst-prone, while no outbursts have been reported in Australian collieries working seams with a reflectance below 1.00%. Other gases, made up largely of CO_2 rather than methane, may also be introduced due to the effects of igneous intrusions or deeper seated magmatic processes on the coal seam.

The actual location of many outbursts is often related to the presence of particular

structures in the coal seam, such as specific faults, folds, joints, cleat or fracture patterns. These structures may represent points where stress concentrations are naturally developed, or where accumulations of gas may build up during the history of coal seam formation, Once such a relation is established, it may be possible to delineate the location of outburst-prone areas in the mine by evaluating and mapping the features concerned.

Rockbursts and gas outbursts are generally preceeded by small-scale or microseismic shocks. A network of geophones can be used in the mine to record these shocks, providing much the same type of data as that obtained in crustal earthquake studies. The location of each individual microseismic event is determined from differences in the arrival time of the signal at the various geophone stations, and maps of shock centres may be used to delineate potential outburst zones. The rate of shock generation from such a zone tends to change very rapidly in the interval immediately preceding failure, and by plotting the number of bumps recorded from each zone per day, an estimate of the relative stability of different parts of the working area can be made.

Microseismic monitoring of this type is also potentially useful in providing warning of less violent, but nevertheless still dangerous problems with strata behaviour, such as roof falls. However, the seismic pulse is of lesser intensity in these circumstances, and therefore more difficult to distinguish from the background noise produced by work in the mine. Experiments by Hooker *et al* (1970) suggest that only a relatively short warning time is likely to be given compared to that obtained for outburst phenomena.

The pressure of gas in the seam can be reduced, in many cases, by a pattern of boreholes drilled ahead of the face to provide a series of drainage paths. In situ gas pressures, gas compositions and anticipated flow rates from such operations may be evaluated, if necessary, before mining commences. A series of bores may be sunk from the surface to provide the gas drainage system, either meeting the coal bed essentially at right angles, or deflected to meet the seam approximately parallel to the bedding plane. More commonly, however, the bores are drilled parallel to the seam from appropriate underground locations. The gas may be drawn off, using suction if necessary in impermeable seams, and discharged at a convenient point on the ground surface. If the gas is mainly methane, it may even be processed and marketed as a by-product of the mining operation.

Several additional methods for the prediction and prevention of outbursts are described by authors such as Neyman *et al* (1972). These include an evaluation of the mechanical properties of the coal itself, and an assessment of the degree of difficulty encountered when drilling small-diameter boreholes several metres ahead of the face.

(*From Coal Geology and Coal Technology*, *pp*257—259)

New Words and Expressions

1. severity [si'veriti] n. 严重；严厉
2. rockburst ['rɔkbə:st] n.. 岩石突出
3. bump [bʌmp] n. 岩石突出
   pressure ~s 岩爆

shock ～s 冲击地压

4. overstressing ['ouvə'stresiŋ] n. 逾限应力；超负载

5. blowout [blou'aut] n. 井喷；爆裂

6. unmined ['ʌn'maind] a. 未开采的

7. sorb [sɔ:b] v. 吸附；吸收

8. microseismic ['maikrəu'saizmik] a. 微震的；脉动的

9. geophone ['dʒi:əufəun] n. 地震检波器

10. deflect [di'flekt] v. 使偏斜

11. suction ['sʌkʃən] n. 负压；吸力

Lesson Thirteen

Text

The Hydrologic Cycle

The amount of water on earth is immense, an estimated 1.36 billion cubic kilometers (326 million cubic miles). Of this total, the vast bulk—97.2 percent—is part of the world ocean. Icecaps and glaciers account for another 2.15 percent, leaving only 0.65 percent to be divided among lakes, streams, subsurface water, and the atmosphere (Table 1). Although the percentage of the earth's total water found in each of the latter sources is but a small fraction of the total inventory, the absolute quantities are great.

Table 1 Distribution of the World's Estimated Water Supply

Supply	Surface Area (square miles)	Water Volume (cubic miles)*	% of Total Water
Surface water			
Freshwater lakes	330 000	30 000	0.0090
Saline lakes and inland seas	270 000	25 000	0.0080
Average in stream channels		300	0.0001
Subsurface water			
Vadose water (soil moisture and intermediate zone water)	50 000 000	16000	0.005
Groundwater within one-half mile of surface		1 000 000	0.310
Groundwater (deep-lying)		1 000 000	0.310
Total liquid water in land areas	50 600 000	2 070 000	0.642
Ice caps and glaciers	6 900 000	7 000 000	2.150
Atmosphere	197 000 000	3 100	0.001
World ocean	139 500 000	317 000 000	97.200
Totals (rounded)		326 000 000	100.000

SOURCE: U. S. Geological Survey

* A cubic mile of water equals 1.1 trillion gallons.

Water is continually on the move; there is a constant interchange of water between the various sources. This unending circulation of the earth's water is known as the hydrologic, or water, cycle (Figure). It is a gigantic system, powered by energy from the sun, operating in and on the land and oceans and in the atmosphere. Water from the surface of the oceans is evaporated into the atmosphere by the energy provided from the sun. Winds transport the moisture-laden air to different locations where it condenses to form clouds and eventu-

ally falls to the surface as precipitation. The precipitation which falls into the ocean has ended its cycle and is ready to begin another. The water which falls on the continents, however, must still make its way back to the ocean.

What happens to precipitation once it has fallen on the land? A portion of the water soaks into the ground, some of it moving downward, then laterally, finally seeping into lakes, streams, or directly into the ocean. When the rate of rainfall is greater than the earth's ability to absorb it, the additional water flows over the surface into lakes and streams. Much of the water which soaks in (infiltration) or runs off (runoff) eventually finds its way back to the atmosphere. Evaporation from the soil, lakes, and streams is continuous. Also, some of the water which infiltrates the ground surface is absorbed by plants, which then release it into atmosphere. This process is called transpiration. When precipitation falls at high elevations or high latitudes, the water may not immediately soak in, run off, or evaporate. Instead it may become part of a snowfield or a glacier. Although the water can be tied up in this fashion for many years, it will eventually melt and continue its path to the sea. A diagram of the earth's water balance, a quantitative view of the hydrologic cycle, is shown in the Figure.

The hydrologic cycle represents the continuous movement of water from the oceans to the atmosphere, from the atmosphere to the land, and from the land back to the sea. The wearing down of the earth's land surface is primarily attributable to the last of the steps in this cycle

(*From Earth Science*, 1976, *pp*48 49)

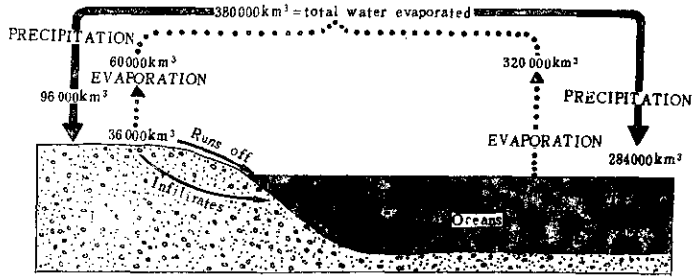


Figure The earth's water balance. About 320 000 cubic kilometers (80 000 cubic miles) of water are evaporated each year from the oceans, while evaporation from the land (including lakes and streams) contributes 60 000 cubic kilometers (15 000 cubic miles) of water. Of this total of 380 000 cubic kilometers (95 000 cubic miles) of water, about 284 000 cubic kilometers (71 000 cubic miles) fall back to the ocean, and the remaining 96 000 cubic kilometers (24 000 cubic miles) fall on the earth's land surface. Since 60 000 cubic kilometers (15 000 cubic miles) of water evaporate from the land, 36 000 cubic kilometers (9 000 cubic miles) of water remain to erode the land during the journey back to the oceans.

New Words and Expressions

1. hydrologic cycle 水（文）循环
2. immense [i'mens] a. 巨大的；无限的
3. vast [vɑ:st] a. 巨大的；无边无际的
4. bulk [bʌlk] n. 容积（量）；大部分
5. icecap ['ais'kæp] n. 冰帽；冰盖
6. account for 总数（量）是；说明；是…的原因
7. inventory ['invəntri] n. 清单；（…）总数
8. interchange [ˌintə('tʃeindʒ] v., n. 交换；交替
9. unending [ʌn'endiŋ] a. 无尽的；不停的；不断的
10. gigantic [dʒai'gæntik] a. 巨大的
11. moisture ['mɔistʃə] n. 湿气；水分；湿度；潮湿
12. happen to… 发生
13. soak into 渗透到…
14. seep into 渗流（出）到…
15. soak in 浸出；渗入
16. infiltration [ˌinfil'treiʃən] n. 渗入
17. infiltrate [in'filtreit] vt.（使）渗入；透过；渗透
18. transpiration [ˌtranspi'reiʃən] n. 蒸腾（作用）
19. elevation [ˌeli'veiʃən] n. 高处；高地；高度；海拔
20. snowfield ['snəu'fi:ld] n. 雪原
21. tied up （停）滞留；束缚
22. fashion ['fæʃən] n. 方式；式样；型式

Notes to the Text

1. Although the percentage of the earth's total water found in each of the latter sources is but a small fraction of the total inventory, the absolute quantities are great. 尽管后几种水源的全球总水量所占百分比只是全球总水量的一小部分，但它的绝对水量却是巨大的。

   句中 "found…sources" 为一过去分词短语，作 "the earth's total water" 的后置定语；but 在这里起副词作用，作"不过"、"只"解；latter sources 是指前句中的"lakes、streams、subsurface water 和 the atmosphere"。

2. The wearing down of the earth's land surface is primarily attributable to the last of the steps in this cycle. 地球陆地表面的侵蚀主要是由于这种水文循环的各个阶段的持续（长期）作用造成的。

   句中 "wearing down" 是 "磨损、侵蚀" 的意思；"is attributable to" 这一词组意为 "可归因于…的" 或 "因…原因（作用）造成的"；"last" 在这里作 "持续" 解。

Translation Guide

长难句的分析及译法（I）

英语中有些长句的结构比较复杂、层次重叠，理解和翻译时有一定难度，故许多译者把这样的句子俗称长难句。长难句之所以长而难，主要是因为这种句子在简单的基本句型上经过了不同程度的扩展和变化。这种扩展和变化的方式很多，它可以是增加句子的修饰成分（定语或状语）、并列成分或附加成分（插入语、同位语或独立成分），也可以是由各种短语或从句来充当句子中的某些成分，甚至短语和从句本身又带有短语和从句，从而形成多级短语和多级从句。此外，还可出现句子倒装和省略以及词或句子之间的分隔现象等变化，从而使句子的意思不易理解并难以简明、确切表达。为了帮助初学译者解决这一难点，下面就来简要介绍长难句的一般分析方法和译法。

Ⅰ．长难句分析的一般步骤与方法

（1）遇到长难句时，先通读全句，确定专业术语和各种词组的词义，然后分析句子的主要成分——主语和谓语。

（2）分析句型，看这个句子是简单句还是复合句，对复合句要根据连接词或关联词弄清是并列复合句还是主从复合句。

（3）分析句中主要扩展成分，包括所有的短语和从句的类型及其充当的成分，注意辨析句中的分词、动名词和谓语动词。

（4）分析句中次要扩展成分或附加成分，如插入语、同位语或其它独立成分，确定它们所修饰的对象及与句中主要成分的关系。

（5）综合分析句中各种成分之间的相互关系，可用图解或划线的方法把相关成分联系起来，注意是否存在有倒装、省略或分隔现象。

（6）通过对全句的词义确定和语法分析并结合上下文和专业内容准确理解原意后，按中文表达习惯译成汉语。

Ⅱ．长难句的分析举例

1．扩展的简单句的分析例解

1）A comparison of the map indicating the centers of major earthquakes with the one showing the location of the world's active volcanoes demonstrates some of the similarities in their distribution.

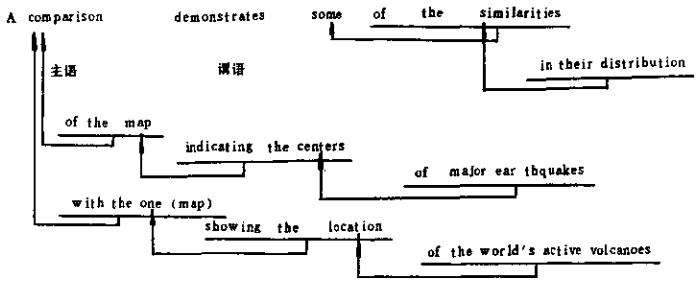
分析：

（1）这个简单句的主要成分主语是 comparison，谓语是 demonstrates。

（2）扩展成分为介词短语和分词短语，均起定语作用，即主语 comparison 带两个介词短语“of…earthquakes”和“with…volcanoes”，每个介词短语又各带有一个分词短语（“indicating…”和“showing…”），每个分词短语再各带一个介词短词（“of major earthquakes”和“of the world's active volcanoes”）；宾语带一个二级介词短语。

（3）句中的不定代词 one 代替前面出现过的名词 map。

图解：



译文：

把标有主震震中的地图与表示世界上活火山位置的地图进行对比，就可以看出它们的分布有某些相似之处。

2) Indirect evidence of the existence of life in the Precambrian is furnished by huge volumes of calcareous materials in ancient limestones and marbles, of carbon in graphite deposits, and of enormous precambrian sedimentary iron ore deposits.

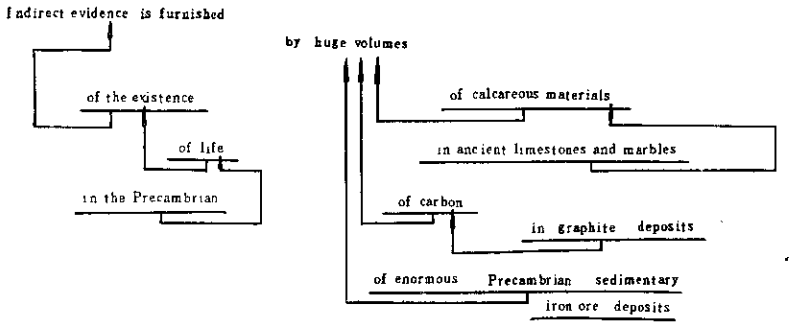
分析：

(1) 这个简单句的主语为 evidence，谓语为 is furnished，本句为一被动语态句。

(2) 扩展成分：主语 evidence 带一个多级介词短语；huge volumes 后跟有三个并列介词短语即 "of calcareous…marbles"，"of carbon…deposits" 和 "of enormous…deposits"。

(3) "huge volumes" 为 "大量" 之意，为使译文明确，可重复与三个并列介词短语一起译出。

图解：



译文：

古代石灰岩和大理岩中的大量石灰质物质、石墨矿床中大量的碳、以及大量的前寒武纪沉积铁矿床，提供了前寒武纪存在生命的间接证据。

Exercises

1. Questions for review:
   1) What is hydrologic cycle?
   2) How do the vapours result in droplet growth?
   3) What is hydrogeology concerned primarily with?
   4) Why is hydrogeology also a branch of hydrology in the broad sense?
   5) What subjects are essential for hydrogeological studies?why?
2. Give the Chinese/English equivalents for the following:

the hydrologic cycle	水电站
the ground water table	蒸发作用
the surface runoff	蒸腾作用

municipal water supply	环境污染
geotechnic constructions	水库

3. Write one complete sentence in English for each term listed below:

evaporation **precipitation** **hydrology**

condensation **transpiration** **hydrogeology**

4. Translating the following passage into Chinese:

Water resources are divisible into two distinct categories——the surface water resoures and the ground water resources. Al though the water resources of the earth are abundant, resources of usable quality of water are limited. About 97 percent of the available water resources ($1.25\times10^{18}m^3$) is contaied in the oceans. The total quantity of fresh water is estimated at about $4.1\times10^{18}m^3$ which is distributed as follows: 75 percent in polar ice and glaciers, 14 percent in ground water between depth of 800 and 4000m and 11 percent at depths of less than 800m, 0.3 percent in lakes, 0.6 percent as soil moisture, 0.035 percent in atmosphere, and 0.03 percent in rivers. Water containd in these bodies is transient to a varying degree; the residence time in oceans and seas is about 4000 years, in the subsur face it may vary from less than a day to thou sands of years. The ground water resources are distributed unevenly in various geological formations, both in space and time.

5. Translate the following sentences into English:

1) 当雨降落到地上时，一部分水会渗入地下，另一部分水形成地表迳流。

2) 水文地质学可以用来寻找地下水供水水源。

3) 水文地质学与地层学、岩石学、构造地质学、地貌学、水文学等学科密切相关。

4) 太阳的热蒸发了江河湖海里的水。

5) 水文地质学研究是以分析地壳形成历史为基础而发展起来的。

Reading Material

Hydrology and Hydrogeology

Hydrology is the science which deals with the occurrence, distribution and disposal of water on the planet earth; it is the science which deals with the various phases of the hydro logic cycle.

Hydrologic cycle is the water transfer cycle which occurs continuously in nature; the three important phases of the hydrologic cycle are: (a) Evaporation and evapotranspiration (b) precipitation and (c) runoff. The globe has one-third land and two-thirds ocean. Evaporation from the surfaces of ponds, lakes, reservoirs, ocean surface, etc. and transpiration from surface vegetation, i. e. from plant leaves of cropped land and forests, etc. take place. These vapours rise to the sky and are condensed at higher altitudes by condensation nuclei and form clouds, resulting in droplet growth. The clouds melt and sometimes burst resulting in precipitation of different forms like rain, snow, hail, sleet, mist, dew and frost.

A part of this precipitation flows over the land called runoff and a part infilters into the soil which builds up the ground water table. The surface runoff joins the streams and the water is stored in reservoirs. A portion of surface runoff and ground water flows back to ocean. Again evaporation starts from the surfaces of lakes, reservoirs and ocean and the cycle repeats. Of these three phases of the hydrologic cycle, namely, evaporation, precipitation and runoff, it is the 'runoff phase' which is important to a civil engineer since he is concerned with the storage of surface runoff in tanks and reservoirs for the purposes of irrigation, municipal water supply and hydroelectric power etc.

Hydrogeology is concerned primarily with the mode of occurrence, distribution, movement and chemistry of water occurring in the subsurface in relation to the geological environment. With an increase in the emphasis on hydrology, the subject passes into the realm of geohydrology. The distinction is, however, arbitrary. Usually, the study of one cannot be divorced from the study of the other, in order to understand the interrelationships between the geologic and hydrologic environments.

Hydrogeology is one of the Earth sciences. Studies develop from a basis of an analysis of the history of the formation of the Earth's crust, the outermost 30km (approximately) zone of the Earth, because it is impossible to understand the history of water in the Earth without considering the rock surrounding it and with which it was originally formed from the earliest times in Earth history. Hydrogeology is also a branch of hydrology in the broad sense, because it is an inseparable part of a study of the whole of the Earth's hydrosphere (water above the ground).

Hydrogeology finds application in identifying the source points for ground water supplies and in the estimation of ground water reserves, mineral prospecting and mining, tackling problems related to pollution, evaluation of sites for geotechnic constructions, etc. concerning geologists, geophysicists, hydrologists, engineers engaged in drilling, irrigation, public health and civil engineering, agronomists and environmental scientists, legal professionals, and planners. An understanding of the hydrogeological set-up of an area is essential for proper management of water resources and protection of the environment from degradation. A knowledge of the basic principles of geology, particularly stratigraphy, petrography and structural geology; geomorphology, hydrology, physics, chemistry and mathematics is essential for hydrogeological studies. Because hydrogeology encompasses several disciplines, an interdisciplinary approach is often the best course for the achievement of satisfactory results from investigations.

(*From Hydrology, p*11 *and Hydrogeology, pp* 1—3)

New Words and Expressions

1. hydrology [hai'drɔlədʒi] n. 水文学
2. hydrogeology ['haidrəudʒi'ɔlədʒi] n. 水文地质学
3. occurrence [ə'kʌrəns] n. 发生；出现；产状
4. disposal [dis'pəuzəl] n. 处理；配置
5. phase [feiz] n. 阶段；状态
6. hydrologic cycle 水（文）循环
7. evapotranspiration [i,væpə,trænspi'reiʃən] n. 蒸发蒸腾（作用）
8. precipitation [pri,sipi'teiʃən] n. 降水（量）；降雨（量）；沉淀
9. runoff ['rʌnɔ:f] n. 径流
10. transpiration [,trænspi'reiʃən] n. 蒸腾（作用）
11. condense [kən'dens] v. 冷凝；凝结
12. condensation [kɔnden'seiʃən] n. 冷凝作用；凝结（作用）
13. nuclei ['nju:klai] n. 核（单数 nucleus）
14. droplet ['drɔplit] n. 小（水）滴；液滴
15. burst [bə:st] v. 爆炸；爆发
16. hail [heil] n. 雹；冰雹
17. sleet [sli:t] n. 霰；雨（夹）雪
18. mist [mist] n. 雾；烟雾
19. dew [dju:] n. 露（水）
20. frost [frɔst] n. 霜；霜冻
21. infilter ['infiltə] v. 渗入（into）
22. flow back to 流回到
23. namely ['neimli] ad. 即；也就是；那就是
24. civil engineer 土木工程师
25. storage ['stɔ:ridʒ] n. 贮藏；储集
26. tank [tæŋk] n. 贮水池
27. municipal [mju (:) 'nisipəl] a. 城市的；市政的
28. hydroelectric power 水电站
29. emphases ['emfəsi:z] n. 强调；加强，（单数 emphasis）
30. pass into 变成；成为；进入
31. arbitrary ['ɑ:bitrəri] a. 任意的；随机的；不定的
32. realm [relm] n. 领域；范围
33. geohydrology [,dʒi:əuhai'drɔlədʒi] n. 水文地质学
34. divorce [di'vɔ:s] vt. （使）脱离
35. interrelationship n. 相互关系（联系）
36. in the broad sense 从广义来说
37. inseparable [in'seprəbl] a. 不可分离（割）的；分不开的
38. tackle ['tækl] v. 解决；处理
39. geotechnic [dʒiəu'teknik] a. 土工技术的
40. agronomist [ə'grɔnəmist] n. 农业专家；农学家；农艺师
41. set-up ['setʌp] n. 计划；方案；总体布置
42. degradation [degrə'deiʃən] n. 降低；减少；降级
43. encompass [in'kʌmpəs] v. 包含；包括；包围
44. interdisciplinary [intə'disiplinəri] a. （各）学科（之）间的

Lesson Fourteen

Text

Subsurface Water

Water existing in the liquid, solid or gaseous state in the rocks of the earth is called subsurface water. Subsurface water can be divided into ground water or phreatic water, vadose water and internal water. Ground water occurs in the zone of saturation in which all interconnected voids are filled with water that is under hydrostatic pressure. Between the upper surface of this zone of saturation, called the water table, and the ground surface is the zone of aeration, containing vadose water which includes water held in interstices of capillary dimensions, water percolating from the surface to the zone of saturation, and water in the form of vapour occupying voids.

According to origin and source, subsurface water can be classified as connate water if the water occurring in a rock formation was entrapped during the deposition of the rock (as in some marine sediments), meteoric water if it was derived from atmospheric precipitation, and as juvenile water if it was derived from the interior of the earth.

Zone of Aeration: The form and configuration of the zone of aeration is largely controlled by topography, geology climate, drainage, and vagetation, all of which control the position of the water table. The zone of aeration is thick in topographic highs, highly permeable formations, arid climates and drainage divides. Water-bearing and water-yielding characteristics in the zone of aeration, control in a large measure the percolation of water to the zone of saturation. The zone of aeration may range from zero in the outcrop areas of water table to over hundred meters in arid climates in the upland regions underlain by highly permeable formations.

Water in the zone of aeration is held against gravity most of the time, in capillary interstices and in thin films over surfaces of the grains due to strong molecular attraction of the solid particles at the solid/liquid interface. It is called pellicular water. When the soil is saturated and recharge occurs, the interstices may be filled with water to saturation capacity and may revert to retention capacity after complete drainage. Water moving under gravity through larger interstices may reach the water table faster than water moving through smaller interstices. Thus, the moisture content may differ at different places within the zone of aeration. The zone of aeration may be divided into (1) belt of soil water (2) intermediate belt and (3) capillary fringe.

Zone of Saturation: Although the lower part of the capillary fringe (overlying the water table), specially in materials containing minute interstices, is saturated, this part of the

capillary fringe is not included in the zone of saturation as the water in it is under less than atmospheric pressure and is not yielded freely to wells. Except for oil-bearing and gasbearing rocks, intercomunicating interstices in the phreatic zone are filled with water under hydrostatic pressure. The width of the zone may be small in areas underlain by massive rocks with shallow fractures and weathered layers to thousands of metres in areas underlain by thick sequence of sedimentary rocks.

There may be two or more zones of saturation in some areas. Where there is a layer of impermeable rock in the zone of aeration, downward movement of water may be retarded, resulting in saturation of the interstices and formation of perched aquifer above the impermeable layer. Where one or more perched aquifers are found, the water table below the lowermost zone is called the main water table.

The water table is a discontinuous surface in fissured consolidated rocks, in which large unsaturated blocks of rock may separate water-saturated fissures. A water table may be absent altogether where an impermeable rock overlies permeable saturated rock. In limestone caverns and other large interstices, the water table may be virtually an open water surface.

The position of the water table depends on the topography, geological structure, areas of recharge and discharge of ground water, the permeability characteristics of underlying rocks and ground water withdrawals. The water table in many places is a subdued replica of the land surface. The water table tends to be more uniform in flat terrain and rocks of high permeability. It is generally deeper in uplands and shallower in valley bottoms. The water table is locally deep in areas of heavy ground water extraction.

The zone of saturation consists of rocks of different water-bearing and water-yielding properties. A rock formation, sequence of formations or part of a formation which yields appreciable quantities of water to wells and springs is called an aquifer. A semipermeable layer that yields water slowly in comparison to an adjoining aquifer is called an aquitard. A relatively impermeable layer, the yield of which is insignificant in comparison to an adjoining aquifer, is called an aquiclude. These terms are only relative. In contrast to the above, a rock that does not store any water is an aquifuge. Saturated formations consisting of one or more aquifers, together with the associated layers, comprise a ground water reservoir. A ground water reservoir may consist of a variety of rock types ranging from fissured to granular varieties

(*From Hydrogeology*, *pp*24—28)

New Words and Expressions

1. phreatic [fri'ætik] a. 潜水的
   ~ water 潜水
2. vadose ['veidəus] n. 渗流
   ~ water 渗流水
3. saturation [ˌsætʃə'reiʃən] n. 饱和
4. interconnect ['intə (:) kə'nekt] vt. 使相互联系；使互相结和
5. void [vɔid] n. 空隙；孔隙
6. hydrostatic [ˌhaidrəu'stætik] a. 静水的；流体静力（学）的

7. aeration [ˌeiəˈreiʃən] n. 通气；充气；通风
~ zone 饱气带
8. interstice [inˈtəːstis] n. 空隙；间隙
9. capillary [kəˈpiləri] n., a. 毛细管；毛细作用的
10. percolate [ˈpəːkəleit] v. (使) 渗透
11. connate [ˈkɔneit] a. 同生的；同源的；先天的
~ water 原生水
12. entrap [inˈtræp] vt. 诱捕；圈闭
13. meteoric [ˌmiːtiˈɔrik] a. 大气的；气象的
~ water 雨水
14. juvenile [ˈdʒuːvinail] a. 幼年的；初生的
~ water 初生水
15. configuration [kənˌfigjuˈreiʃən] n. 轮廓；构型；位形；组态
16. drainage [ˈdʒeinidʒ] n. 排水；放水
~ divide 分水岭
17. water-yielding 给水的；涌水的
18. in a large measure 大部分
19. percolation [ˌpəːkəˈleiʃən] n. 渗透；渗漏
20. upland [ˈʌplənd] n. 高地
21. molecular [məuˈlekjulə] a. 分子的
22. interface [ˈintəfeis] n. 分界面
23. pellicular [peˈlikjulə] a. 薄膜的
~ water 薄膜水
24. recharge [ˈriːtʃɑːdʒ] v. 补给；回灌
25. revert to 回复
26. retention [riˈtenʃən] n. 保留；保持；滞留
27. moisture content 含水量；湿分含量
28. capillary fringe 毛细作用带
29. intercomunicate [ˌintə (ː) kəˈmjuːnikeit] vi. 互通；内部互通；互相联系
30. impermeable [imˈpəːmjəbl] a. 不渗透的；不透水的
31. retard [riˈtɑːd] vt. 延迟；使停滞；阻止；妨碍
32. perched aquifer 滞水层（滞留含水层）
33. fissured [ˈfiʃəd] a. 具裂隙的
34. discharge [disˈtʃɑːdʒ] v., n. 排泄；流量；涌水量
35. withdrawal [wiðˈdrɔːəl] n. 抽水（量）排水（量）
36. subdued [səbˈdjuːd] a. 平缓的；削低的
37. terrain [ˈterein] n. 地形；地体；地面
38. extraction [ikˈstrækʃən] n. 抽出；提取
39. appreciable [əˈpriːʃiəbl] a. 可估计的
40. aquifuge [ˈækwifjuːdʒ] n. 不透水层
41. aquifer [ˈækwifə] n. 含水层
42. granular [ˈgrænjulə] a. 颗粒状的；粒面的
43. aquiclude [ˈækwiklu:d] n. 隔水层
44. aquitard [ˈækwitəd] n. 弱含水层

Notes to the Text

1. The zone of aeration may range from zero in the outcrop areas of water table to over hundred meters in arid climates in the upland regions underlain by highly permeable formations. 饱气带（厚度）的变化范围较大，在潜水面露头区为0，到气候干旱且下面有高渗透性岩层的地势高的地区则可变为数百米以上。
句中“range from…to…”意为“…变化范围从…到…”；under lain by…下伏为…。系过去分词短语作“upland regions”的后置定语。
2. Water in the zone of aeration is held against gravity most of the time, in capillary interstices and in thin films over surfaces of the grains due to strong molecular attraction of the solid particles at the solid/liquid interface. 由于在固体与液体间面上固体颗粒的强分子吸引作用，饱气带中的水时常能克服重力作用而保持在毛细孔隙中和颗粒表面上的薄膜中。
is held in…被保持在…（位置）；介词against作“逆着，顶着”解，这里可译为“克服”。这一介词短语在句中作状语；due to 可看作复合介词，作“由于”解。

Translation Guide

长难句的分析及译法（Ⅱ）

2. **长难复合句的分析例解**（限于篇幅，图解分析从略）

1) The rocks beneath are folded or tilted; they may be metamorphased and intruded by lava; they contain different fossils; they do not conform or fit in with the younger rocks resting on them; their surface is weathered and eroded.

分析：

(1) 这是一个并列复合句，由五个分句构成，彼此被分号分开。

(2) 在第四个分句中，fit with 是动词短语，与 conform 共用 with，with 不在重复。此处 or fit in (with) 是进一步附加说明前一短语动词的意思，根据具体情况，可不单独译出。

(3) 为使译文简练，分句中的主语代词不必一一译出。

译文：

下面岩层已经褶曲；也可能已经变质，其中有熔岩侵入；含有不同的化石；与上覆的新岩层不整合；有一个风化剥蚀面。

2) They (the folds) are known as anticlines or upfolds, when the beds are bent upward as in an arch; as synclines or downfolds, when the beds sink into a trough; as monoclines when the fold has only a single slope, joining the ground raised from its continuation on a lower level; as isoclines when the folds have been so pressed together that the summits have been forced over so that both sides of the fold slope in the same direction.

分析：

(1) 本句由四个并列关系的复合句组成，其中每一个复合句都有一个由 when 引出的时间状语从句。

(2) 后三个复合句中的主句，在引导补语的 as 之前都省略了主语和谓语（"they are known"）。

(3) 将这类并列复合句译成中文时，各原分句中相同的主语可视具体情况不必一一译出。

译文：

当岩层向上弯曲呈拱形时，它们（这种褶皱）就称为背斜或隆褶皱；当岩层下弯而呈凹槽形时，就叫做向斜或槽褶皱；当褶皱只有一个斜层，而且这个斜层又与从较低的位置延续上来的地面相接，就叫做单斜；当几个褶皱一起受挤压，以致它们的顶部被过度的推挤，因而褶皱的两翼均向同一方向倾斜时，就叫做等斜褶皱。

3) The historical geologist will tell you approximately when the first forms of life developed, what kinds of plants and animals lived during each period, and when man may have made his appearance on the earth.

分析：

(1) 这是一个带有三个并列宾语的主从复合句。主句的主语是 The historical geologist，

谓语是 will tell。

(2) 三个并列的宾语从句分别依次由“when，what 和 when”引出，前二者由逗号分开，后二者由连接词 and 连接并在它之前由逗号分开。

(3) 句中的 approximately 修饰主句的谓语，不是修饰 when 引导的从句。

(4) “and”连接句子时，往往不译成中文，连接词和词组时须译成中文。

译文：

地史学家会大致地告诉你：最初的生物种类是在什么时期进化的，每个纪都生存过何种动植物，大概什么时期地球上出现了人类。

4) Since one of the critical differences between minerals and rocks is that minerals are approximately homogeneous substances, and most rocks are not, this means that one piece of quartz will be about as hard as another piece, that it will have the same specific gravity, and if formed in a similar environment, it will have about the same crystal form.

分析：

(1) 这是一个较复杂的主从复合句，主句的主语是 this，谓语是 means，带一个原因状语从句（“since…not,”）和三个并列的宾语从句，即依次为“that…piece”，“that…gravity”和“and if…form”。

(2) 原因状语从句位于主句前，带有两个并列的表语从句，即“that…substances”和“and most…not”。

(3) 第三个宾语从句又带一个条件状语从句“if…environment”，其中在 if 和 formed 之间省略了 it is。

译文：

由于矿物同岩石的一个重要区别在于矿物是近乎均质的物质，而大部分岩石则不是，因此这就意味着，每块石英的硬度大致相同、比重相同，而且如果是在相似的环境中形成的话，还会有大致相同的晶形。

5) In many such ranges, complex masses made up of cherty sedimentary rocks, peridotite, serpentinite, and tholeiitic pillow lavas——an assemblage precisely like the mater ials dredged from the Mid-Atlantic Ridge and exposed on St. Pauls Rocks——are all jumbled together as though stirred in a giant mixing bowl, to form a melange.

分析：

(1) 这是一个有分隔和省略现象的复杂主从复合句，主句的主语是 masses，谓语是 are jumbled，二者相隔很远。这种分隔是由于主语后面有修饰语。分词短语“made up of…lavas”为 masses 的定语，两个破折号内有 masses 的同位语 assemblage。而“like the materials”这一介词短语是 assemblage 的后置定语。“dredged from…Ridge”和“exposed on…Rocks”两个分词短语都是修饰 materials 的后置定语。

(2) as though 引出的方式状语从句省略了 they had been。

(3) “to form a melange”不定式短语作目的状语，说明主句的谓语。

译文：

在许多这种山脊里，由燧石沉积岩、橄榄岩、蛇纹岩以及拉斑玄武岩的枕状熔岩组成的一套复杂岩体（极象从大西洋中脊取出而暴露在圣保罗罗克斯的一套物质），就好象在调拌食品的大碗里经过搅拌似的，全都混杂在一起，而成为混杂岩。

3. 长难句的译法

翻译长难句时，首先要抓住全句的中心内容，弄清句子由几部分构成，它们之间存在什么样的语法关系，同时要特别注意单词、短语、从句的并列层次和扩展层次，然后根据汉语的表达习惯，予以重新安排，不要过分拘泥于原文的结构形式。长难句的译法一般有三种，即顺译法、逆译法和分译法。现举例说明如下：

1）顺译法——按照原文的上下层次顺序而译

How these two things — energy and matter behave, how they interact one with the other, and how people control them to serve themselves make up the substance of two basic physical sciences, physics and chemistry.

能和物质这两种东西如何起作用，它们如何相互影响，人们如何控制它们使之为自己服务，这些问题构成两门基础自然科学——物理和化学的主要内容。

In fact, the generally accepted theory now is that the production of rain depends upon the presence of dust particles in the air, which serve as nuclei about which the drops may form.

事实上，目前普遍公认的理论是：雨的形成依赖于空气中尘粒的存在，因为尘粒可作为晶核，使雨珠在其周围生成。

2）逆译法——改变原文叙述层次，由下而上逆序而译

The method normally employed for free electrons to be produced in electron tubes is thermionic emission, in which advantage is taken of the fact that, if a solid body is heated sufficiently, some of the electrons that it contains will escape from its surface into the surrounding space.

固体被加热到足够温度时，它所含的电子就会有一部分离开表面飞逸到周围空间中去，这种现象叫做热电放射。通常，电子管就是利用这种现象来产生自由电子的。

3）分译法——把与主句内容联系不很紧密的从句或分词短语译成若干短句

Many sedimentary rocks contain such features as ripple marks, exactly like those we can see forming in sediments at the bottom of present-day lakes or shallow seas.

我们可以看到，现在的湖底或海底部的沉积物中形成了波痕。许多沉积岩都含有类似这种波痕的特征。

Coal of the highest rank, called anthracite, occurs in certain localities where unusually high pressure due to deep burial and subsequent earth movements, combined with a moderate increase of temperature, has facilitated the driving-off of nearly all the volatile constituents.

最高牌号的煤叫做无烟煤，生成于这样的地区，即那里由于埋藏很深以及后来的地壳运动而产生的异乎寻常的高压，同适当增加的温度相结合，促使几乎所有的挥发物质排除掉。

Exercises

1. Questions for review:
   1) Wtat is water table?
   2) What is the distinction between the zone of aeration and the zone of saturation?
   3) Why can water in the zone of aeration be held in capillary interstices?
   4) How were the perched aquifers formed?
   5) What does the position of the water table depend on?
   6) Where can we find the saturated zone?
2. Choose the correct term given in brackets to complete each statement:
   1) A rock that does not store any water is _____.
      a. an aquifuge b. an aquifer c. a perched aquifer
   2) Water that was derived from atmospheric precipitation is _____.
      a. the connate water b. meteoric water c. juvenile water
   3) Water existing in the zone of saturation is called as _____.
      a. the vadose water b. internal water c. the phreatic water
   4) The amount of open space in a material is often referred to as _____.
      a. the porosity b. the permeability c. the density
   5) The pellicular water is held in _____.
      a. capillary interstices b. interstices in the phreatic zone c. a+b
3. Write one complete sentence in English for each term listed below:

subsurface water	**soil water**	**vadose water**
surface water	**ground water**	**internal water**

4. Translating the follwing passage into Chinese:

   Many people depend on finding the water table as a source of water. Just how far down would you have to go to get to the water table?Generally, the water table roughly follows the slope of the region. The depth of the water table rises and falls depending on many factors. Heavy rains or melting snows make the water table rise. It may rise to the surface, completely filling the zone of aeration with water. Any further rain cannot seep into the ground. Water then builds up on the surface causing standing water or flooding. Dry spells, and heavy pumping of water from wells cause the water table to drop. Seepage into streams and lakes, and the amount of plant growth on the surface can also affect the level of the water table.
5. Translate the following sentences into English:
   1) 地下水可分为潜水、渗流水和深层水。
   2) 饱气带的位形主要受地形、地质气候、排水和植被条件控制。
   3) 水经大孔隙流到潜水面比通过小孔隙要快得多。
   4) 饱水带由不同含水和涌水性质的岩石组成。

5）物质的孔隙度是由许多因素综合决定的，这些因素包括它的颗粒形态、它的颗粒填集方式和它们是否具有分选性。

6）物质的渗透性取决于两个因素，首先是物质孔隙的大小，其次是孔隙的内联方式。

Reading Material

How Water Enters the Earth

Right after a rainstorm, the ground and streets are drenched with water. Yet in a few hours, both may be dry. Where did the water go?Read this section to find out.

Infiltration: When you spill a drink at the beach, it seeps right into the sand. After a storm, rain water, too can seep into the ground. The seepage of precipitation into the earth is called infiltration.

Infiltration is possible because the earth's surface is not completely solid. Much of the earth's surface is made of loose particles of rock and soil. Between these particles are empty spaces called pores. Pores are usually filled with air. Water infiltrates the earth's surface by entering these pores and forcing the air out.

Porosity and Permeability: The amount of water that can infiltrate the ground depends on two factors. First it depends on how much space is available for rain to seep into. Second, it depends on how easily the water can enter and flow through the material.

Porosity is the amount of open space in a material. The porosity of a material is expressed as a percent of its total volume. Suppose that half the volume of a sample of rock is open space. Then that sample has a porosity of 50%. Earth materials differ greatly in their porosity. Loose rock particles, or sediments like sand, gravel, and clay have the highest porosity. But even rocks that appear solid have some empty spaces.

The porosity of a material is determined by a combination of many factors. These factors include the shape of its particles, how its particles are packed, and whether or not they are sorted.

Permeability is the rate at which a fluid can move through a material. Gravel is said to be very permeable. Fluids can pass through gravel easily. On the other hand, shale is an impermeable rock. That is, fluids cannot flow through shale.

The permeability of a material depends on two factors. It depends on how large a material's pores are. It also depends on how interconnected the pores are. Small pores slow the flow of water through a material. And if pores are not interconnected, water cannot get from one pore to another. Water cannot pass through the material as a result.

It is useful to know the porosity and permeability of the ground. From its porosity, hydrologists can eatimate the extent of a region's underground water supply. If its permeability is known, they can determine how fast the rain water will seep into the ground. With this information, hydrologists can make important predictions. They can predict how fast and in what direction sewage water from septic tanks will flow. These predictions help en-

gineers place septic tanks far from sources of fresh water. In this way, sources of drinking water are protected from contamination.

(*From Earth Science*, 1986, *pp*161—163)

New Words and Expressions

1. rainstorm ['reinstɔ:m] n. 暴风雨
2. drench [drenʧ] vt. 使浸透；使淋透
3. spill [spil] v. (使) 溢出；溅出；倾倒出
4. porosity [pɔ:'rɔsiti] n. 孔隙度；孔隙率
5. permeability [ˌpə:mjə'biliti] n. 渗透性 (率)；透水性
6. rock particles 岩石颗粒
7. pack [pæk] v. 填塞；挤满
8. sort [sɔ:t] v., n. 分选；把…分类；种类；分类
9. on the other hand 另一方面
10. interconnect ['intə(:) kə'nekt] vt. 使互相联系；使互相结合
11. pass through 穿过；经过；通过
12. seep into 渗入
13. prediction [pri'dikʃən] n. 预测；预示；预报
14. predict [pri'dikt] v. 预示；预测
15. sewage ['sju:idʒ] n. 污水
16. septic ['septik] a. 引起腐烂的
    ～ tank 化粪池
17. contamination [kənˌtæmi'neiʃən] n. 污染

Lesson Fifteen

Text

Types of Aquifers

Aquifers are classified as unconfined, confined and leaky. An aquifer, the upper surface of which is defined by the water table, is called an unconfined, water table or phreatic aquifer. The water table is in vertical contact with the atmosphere through the soil interstices. Rest water level in a well of small diameter tapping an unconfined aquifer represents the position of the water table at the point. A confined aquifer, also known as artesian or pressure aquifer, is one which is separated from the atmosphere by a relatively impermeable confining rock which functions as an aquifuge, aquiclude or aquitard. The water in a confined aquifer exerts an upward hydrostatic pressure greater than the atmosphere on the overlying impermeable strata. In a tightly cased well penetrating a confined aquifer, the water level will rise above the top of the aquifer corresponding to the hydrostatic pressure head of the water in the aquifer. The imaginary surface defining this pressure level of ground water in the aquifer is termed the piezometric surface or piestic surface. When there are several aquifers, each aquifer has its own piezometric surface. Where the piezometric surface lies above the ground surface, wells tapping the aquifer flow naturally.

An intermediate type of aquifer is the leaky aquifer or semiconfined aquifer, in which the confining layer is semipermeable (aquitard). Ground water in a leaky aquifer moves across semipermeable layers, depending on the differences in the pressure heads in the materials above and below and permeability characteristics of the aquitards.

Each artesian aquifer has a recharge or intake area, a conduit or transitional area, and a discharge area. The dischareg area may correspond to an area of upward leakage of water or downslope outcrop of the artesian aquifer. The distribution of hydrostatic head in an artesian aquifer is controlled by the difference between the elevations at which confinement of water begins in the recharge area and the discharge area. Local variations in the distribution of bead may occur due to several factors like geological structure, lithological characteristics, overburden pressure, recharge and discharge.

Artesian water is distributed in diverse and complex hydrogeological frameworks such as synclinal troughs, anticlinal limbs, foredeeps, monoclines, fault troughs and tectonic fracture zones. Artesian water may be struck in formations irrespective of their geological age, but more important occurrences are in stratiform aquifers of Palaeozoic and younger ages. Important artesian aquifers comprise sedimentary formations, but volcanics also form major artesian aquifers in some places. Localised artesian conditions are also found in crys-

talline rocks.

In a given location there may be several aquifers with different degrees of confinement and interconnection between them, which together form an aquifer system. Regionally extensive, impermeable or relatively impermeable formations restrict hydraulic interconnection between different aquifer systems. As a result, each aquifer system may have distinctive hydrogeologic and hydrogeochemical characteristics. An aquifer system may encompass a stratigraphic unit from a stage to a whole system.

(*From Hydrogeology*, *pp*28- 30)

New Words and Expressions

1. confined aquifer 承压含水层
2. *unconfined aquifer* 非承压含水层
3. leaky aquifer 越流含水层（半承压含水层）
4. phreatic aquifer 潜水含水层
5. rest water level 静止水位
6. artesian [a:'ti:zjən] a. 自流的
   ~ aquifer 自流水含水层；承压含水层
7. function as 起…的作用
8. pressure head 压头；压差；承压水位；承压水头
9. imaginary [i'mædʒinəri] a. 假想的；虚构的
   ~ surface 理想水面
10. piezometric [ˌpaiəzə'metrik] a. 测压（水位）的
    ~ (piestic) surface 测压面
11. tap [tæp] n. vt. 龙头；排水孔；（开孔）使流出；接通（自来水等）
12. semiconfined aquifer 半承压含水层
13. semipermeable ['semi'pə:mjəbl] a. 半渗透的；半透水的
14. intake ['inteik] n. 吸入；垂直补给
    ~ area 受水区；垂直补给区
15. conduit ['kɔndit] n. 水道；管道；排水渠
16. transitional [træn'siʒənl] a. 过渡的
    ~ area 过渡区
17. leakage ['li:kidʒ] n. 渗透；渗流；越流
18. elevation [ˌeli'veiʃən] n. 高程；高度；高地；海拔
19. confinement ['kɔnfainmənt] n. 边缘；区域；范围；境界
20. overburden ['əuvə'bə:dn] n. 负载；覆盖层；表土；风化层
21. synclinal [siŋ'klainl] a. 向斜的
22. trough [trɔf] n. 槽；波谷；地堑
23. anticlinal ['ænti'klainl] a. 背斜的
    ~ limb 背斜翼
24. foredeep ['fɔ:di:p] n. 前渊；陆外渊；外地槽
25. monocline ['mɔnəklain] n. 单斜构造
26. fault troughs 地堑
27. *tectonic fracture zones* 构造断裂带
28. irrespective of 不管；不论；不考虑；与…无论
29. stratiform ['strætifɔ:m] n. 层状
30. hydraulic [hai'drɔlik] a. 水力的；水压的
31. encompass [in'kʌmpəs] v. 围绕；包含（括）；拥有

Notes to the Text

1. A confined aquifer, also known as artesian or pressure aquifer, is one which is separated from the atmosphere by a relatively impermeable confining rock which functions as an aquifuge, aquiclude or aquitard. 承压含水层，也叫自流含水层或压力含水层，它被一层起不透水（隔水）层作用的非渗透性岩层与大气分开。

   句中 also known as artesian or pressure aquifer，是一插入语句，前面省略了 it is；"which functions as…" 为定语从句，修饰前面的 rock。"be known as…" 意思是 "通称为…" 或 "叫做…"。

2. In a given location there may be several aquifers with different degrees of confinement and interconnection between them, which together form an aquifer system. 在某些地区，可存在若干个含水层，这些含水层各有不同程度的承压范围，并且彼此间相连的情况也不一样，它们共同构成了一个含水层系统。

句中“which together … system.”系非限制性定语从句，是对主句中“several aquifers”的附加说明。这种定语从句相当于并列句。

Exercises

1. Questions for review:
   1) What is an aquifer?
   2) What is the distribution of hydrostatic head in an artesian aquifer controlled by?
   3) Why may local variations in the distribution of pressure head occur?
   4) What rocks may important artesian aquifers be struck in?
   5) Do you know how to distinguish the unconfined aquifer, the confined aquifer and the leaky aquifer?
2. Select the letter of the answer that best completes each of the following:
   1) _____ is also known as artesian aquifer.
      (a) an unconfined aquifer (b) a leaky aquifer
      (c) a confined aquifer (d) (a) + (b) + (c)
   2) Each artesian aquifer has _____.
      (a) a recharge area, (b) a transitional area
      (c) and a discharge area (d) (a) + (b) + (c)
   3) More important artesian water often occurs in stratiform aquifers of _____ _____ ages.
      (a) Palaeozoic. (b) Mesozoic
      (c) and Cenozoic (d) (a) + (b) + (c)
   4) Artesian water may be distributed in _____.
      (a) sedimentary formations (b) volcanics
      (c) and crystalline rocks (d) (a) + (b) + (c)
   5) The well from which water must be pumped to the surface is _____.
      (a) a artesian well (b) a nonflowing well
      (c) gusher (d) (a) + (b) + (c)
3. Give the Chinese/English equivalents for the following:

aquiclude	透水层
piezometric surface	半承压含水层
pressure head	半渗透岩层
hydrostatic head	补给区
artesian system	排水区

cone of depression	年抽水量
mineral explorations	间歇性热泉
anticlinal limbs	单斜构造

4. Translate the following passage into Chinese:

When underground water reaches an impermeable layer or the water table, it may continue to move through an aquifer. An aquifer is a layer of rock or sediment through which water freely passes. Aquifers are usually layers of gravel, sand, sandstone, or cracked limestone. In an aquifer, water can travel far from where it first entered the ground as rainfall. Water can travel through an aquifer at different speeds. Its speed depends on two factors. The first factor is the slope and permeability of the land. The second factor is the supply of water.

5. Translate the following sentences into English:

1) 地下水是充满在地面底下土壤与岩石孔隙中的水。

2) 每个含水层有它自己的测压面。

3) 每个自流含水层有补给区、水道区和排泄区。

4) 在结晶岩地区也能找到局部的自流含水层。

5) 因此，每个含水层系统可以有明显的水文地质和水文地球化学特征。

6) 当潜水面与地面交会时便生成泉。

7) 根据定义，热泉中的水比年平均气温高6·9℃。

8) 热泉和间歇喷泉中的地下水比其它地下水含有更多的溶解物质。

Reading Materials

(A) Wells and Springs

The most common device used by humans for removing groundwater is the well, an opening bored into the zone of saturation. Wells serve as reservoirs into which groundwater moves and from which it can be pumped to the surface. Digging for water dates back many centuries and continues to be an important method of obtaining water. Today in many parts of the world, including the United States, water from wells irrigates more land than does water from streams.

The level of the water table may fluctuate considerably during the course of a year, dropping during dry seasons and rising following periods of rain. Therefore, to insure a continuous supply of water, a well should penetrate many meters below the water table. When water is pumped from a well, it produces a depression in the water table, roughly conical in shape, known as a cone of depression. If pumping is heavy, the water table may not only be lowered immediately around the well but may extend over a large area. Under these circumstances, it can be said that the groundwater is literally being "mined", for even if pumping were to cease immediately, it could take hundreds of years for the groundwater

to be replenished. The following example illustrates this point:

Consider for example, a location in the dry southwestern United States where annual recharge to an aquifer is on the order of only two-tenths of an inch of water. In such areas it is not uncommon to pump two feet or more of water per year for irrigation or other uses. In this oversimplified example if the entire aquifer were pumped at that rate, yearly pumpage would be equivalent to 120 years' recharge, and ten years of pumping would remove a 1200-year accumulation of water. New recharge during the pumping period would be negligible. Mechanical problems and economic factors prevent complete dewatering of an aquifer, but the example is valid in principle.

When the water table intersects the ground surface, springs result. There are many circumstances which might create springs. In some places the main zone of saturation is overlain by unsaturated material that contains an impervious layer, above which a local zone of saturation may occur. If this perched water table intersects a hillside a spring or series of spring are found. Springs also occur when fractures or solution channels (subterranean channels created when soluble rock, such as limestone, is dissolved by groundwater) intersect the surface.

(*From Earth Science*, 1976, *pp.* 68--69)

New Words and Expressions

1. pump [pʌmp] *n.*, v. 泵；用泵抽（水）
2. date back 追溯（到）
3. fluctuate ['flʌktjueit] v. 波动；动摇
4. dropping ['drɔpiŋ] n. 下降；落下
5. insure [in'ʃuə] vt. 给…保险；保证（使…得到）；为…提供保证
6. depression [di'preʃən] n. 凹陷
7. conical ['kɔnikəl] a. 圆锥形的
8. cone of depression 沉陷锥；下降漏斗
9. mined [maind] v. 开采
10. cease [si:s] v. 停止；结束
11. replenish [ri'pleniʃ] vt. （再）注满；（再）添满；补充（给）
12. oversimplify ['əuvəsimplifai] vt. 过于简化
13. yearly pumpage 每年抽水量
14. equivalent to 等于；相当于
15. dewatering [di:'wɔ:təriŋ] *n.* 抽水；排水
16. valid ['vælid] a. 有效的；有根据的
17. intersect [intə'sekt] v. 横切；贯穿；交叉；交会
18. be overlain by 上覆为
19. impervious [im'pə:vjəs] a. 不透水的；不渗透的
20. hillside ['hil'said] n. 山腰；山坡

(B) Artesian Wells, Hot Springs and Geysers

Artesian Wells: The term artesian is applied to any situation in which groundwater rises in a well above the level where it was initially encountered. For such a situation to occur, two conditions must exist: (1) Water must be confined to an aquifer that is inclined so that one end is exposed at the surface, where it can receive water; and (2) Impermeable layers, both above and below the aquifer, must be present to prevent the water from escaping. When such a layer is tapped, the pressure created by the weight of the water above will cause the

water to rise. If there were no friction the water in the well would rise to the level of the water at the top of the aquifer. However friction reduces the height of this pressure surface. The greater the distance from the recharge area (area where water enters the inclined aquifer), the greater the friction and the less the rise of water. In Figure Well 1 is a non-flowing artesian well because at this location the pressure surface is below ground level, when the pressure surface is above the ground and a wall is drilled into the aquifer (Well 2, Figure), a flowing artesian well is created.

Artesian systems act as conduits, transmitting water from remote areas of recharge great distances to the points of discharge. In this manner water which fell in central Wisconsin years ago is now taken from the ground and used by communities many miles distant, in Illinois. In south Dakota such a system has brought water from the Black Hills in the west, eastward across the state. On a different scale, city water systems may be considered examples of man-made artesian systems. The water tower, into which water is pumped, may be considered the area of recharge, the pipes the confined aquifer, and the faucets in homes the flowing artesian wells.

Hot Springs: By definition, the water in hot springs is 6—9° C (10—15°F) warmer than the mean annual air temperature for the localities where they occur. In the United States alone, there are well over 1000 such springs.

Mineral explorations over the world have shown that temperatures in deep mines and oil wells usually rise with an increase in depth below the surface. Temperatures in such situations increase an average of about 0.6℃ per 30 meters (1℉ per 100 feet). Therefore when groundwater circulates at great depths, it becomes heated, and if it rises to the surface, the water emerges as a hot spring. The water of some hot spring in the United States, particularly in the East, is heated in this manner. This example indicates that the great majority (over 95 percent) of the hot springs (and geysers) in the United States are found in the West. The reason for such a distribution is that the source of heat for most hot springs is cooling igneous rock, and it is in the West that igneous activity has been most recent.

Geysers: Geysers are intermittent hot spring or fountains where columns of water are ejected with great force at various intervals, often rising 30-60 meters (100-200 feet). After the jet of water ceases, a column of steam rushes out, usually with a thundering roar. Perhaps the most famous geyser in the world is Old Faithful in Yellowstone National Park, which erupts about once each hour. Geyses are also found in other parts of the world, including New Zealand and Iceland, where the term geyser, meaning "spouter" or "gusher", was coined.

Geysers occur when groundwater in heated in underground chambers. At the bottom of the chamber, the water is under great pressure because of the weight of the overlying water. Consequently, a temperature above 100℃ (212℉) is required before it will boil. For example, at the bottom of a 300-meter (1000-foot) chamber water must attain a temperature of nearly 230℃ (450℉) before it will boil. The heating causes the water to expand,

with the result that some flows out at the top. This decreases the pressure, and the water quickly turns to steam and causes the geyser to erupt.

Groundwater from hot springs and geysers usually contains more material in solution than groundwater from other sources because hot water is a more effective dissolver than cold. When the water contains much dissolved silica, geyserite is deposited around the spring. Travertine, a form of calcite, is a characteristic deposit at hot springs in limestone regions. Some hot springs contain sulfur. In addition to making the water taste bad, sulfur emits an uppleasant odor. Undoubtedly Rotten Egg Spring, Nevada, is such a situation. (*From Earth Science*, 1976, *pp.* 69—72)

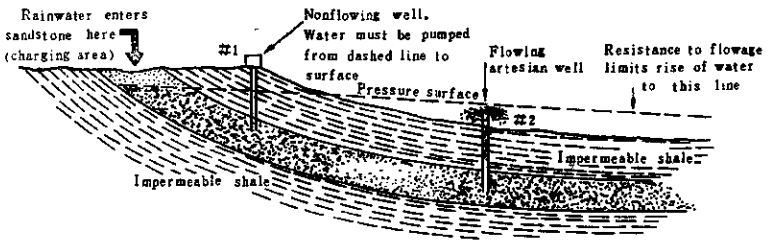


Figure Artesian systems occur when an inclined aquifer is surrounded by impermeable beds. (Foster, Physical Geology, 2nd ed, Merrill, 1975)

New Words and Expressions

1. encounter [in'kauntə] v. 碰到；遇到
2. incline [in'klain] v. (使) 倾斜；(使) 倾向于
3. prevent…from 阻止…；防止…以免…
4. friction ['frikʃən] n. 摩擦力
5. nonflowing ['nɔn'fləuiŋ] a. 非流动的；非自流的
6. act as 充当；起…作用
7. Wisconsin [wis'kɔnsin] n. (美国) 威斯康星(州)
8. Illinois [ili'nɔiz] n. (美国) 伊利诺斯(州)
9. south Dakota [də'kəutə] n. (美国) 南达科他州
10. Black Hills 布莱克山(美国)
11. faucet ['fɔ:sit] n. (水) 龙头
12. hot spring 热泉
13. mean annual air temperature 平均年气温
14. exploration [ˌeksplɔ:'reiʃən] n. 勘探
15. circulate ['sə:kju:leit] v. (使) 循环；环境
16. emerge [i'mə:dʒ] vi. 出现；形成
17. geyser ['gaizə] n. 间歇喷泉
18. intermittent [ˌintə'mitənt] a. 间歇性；周期性
19. fountain ['fauntin] n. 喷泉；自流井
20. column ['kɔləm] n. 柱；圆柱
21. eject [i (:) 'dʒekt] vt. 逐出；驱逐；排斥
22. jet [dʒet] v. 喷射出
23. rush out 冲出
24. thundering ['θʌndəriŋ] a. 雷鸣似的；极大的
25. roar [rɔ:] n. 吼；咆哮；轰鸣声
26. old Faithful 老忠诚泉
27. Yellowstone National Park 黄石国家公园
28. erupt [i'rʌpt] v. 喷出
29. New Zealand [nju:'ziləndˌ] n. 新西兰
30. Iceland ['aisləndˌ] n. 冰岛
31. spouter [spautə] n. 喷井；喷口；喷流
32. gusher [gʌʃə] n. 自喷井；喷出
33. coin [kɔin] vt. 造(新词等)
34. consequently [kɔn'sikwəntli] ad. 因而；所以
35. attain [ə'tein] v. 达到；获得

36. dissolver [di'zɔlvə] n. 溶剂
37. geyserite ['gaizəsrait] n. 硅华
38. travertine ['trævəti:n] n. 石灰华；钙华
39. in addition to 除…之外
40. emit [i'mit] v. 喷出；发射
41. odor [əudə] n. 气味；臭气
42. undoubtedly [ʌn'dautidli] ad. 无容置疑的；肯定的
43. Rotten Egg Spring 臭蛋泉
44. Nevada [ne'vɑ:də] n. （美国）内华达（州）

Lesson Sixteen

Text

Ground Water Flow——Darcy's Law

Ground water is in constant motion from a point of recharge to a point of discharge, in accordance with laws governing flow of fluids in porous media. The law of linear resistance gives the rate at which ground water in motion loses energy. Further, because of addition to and withdrawal from ground water storage, the volume of ground water in motion changes with time and distance according to the principle of conservation of mass. In general terms, this can be expressed as

Mass inflow rate = Mass outflow rate + change of mass storage with time

The above relation is often termed the equation of continuity.

Darcy's Law: From the results of experiments on the flow of water through uniform sands, more than a century ago, Darcy found that the velocity of flow through porous media is proportional to the head loss and inversely proportional to the length of the flow path. This relationship, known as Darcy's law or the law of linear resistance has been expressed in various forms, one of which is

$$Q = KA\frac{h_1}{l}$$

Where Q = discharge in m^3/day

K = hydraulic conductivity in m^3/day/m^2 (or m/day)

h_1 = head loss in metres over a distance l, also in metres, in the flow direction

A = cross sectional area of the porous medium through which flow occurs, in m^2, measured at right angles to the direction of flow

Sometimes the right-hand side of the equation is assigned a-ve sign to imply flow in the direction of decreasing head.

Where an infinitesimal section is considered, Darcy's law can be expressed as

$$Q = KA\frac{dh}{dl}$$

Where dh/dl is the hydraulic gradient.

The quantity Q/A, called Darcian velocity, or specific discharge, although having dimension of velocity, expresses only the rate of flow per unit cross-sectional area that in-

cludes solids and interstices. The average interstitial velocity is given by

$$V=\frac{KI}{\theta}$$

Where V=velocity of flow through the pore space in meters per day

θ=effective porosity (in decimal fraction)

The factor of proportionality K is a property of the soil, rock or aquifer, to transmit water. In metric units, as adopted in this book, hydraulic conductivity K is defined as the rate of flow in cubic metres per day through a cross-sectional area of one square metre under a hydraulic gradient of one metre per metre at the prevailing kinematic viscosity. The term permeahility is used to express the general water-transmissive character of the rocks.

Changes in the temperature affect the hydraulic conductivity of water-bearing materials due to changes in the viscosity of water. Hydraulic conductivity of various materials, specially those that lack significant differences, can be compared only when they are referred to a standard temperature, which is usually taken as 60°F. The formula for converting hydraulic conductivity determined at other temperature to standard temperature is

$$K_t=\frac{K_L V_L}{V_t}$$

Where K_t=hydraulic conductivity at standard temperature

K_L=hydraulic conductivity at laboratory temperature

V_L and V_t=kinematic viscosities of water at laboratory and standard temperatures, respectively

(*From Hydrogeology*, *pp*53—55)

New Words and Expressions

1. Darcy's Law 达西定律
2. in accordance with 根据；按照；和…一致
3. govern ['gʌvən] v. 控制；统治
4. porous ['pɔ:rəs] a. 多孔的
5. media ['mi:djə] n. 介质；中间（单数 medium）
6. linear ['liniə] a. 线性的；（直）线的
7. resistance [ri'zɪstəns] n. 阻力；抵抗
8. addition to 增加
9. withdrawal [wið'drɔ:əl] n. 排出；抽水（量）；排水（量）
10. conservation [kɔnsə'veiʃən] n. 守恒；保存；保持
11. mass [mæs] n. 物质；质量
12. inflow ['infləu] n. 进入（量）；入流；垂直补给
13. outflow ['autfləu] n. 流出（量）；溢出（量）
14. equation [i'kweiʃən] n. 方程（式）
15. continuity [ˌkɔnti'nju:ti] n. 连续性
16. velocity [vi'lɔsiti] n. 速度
17. proportional to 与…成比例的
    inversely ~ 与…成反比
18. head loss 水头损失
19. path [pɑ:θ] n. 途径；路线；轨迹
20. discharge [dis'tʃɑ:dʒ] n. 流量；涌水量；排泄
21. hydraulic conductivity 渗透系数；水力传导率
22. cross sectional area 横断面积
23. at right angles to
    与…成直角；与…垂直
24. right——hand side 右侧
25. assign [ə'sain] vt. 确定；给定
26. sign [sain] n. 符号；记号；标记；标志
27. imply [im'plai] vt. 意思是；暗指；包含
28. infinitesimal [ˌinfini'tesiməl] a. 无限小的；无

穷小的

29. section ['sekʃən] n. 断面；剖面
30. hydraulic gradient 水力梯度
31. pore space 孔隙
32. effective porosity 有效空隙度
33. decimal ['desiməl] a. 十进位的；小数的
    ~ fraction （十进制）小数；十进分数
34. proportionality [prəpɔ:ʃə'næliti] n. 比例；比值
35. in metric units 在公制单位中
36. be defined as 被定义为
37. cubic metre 立方米
38. prevailing [pri'veiliŋ] a. 通行的；占优势的
39. kinematic [kaini'mætik] a. 运动的；运动学的
    ~ viscosity （运）动粘滞性；动粘滞度
40. water —transmissive 导水的；传送水的
41. formula ['fɔ:mjulə] n. 公式
42. converting [kən'və:tiŋ] n. 转换；变换

Notes to the Text

1. From the results of experiments on the flow of water through uniform sands, more than a century ago, Darcy found that the velocity of flow through porous media is proportional to the head loss and inversely proportional to the length of the flow path. 一个多世纪以前，达西根据水通过均匀砂流动实验的结果发现，水通过多孔介质流动的速度与水头损失成正比，而与流动的距离成反比。

   这里介词短语 "from…" 意为 "根据…"，在句中作状语，表示推论或根源。又如：

   From what is said above, I think this answer is right.

   根据以上所述，我想这个答案是对的。

   be (directly/inversely) proportional to…与…成（正/反）比。例如：

   The pressure of a gas is (directly) proportional to its absolute temperature when its volume remains constant.

   当气体体积保持不变时，气体压力就和其绝对温度成正比。

   The pressure of a gas is inversely proportional to its volume, if its temperature is kept constant.

   如果温度保持不变，则气体压力和其体积成反比。

2. Hydraulic conductivity of various materials, specially those that lack significant differences, can be compared only when they are referred to a standard temperature, which is usually taken as 60°F。各种物质的渗透系数，特别是那些无重大差别的系数，只有当它们是指标准温度（常取作华氏60度）时才能比较。

   句中 "specially…differences" 为非限制性同位语，是对主语作进一步解释，也有类似的宾语同位语，如：

   I want very much to see these new books, especially the one you mentioned.

   我很想看这些新书，特别是你提到的那一本。

   "which is…" 是非限制性定语从句，是对前面状语从句中的 "standard temperature" 作进一步说明。

Exercises

1. Questions for review:
   1) What is Darcy's Law?
   2) What is often termed the equation of continuity?
   3) Why can the changes in the temperature affect the hydraulic conductivity of water-bearing materials?
   4) How can the average interstitial velocity be computed?
   5) What temperature is usually taken as 60°F?
2. Choose the correct term from the list below to complete each of these sentences:
   geohydrology, geochemistry, hydrology, geothermics, geomorphology, stratigraphy
   1) _____ is a science which studies the sequence of the rocks in the earth's crust.
   2) _____ is a science dealing with the character, source and mode of occurrence of underground water.
   3) _____ is a science which deals with the chemical composition of the earth's crust and chemical changes in it.
   4) _____ is a science which deals with the occurrence, distribution and disposal of water on the planet earth.
   5) _____ is a science dealing with the heat of the earth's interior.
   6) _____ is a science which studies the land and submarine relief feature of the earth's surface.
3. Write one complete sentence for each term listed below:

recharge	**potassiun**	**sodium**
discharge	**water level**	**magnesium**
calcium	**piezometric level**	

4. Translating the following passage into Chinese:

Water in the unsaturated zone above the water table is called vadose water. Water in this zone is percolating downward toward the saturated zone. A certain amount of vadose water is always present because of surface tension with rock and soil particles.

The quantity of groundwater that can be stored in rocks depends upon the volume occupied by open spaces, that is, the porosity of the material. The openings may be pores in sediment or sedimentary rock, or fractures in crystalline rocks. Porosity alone, however, is not a satisfactory measure of a material's capacity to yield groundwater. The permeability of a material, its ability to transmit water is of prime importance. In material like clay, which has very small openings, most of the water may be held by molecular attraction and be unable to move. Therefore, even though some clays have high porosities, they yield little or no water. On the other hand, material with large openings may yield much water, although the porosity may be small.

The rate of groundwater movement is usually very slow, especially when compared to the movement of streams. Rather than measuring velocity in meters per second or kilometers per hour, the movement of groundwater is measured in meters or centimeters per day. Although rates of tens of meters per day have been measured, a rate of 12-15 meters (40-50 feet) per day is considered high.

5. Translate the following sentences into English:

1) 在潮湿地区，潜水面可能就在接近地表的地方。

2) 地下水不断地从补给区流向排泄区。

3) 水位变动的大小受潜水面变动带内物质含水性质的控制。

4) 世界有一些地区地下水的过量抽出造成地下水位下降100米以上。

5) 要评价饮用水和工农业用水的可行性，必须测定水的物理、细菌和化学质量。

6) 水中的细菌和微生物太小，一般用肉眼是看不见的。

7) 水的物理质量包括颜色、气味、味道、浊度和温度。

Reading Materials

(A) Recharge and Discharge Areas

Areas can be delineated into recharge and discharge areas depending on whether, water in these areas, is added to or abstracted from the zone of saturation. In the case of an unconfined aquifer, usually the areas occupying higher elevations with deeper water table constitute the recharge areas, whereas the topographic lows with shallow water table comprise natural discharge areas. Between these two lies an intermediate transition zone characterised by the existence of recharge conditions in some part of the year and discharge conditions in others. The boundaries keep changing depending on the depth of the water table. In the case of an artesian aquifer the recharge area is restricted to the outcrop of the aquifer where it becomes unconfined. If the confining layer is semipermeable, water may be supplied to or lost from the aquifer depending on the head differences.

Ground water discharge areas are characterised by outcropping of the water table or the capillary fringe through which water is lost to the atmosphere by evaporation and transpiration or to streams as base flow. In general, the outlets of ground water are diffuse, in the form of seeps, but at places, the flow may be directed, in the form of springs, through well-defined outlets.

The discharge of springs varies widely, depending on the area contributing to recharge of the aquifer and rate of recharge. The catchment areas may range from less than a hectare to several hundred square km. In arid regions, where the rainfall infiltration is low due to high evaporation, large springs can issue only if the catchment area is large. The temperature and discharges of springs with large catchments and deep sources are less variable than those with smaller catchments and fed from shallow depth. A combination of high rainfall and recharge rate can give rise to large springs even from small catchment areas. If

recharge rates are low due to occurrence of impermeable rocks, spring discharge may be low even when the catchment area is large. Recharge rates can be computed by expressing spring discharge in terms of unit area.

Water Level Fluctuations: Differences in the quantities of ground water supply and disposal result in changes in storage and fluctuation of ground water levels. A rise in the water level indicates that accretion to ground water storage is taking place. Similarly, a decline in the water level indicates that the ground water in storage is being depthed.

Water table fluctuations in response to precipitation are comparatively greater in uplands and interfluves corresponding to recharge areas than in lowlands and valley bottoms, corresponding to discharge areas. Water table levels establish a rising trend in areas brought under surface water irrigation. Water tables of the aquifers in hydraulic continuity with surface water bodies fluctuate sympathetically, corresponding to changes in levels in the surface water bodies changes in evaporation rates between day time and night time in shallow water table tracts result in diurnal fluctuation of the water table. Some of the controlling factors affecting water table fluctuations are rainfall, topography, stream flow and irrigation.

All other factors remaining the same, the magnitude of fluctuation is governed by the water-bearing properties of the materials in the zone of water table fluctuation. The fluctuation in materials having high specific yield is comparatively less than that in materials having low specific yield. For example, the fluctuation of the water table in consolidated rocks is usually more than in unconsolidated rocks.

Piezometric levels in wells tapping artesian aquifers fluctuate in response to water table fluctuations in the intake areas, and to addition and abstraction of water in the aquifer. Piezometric surfaces of leaky aquifers under lying phreatic aquifers respond to water table fluctuations not only in the intake area but also over the rest of the aquifer. Unlike the fluctuation of the water table, involving saturation or desaturation of materials, fluctuation of the piezometric surface is related to the elastic properties of the aquifer and the confining layers.

Decline of water levels due to pumping of wells followed by rise during rest periods is common to both the water table and artesian aquifers. Excessive ground water withdrawals in several parts of the world have resulted in water level declines of over 100 m. Restoration of water levels by artificial recharge has been one of the major aims of ground water management.

Water levels of wells tapping phreatic aquifers are not usually affected by barometric change, tidal loading, seismic vibrations and passage of trains but piezometric levels in artesian wells are affected by them. However, the water table may also respond to them.

In transitional zones where an aquifer is confined by an overlying confining layer during periods of high water levels, and is unconfined during summer and fall when the water level recedes below the base of the confining layer, the rate of recession and rise, as the

case may be, changes abruptly at the contact. The water level changes are more rapid under confined conditions than under unconfined conditions.

(*From Hydrogeology*, *pp*30—35)

New Words and Expressions

1. delineate [di'linieit] vt. 叙述；描述；勾划
2. abstract [æb'strækt] vt. 抽出；取出；提取
3. topographic [ˌtɔpə'græfik] a. 地形（学）的
4. intermediate transition zone 中间过渡带
5. be restricted to… （只）限于…；被限制在…
6. head difference 水头差
7. base flow 底流；基流；基本径流
8. outlet ['autlet] n. 排水口；出口
9. diffuse [difju:z] v.，a. 扩散（的）；分散（的）
10. direct [di'rekt] v. 引导；控制；指向
11. catchment area 汇水面积；集水面积
12. issue ['iʃ (j) u:] v.，n. 流出；出口
13. feed [fi:d] v. 补给，供水
14. in terms of 按照
15. water level 水位；水准面
16. fluctuation [ˌflʌktju'eiʃən] n. 变动；波动
17. disposal [dis'pəuzəl] n. 处理
18. accretion [æ'kri:ʃən] n. 增加；增大
19. similarly ['similəli] ad. 同样（地）
20. decline [di'klain] v.，n. 下降
21. depth [depθ] v. 变深；n. 深度
22. interfluve ['intəflu:v] n. 河间地；江河分水区
23. bring under 控制；纳入（…之下）
24. sympathetically [simpə'θetikəli] ad. 同感地；同样地；一致地；共鸣
25. tract [trækt] n. 土地；地域
26. diurnal [dai'ə:nl] a.，n. 昼夜（的）
27. magnitude ['mægnitju:d] n. 大小；数量；幅度
28. high specific yield 高流量；高单位流水量
low specific yield 低流量；低单位流水量
29. piezometric level 测压水位；承压水位
30. abstraction [æb'strækʃən] n. 退流；提取；引出
31. desaturation [diˌsætʃə'reiʃən] n. 减饱和（作用）
32. be related to… 与…有关（的）
33. elastic [i'læstik] a. 弹性的
34. excessive [ik'sesiv] a. 极度的；过多的
35. restoration [ˌrestə'reiʃən] n. 恢复
36. tidal loading 潮压；潮汐载荷
37. passage ['pæsidʒ] n. 通道
38. recede [ri'si:d] vi. 降低
39. recession [ri'seʃən] n. 下降

(B) Quality of Water

Determination of the physical, bacteriological and chemical quality of water is essential for assessing the suitability of water for various purposes like drinking, domestic use, industries and agriculture. Besides, a study of the chemistry of water helps in interpreting the geological environment, source, direction and movement of ground water, recharge-discharge relationships, climatic influence, presence of ore bodies, and in economic evaluation of mineral rich waters. A knowledge of water quality is also essential for rational management of water and land resources.

Bacteriological quality: Bacteria and micro-organisms present in water are too small to be seen by the naked eye. Some of the bacteria are harmless while some are disease-causing, known as pathogenic bacteria. coliforms, which are present in the intestines of human beings and other warm-blooded animals, are transmitted though faecal matter. Although

coliforms are harmless; their presence in ground water indicates the possibility of the presence of pathogenic bacteria.

An indirect index of the presence of organic matter in the water is the biochemical oxygen demand (BOD), which is the amount of oxygen required to cause biological decomposition of organic matter and waste. When oxidation is complete and no oxygen is required, BOD is zero.

Ground water is generally free of pathogenic organisms unless polluted by surface drainage. The organisms are removed during the course of ground water movement. The travel distance required is greater in sands and gravels, and other high permeability zones like caverns, than in clay.

Physical quality: The physical quality of water includes colour, odour, taste, turbidity and temperature. Ground water, unlike surface water, is generally clear and colourless, with little or no suspended matter and relatively constant temperature. Because of these characteristics, ground water in most hydrogeological situations can be put to direct use without treatment to improve the physical quality. Exceptions are found, for example, in ground water obtained from caverns and other large openings that may allow suspended matter and pollutants to enter the aquifer. The presence of H_2S, methane and some other gases makes the water odorous. Iron compounds, dyes, etc. impart colour and an unpalatable taste to water. Turbidity is caused due to the presence of insoluble matter, organisms and organic matter.

The amount of suspended materials carried in river water may be very large and varies in proportion to the discharge. The amount of suspended matter present in ground water, before it appears as seepage, is negligible. Though concentrations rarely exceed a few ppm, higher concentrations may be found in water from poorly developed wells. Water with a suspended sediment load is of limited use for industrial and other uses. Application of such water reduces infiltration rates of soils and recharge of ground water.

Chemical quality: Water, being an excellent solvent, acquires soluble products from the air and rocks it comes into contact with. Collection and chemical analysis of water samples from surface water bodies, wells and springs form an integral part of hydrogeological studies. Methods and procedures of chemical analysis of water samples, which strictly belong to the domain of chemistry, are not generally relevant in the interpretation of water analysis. The theoretical basis of the study of natural water chemistry is not proposed to be dealt with.

Common dissolved constituents in ground water include Calcium, Magnesium, Sodium, Potassium, Carbonate, Bicarbonate, Sulphate, Chloride, Silica, Iron, Manganese, Fluoride, Boron and some trace constituents. Concentrations of all dissolved salts or ions in water are commonly expressed by weight, weight and volume or by chemical equivalence.

(*From Hydrogeology*, *pp*132—134)

New Words and Expressions

1. bacteriological [ˌbækˌtiərəˈlɔdʒikəl] a. 细菌（学）的
2. assess [əˈses] vt. 估价；评定
3. suitability [ˌsjuːtəˈbiliti] n. 适合性；适用性
4. domestic [dəˈmestik] a. 民用的
5. bacteria [bækˈtiəriə] n. 细菌（单数 bacterium）
6. micro-organisms 微生物
7. naked eye 肉眼
8. pathogenic [ˈpæθɔdʒiːnik] n. 病原的；致病的
9. coliforms [ˈkɔlifɔːmz] n. 大肠杆菌
10. intestines [inˈtestinz] n. 肠
11. warm-blooded 热血的
12. faecal [ˈfiːkəl] a. 粪便的
13. biochemical oxygen demand (BOD) 生化耗（需）养量
14. oxidation [ˌɔksiˈdeiʃən] n. 氧化（作用）
15. odour [ˈəudə] n. 气味，臭气
16. turbidity [tɔːˈbiditi] n. 混浊度
17. constant temperature 恒温
18. pollutant [pəˈljuːtənt] n. 污染物（质）
19. methane [ˈmiːθein] n. 甲烷
20. odorous [ˈəudərəs] a. 有气味
21. dye [dai] v.，n. 染（色）；染料
22. impart [imˈpɑːt] v. 给与；分给
23. unpalatable [ʌnˈpælətəbl] a. 难吃的；令人讨厌的
24. seepage [ˈsiːpidʒ] n. 渗透；过滤；渗出
25. concentration [ˌkɔnsenˈtreiʃən] n. 浓度；富集
26. integral [ˈintigrəl] a. 整体的；完整的
27. domain [dəˈmein] n. 领域；范畴（围）
28. bicarbonate [baiˈkɑːbənit] n. 重碳酸盐；碳酸氢盐
29. sulphate [ˈsʌlfeit] n. 硫酸盐
30. chloride [ˈklɔːraid] n. 氯化物
31. fluoride [ˈfluːəraid] n. 氟化物
32. boron [ˈbɔːrɔn] n. 硼 (B)

Lesson Seventeen

Text

The Geologic Work of Ground Water

The primary erosional work carried on by groundwater is solution (dissolving soluble rock). Rainwater becomes slightly acid as carbon dioxide dissolves in it, producing carbonic acid. As the water percolates through the soil, decaying plants add complex organic acids. In regions where easily soluble rock, especially limestone, underlies the surface, groundwater has its greatest impact. Many areas of the world have landscapes that are to a large extent the result of underground solution. Such areas are said to exhibit karst topography, a term derived from a region in Yugoslavia. Generally, arid and semiarid areas do not develop karst topography. When solution features exist in such regions, they are likely remnants of a time when more humid condidions prevailed.

The most common and widespread features in karst areas are depressions called sinkholes, or sinks. In the limestone areas of Kentucky and southern Indiana there are an estimated 600000 of these depressions, varying in depth from just a meter or two to a maximum of more than 30 meters (100 feet). A sinkhole may form when a cavern roof collapses, or may develop slowly without physical disturbance of the rock as solution gradually carries away material. Following a rainfall in regions with many sinkhole, most runoff is funneled below ground, so streams are often absent. When streams are present, they eventually flow into a sink and are diverted underground. The names of such streams often give a clue to their fate. In the Mammoth Cave area of Kentucky, fox example, there is Sinking Creek, Little Sinking Creek, and Sinking Branch. Other sinkholes become plugged with clay and debris, creating ponds.

Limestone caverns are believed to form at or just below the water table along joints in the rock. Limestone which is not highly jointed tends to have a minimum of solution features, because joints are natural avenues through which groundwater moves. In the course of time solution enlarges the joints, often resulting in a complex system of tunnels and chambers. Since caves are created in the zone of saturation, it is only possible to enter them after the water table has dropped. In the United States, Carlsbad Caverns, New Mexico, and Mammoth Cave, Kentucky, are probably the best-known areas of cavern development. The latter locality includes an elaborate system comprised of at least 240 kilometers (150 miles) of subterranean passageways.

Probably the most striking features found in caves are the bizarre stone formations which often give them a wonderland appearance. Stalactites appear to be large stone icicles

hanging from the roof of the cavern, while stalagmites just up from the floor.

As water seeps through the roof of a cave evaporation leaves a small deposit of calcite behind. Over the centuries a stalactite will gradually form. When the water drops to the floor of the cave some more evaporates, again depositing calcite, and a stalagmite begins growing upward. When a stalamite and a stalactite meet, a column is formed.

(*From Earth Science*, 1976, *pp*73 -75)

New Words and Expressions

1. geologic work 地质作用
2. dissolve [di'zɔlv] v. 分解；(使) 溶解
3. carbonic [kɑ:'bɔnik] a. (含) 碳的
   ~ acid 碳酸
4. impact ['impækt] n. 影响，冲击
5. karst topography 岩溶地形；喀斯特地形
6. Yugoslavia ['ju:gəu'sla:vjə] n. 南斯拉夫
7. remnant ['remnənt] n., a. 侵蚀残余；残余(的)
8. prevail [pri'veil] vi. 胜(过)；占优势；普遍；盛行
9. depression [di'preʃən] n. 洼地；凹陷
10. sinkhole ['siŋkhəul] n. 岩溶坑
11. Kentucky [ken'tʌki] n. 肯塔基 (美国州名)
12. Indiana [ˌindi'ænə] n. 印第安纳 (美国州名)
13. disturbance [dis'tə:bəns] n. 干扰；扰动
14. funnel ['fʌnl] n., vt. 漏斗；使成漏斗形
15. fate [feit] n. 命运；结局；毁灭
16. Mamnoth Cave 猛犸洞穴
17. Sinking Creek 伏河；隐没河
    Little ~ 小伏河
18. Sinking Branch 地下支流 (河)
19. joint [dʒɔint] n., vt. 节理；裂隙；连接；接合；使成节理 (裂隙)
20. avenue ['ævinju:] n. 通道
21. enlarge [in'lɑ:dʒ] v. 扩大
22. tunnel ['tʌnl] n. 巷道；通道
23. Carlsbad Cavern 卡斯巴洞穴
24. New Mexico [nju (:) 'meksikəu] n. 新墨西哥 (美国州名)
25. elaborate [i'læbərit] a. 复杂的；精心制作的
26. comprised of… 由…组成；构成
27. subterranean [ˌsʌbtə'reinjən] a. 地下的
28. passageway ['pæsidʒ'wei] n. 通道
29. bizarre [bi'zɑ:] a. 稀奇古怪的，异乎寻常的
30. stalactite ['stæləktait] n. 钟乳石
31. icicle ['aisikl] n. 冰柱
32. stalagmite ['stæləgmait] n. 石荀

Notes to the Text

1. Limestone which is not highly jointed tends to have a minimum of solution features, because joints are natural avenues through which groundwater moves. 裂隙不太发育的灰岩，一般仅有很小的溶解特征，因为裂隙是地下水运移的天然通道。

   句中 "which…jointed" 和 "through which…moves" 都是限制性定语从句，前者修饰主语，后者修饰原因状语从句中的表语。tend 加不定式意为 "趋 (倾) 向于…" 或译成 "一般…"；"往往…"。如：The force due to the motion of molecules tends to keep them apart.

   由于分子运动而引起的力倾向于使分子保持分开。

2. When the water drops to the floor of the cave some more evaporates, again depositing calcite , and a stalagmite begins growing upward. 当水滴落到溶洞底时，一些水再蒸发，

这样又沉积了方解石，于是石荀就开始向上生长。

句中 and 连接两个并列句，当“于是”解。“again depositing calcite”为分词短语，作第一分句的状语，表示伴随情况。

Exercises

1. Questions for review:
   1) How does rainwater become slightly acid?
   2) What are called sinkholes?
   3) Why does the limestone which is not highly jointed tend to have a minimum of solution features?
   4) Where are probably the best-know areas of cavern development in the United States?
   5) How are the stalactite and the stalamite formed?
2. Choose the correct verbs from the list below to complete each of these sentences:

   examined, resorted, believed, decimated, contributed, attributed

   1) Limestone caverns are _____ to form at or just below the water table along joints in the rock.
   2) The ground water temperature variation was _____ to both lithologic and hydrologic controls.
   3) The shallow water table conditions have _____ to the soil and ground water salinity, by accelerating natural processes of evaporation.
   4) Before an exploration programme is taken up, its relevance from the point of view of social and economic benefits should be _____ to justify investment of funds.
   5) Artificial recharging is also _____ to for the protection of fresh water aquifers against intrusion of saline water from surface and subsurface sources.
   6) These problems are acute in regions of heavy population growth where forests are _____ to bring additional land under agriculture.
3. Give the Chinses/English equivalents for the following:

cavern	岩溶地形
Sinking Creek	钟乳石和石荀
subterranean passageways	塌陷
terrestrial heat	放热和吸热
degradation	毁林
afforestation	地面沉陷

4. Translating the following passage into Chinese:

   Ground water temperature varies within wide limits, from freezing to above the boiling point at the surface. Extremes of ground water temperature are found in polar regions and in regions of volcanic activity. Such extremes of temperature are not found

in the rest of the earth's surface, where the temperature seldom exceeds a few tens of ℃. The ground water temperature distribution depends largely on terrestrial heat, exothermic and endothermic reactions in the rocks, thermal conductivity of rocks, atmospheric temperature, infiltration from atmospheric precipitation and surface water bodies, and movement of ground water. In addition to the natural causes just mentioned, man's activities like mining and discharge of wastes has disturbed the natural ground water temperature distribution.

5. Translate the following sentences into English:
   1) 世界许多地区的地形在很大程度上都是地下水溶解的结果。
   2) 钟乳石好象是悬挂在岩溶洞顶上的大石质冰柱。
   3) 一般来说，干旱和半干旱地区不发育喀斯特地形。
   4) 由于渗流带变薄，一些地区地下水污染的机会增多了。
   5) 水文地质勘探过程中获得的信息主要是含水层的深度和范围、被渗透的岩石类型、水的质量和持续涌水量。
   6) 影响地层分布的常见地质构造是褶皱、断裂和不整合。
   7) 在地下水研究工作中，水文学方面的研究应与地质学及其它相关学科结合起来。

Reading Materials

(A) Hydrogeology and Environment

Most of the human activities involving industrial and agricultural development, and the inadequate management of land and water resources have, directly or indirectly, resulted in the degradation of hydrogeological environment. Some of the major adverse effects have arisen from construction of reservoirs, surface water irrigation, heave ground water exploitation, deforestation and industrial and urban waste disposal. The impact is notable on the quality and quantity of ground water resources, the fertility of land and the stability of the land mass. Water quality deterioration has made potable water resources scarcer and endangered plant and animal life.

The shallow water table conditions created in the vicinity of reservoirs and canal commands have contributed to the soil and ground water salinity, by accelerating natural processes of evaporation. Chances of ground water pollution in such areas is increased due to the thinning of vadose zone. It is estimated that one-third of the irrigated land in the world is affected by salinity problems and each year about 40000 ha. of land becomes unfit for agricultural production because of salt accumulation.

The disposal, without proper treatment, of industrial and urban wastes into streams and other surface water bodies and injection wells and pits is also one of the major causes of deterioration in the water quality, or "pollution". Gaseous emanations from certain industries are also sources of pollution of atmospheric water which is the source of most of

the surface and ground water resources.

Land use practices involving devegetation in any form cause a reduction in the infiltration capacity and ground water recharge, increase in surface runoff and erosion, and increase in evaporation from soil and surface storages. These problems are acute in regions of heavy population growth where forests are decimated to bring additional land under agriculture. Where alternative areas exist, deforestation of a ground water-worthy area will be more productive than deforestation of an area underlain by poor aquifers. Likewise, af forestation programmes should take ground water productivity into consideration.

The subsidence of land surface due to heavy withdrawals of ground water, oil and nat ural gas and increased seismicity due to surface water impoundments and well-injections are well documented. Measures to enhance replenishment of aquifers by artificial recharge and other water conservation measures have been adopted in various parts of the world that are adversely affected by excessive ground water withdrawals and subsidence.

Artificial recharge, by which the infiltration of surface water into the ground water reservoir is increased by altering natural conditions, is one of the measures adopted to restore or enhance supplies from depleted aquifers, control or prevent subsidence of land surface, improve quality of native waters and renovate quality of waste waters. Recharging is doing by ponding water in specially designed basins, pits and shafts, spreading water on artificially prepared or natural land surfaces, injecting water into wells, or by capturing stream-flows. New aquifers may be created and pumping lifts may be reduced where artificial recharge results in rise in water table, thereby saving energy. Artificial recharging is also resorted to for the protection of fresh water aquifers against intrusion of saline water from surface and subsurface sources.

(*From Hydrogeology*, *pp7*--8)

New Words and Expressions

1. inadequate [in'ædikwit] a. 不适当的；不妥当的
2. degradation [ˌdegrə'deiʃən] n. 降解（作用）；退化；恶化；降级
3. adverse ['ædvə:s] a. 逆的；相反的
4. arise [ə'raiz] vi. 发（产）生；上升；出现
5. exploitation [ˌeksplɔi'teiʃən] n. 开发；开采
6. deforestation [di:ˌfɔris'teiʃən] n. 毁林；砍伐森林
7. fertility [fə:'tiliti] n. 肥沃
8. deterioration [ditiəriə'reiʃən] n. 变坏；降低（品质）；恶（退）化
9. vicinity [vi'siniti] n. 近处；附近（地区）
10. accelerate [æk'seləreit] v. 加速；促进；加快
11. irrigated land 水浇地
12. ha. =hectare ['hektɑ:] n. 公顷
13. injection [in'dʒekʃən] n. 注入
14. pit [pit] n. （水）坑
15. emanation [ˌemə'neiʃən] n. 喷气；发射；流（排）出（物）
16. devegetation [divedʒi'teiʃən] n. 毁掉植物；无植被
17. infiltration capacity 渗水量
18. acute [ə'kju:t] a. 尖锐的；严重的
19. decimate ['desimeit] vt. 毁灭…的大部分
20. afforestation [æˌfɔris'teiʃən] n. 造林
21. subsidence [səb'saidəns] n. 下沉；沉降
22. seismicity [saiz'misiti] n. 地震活动
23. impoundment [im'paundmənt] n. 蓄水；贮水

24. document ['dɔkjumənt] vt. 证明
to be well documented 有许多资料证明
25. enhance [in'bɑ:ns] vt. 提高；增强（加）
26. replenishment [ri'plenifmənt] n. 补给；充满；容量
27. conservation [kɔnsə'veiʃən] n. 保存；保持；储备
28. restore [ris'tɔ:] vt. 恢复；提高；增加
29. deplete [di'pli:t] vt. 耗尽；使枯竭；贫乏
30. native ['neitiv] a. 本地的；天然（纯净）的
31. renovate ['renəuveit] vt. 改善（进）；恢复；更新
32. ponding [pɔndiŋ] n. 积水（库）蓄水；坑洼
33. shaft [ʃɑ:ft] n. 竖井；矿井
34. capture stream-flows 袭夺河
35. resort [ri'zɔ:t] vi., n. 求助；依靠
~ to 借助于，凭借，利用

(B) Ground Water Exploration

——Geological and Hydrological Methods

The common objective of ground water exploration is to locate aquifers capable of yielding for various uses, water of suitable quality, in economic quantities, by employing, as required, geological, geophysical, drilling and other techniques. Information sought during the course of exploration are the depth and extent of aquifers, type of rocks to be penetrated, quality of water and sustained yields. Less common objectives of exploration are to study feasibility of artificial recharge, disposal of industrial, nuclear and other wastes, ground water control for mining, etc.

In the first instance, before an exploration programme is taken up, its relevance from the point of view of social and economic benefits should be examined to justify investment of funds. Then follow the technical aspects of exploration, including the schematics of operations. Some areas require to be explored more thoroughly than others, depending on the availability of data, hydrogeology, expected water supplies, etc. The various types of data thrown up during the course of ground water exploration can be synthesised, interpreted and depicted as hydrogeological maps.

Preliminary conclusions concerning many aspects of ground water occurrence and yield prospects can be drawn from geomorphology and geology of the area and structure of the formations. The type of details required for geological prospecting differ from one rock type to another. A knowledge of stratigraphy and structural geology is useful in understanding the order of superposition of various lithological units and their continuity. Petrographic descriptions can give indications regarding consolidation, cementation and porosities of rocks and their water-bearing and yield characteristics. The available geological maps could form the basis for deciding the exploration techniques most suited to the area and the type of drilling rig to be deployed. If a geological map of the target area is not available, a survey has to be undertaken, which may be oriented towards ground checking of interpretations of remote sensing data or mapping of the extent of various lithological units and studying their characteristics from outcrops, excavations and wells. Structure and

the physical characteristics of rocks and their geomorphologic expressions in terms of terrain features are important in delineating the lateral and vertical extent of unproductive and productive zones. Geologic mapping may include a study of fracture patterns which govern the accumulation and flow of ground water in hard rocks.

The common structural features that affect the distribution of geological formations are folds, faults and unconformities. An excellent treatment of structural control on ground water occurrence is found in Meinzer (1923) which has been extensively drawn upon in this section. He cites several examples which are illustrative of the need to have background information on the structural set up of an area. This is necessary for an understanding of the distribution of aquifers in ground water prospecting.

Aspects that have a bearing on sustained productivity on a long term basis, such as recharge and discharge rates and sources, infiltration characteristics of soil, aquifer characteristics, storage changes in soil, surface and ground water bodies, are also investigated. Estimation of the input to and output from the ground water reservoir and the balance of ground water available for development require hydrological studies.

The first and foremost task in the quantitative evaluation of ground water resources basinwise is to properly identify the basin boundaries. The morphometric analyses of catchments of ground water basins provide useful indices of recharge. Besides, various hydrometeorological parameters such as rainfall and evaporation have to be studied in relation to water balance.

In ground water studies, the hydrological aspects are studied combined with the geology. For example, potentiometric surface maps can be interpreted in terms of subsurface hydrogeological conditions. Best results are obtained by integrating geological and hydrological investigations with studies related to meteorology, pedology, agronomy, chemistry and other disciplines as may be relevant to the scope and purpose of the investigation.

Commonly, the older formations are less water-bearing and also less productive. Normally, the younger formations overlie the older ones and are reached earlier during drilling but exceptions may be found (1) where intrusion has occurred into an older formation (2) in closely folded formations resulting in overturning of strata and (3) where formations are faulted and overthrust. In the latter two cases, repetition of beds may occur. In general, the crystalline rocks are regarded as the basement and no purpose is served in penetrating them if a permeable layer has been penetrated above it.

(*From Hydrogeology*, *pp*179 185)

New words and Expressions

1. exploration [ˌeksplɔ:'reiʃən] n. 勘探；勘测；探查
2. locate [ləu'keit] vt. 探明…位置；查出…位置
3. employing [im'plɔiiŋ] n. 使用；雇用
4. seek [si:k] v. (寻) 找；调查；勘查
5. penetrate ['penitreit] v. 渗入 (透)
6. sustained yields 持续涌水量
7. feasibility [fi:zə'biliti] n. 可行性；可比性；现实

性

8. nuclear [ˈnju:kliə] a. 核子的；原子能的
9. benefit [ˈbenifit] n. 利益；好处
10. justify [ˈdʒʌstifai] v. 证明…是；正确的；认为…有理由
11. investment [inˈvestmənt] n. 投资；投入
12. schematic [ski (:) ˈmætik] n. 简（略）图
13. availability [əveiləˈbiliti] n. 可用性；使用价值；有效率
14. throw up 推出；产生
15. synthesise [ˈsinθisaiz] vt. 综合（处理）
16. depict as 描绘成；画成
17. preliminary [priˈliminəri] a. 初步的；预先的
18. prospect [ˈprɔspekt] n. 展望；前景；可能性；勘探
19. draw from 据…得出…；据…推断
20. superposition [ˈsju:pəpəˈziʃən] n. 叠加
21. consolidation [kənˌsɔliˈdeiʃən] n. 固结（作用）
22. drilling rig 钻井装置；钻机
23. deploy [diˈplɔi] v. 、n. 部署；配置；使采用
24. target [ˈtɑ:gɪt] n. 目标；对象
25. undertake [ʌndəˈteik] vt. 着手；从事；开始；进行
26. orient [ˈɔ:riənt] vt. 定向；定（方）位；标定
27. ground checking 地面检查；地面验证
28. remote sensing 遥感；遥测
29. excavation [ˌekskəˈveiʃən] n. 坑道
30. delineate [diˈlinieit] vt. 描述（绘）；勾划
31. unproductive [ˈʌnprəˈdʌktiv] a. 非生产性的；没有收益的
32. draw upon 引用；利用
33. cite [sait] vt. 引用；引证；引述；列举
34. illustrative of 说明…的；作为…的例证
35. structural set up 构造型式；构造配置
36. investigate [inˈvestigeit] v. 调查
37. first and foremost 首先；第一；首要
38. basinwise [ˈbeisnˈwaiz] a. 盆地内的
39. morphometric [ˌmɔ:fɔˈmetrik] a. 地形测量的
40. catchment [ˈkætʃmənt] n. 汇集；汇水
41. indices [ˈindisi:z] n. 标志；系数；索引；（单数 index）
42. hydrometeorological [ˈhaidrəˌmi:tjərəˈlɔdʒikəl] a. 水文气象（学）的
43. parameter [pəˈræmitə] n. 参数
44. potentiometric [pətenʃiəˈmetrik] a. 电位（势）的
    ～ surface maps 地面等势图；地面等测压线图
45. integrate [ˈintigreit] v. 综合；汇集
46. meteorology [mi:tjəˈrɔlədʒi] n. 气象学
47. pedology [piˈdɔlədʒi] n. 土壤学
48. agronomy [əˈgrɔnəmi] n. 农（艺）学；作物学
49. intrusion [inˈtru:ʒən] n. 侵入岩（体）
50. overturning [ˌəuvəˈtə:niŋ] n. 倒转
51. overthrust [ˈəuvəθrʌst] n. 逆掩断层；掩冲断层
52. repetition [ˌrepˈtiʃən] n. 重复
    ～ of beds 地层重复

Lesson Eighteen

Text

Soil

Soil has accurately been called "the bridge between life and the inanimate world". All life owes its existence to the dozen or so elements that ultimately come from the earth's crust. First, weathering converts the rock to soil. Then, plants carry out their role as the great intermediary, assimilating the necessary elements and making them available to animals and people. With few exceptions, the earth's land surface is covered by regolith, the layer of rock and mineral fragments produced by weathering. Some would call this material soil. However soil is more than an accumulation of loose rock debris. Soil is a combination of mineral and organic matter, water, and air, that portion of the regolith that supports the growth of plants. Although the proportions may vary, the major components do not. About one-half of the total volume of a good-quality surface soil is a mixture of disintegrated and decomposed rock (mineral matter) and the remains of animal and plant life (organic matter). The remaining half consists of pore space, where air and water circulate.

The soil profile: If you were to dig a trench, you would see that its walls consisted of a series of horizontal layers. These layers, called horizons, collectively make up the soil profile. Three basic horizons are identified and from top to bottom are labeled A, B, and C, respectively. The A and B horizons may be subdivided further.

The uppermost layer in a soil profile, the A horizon, is often called the surface soil. It is the part of the soil with the greatest biological activity and is therefore the horizon where organic matter is most plentiful. Since it lies at the surface, the A horizon is also the part of the soil that falling rain reaches first. As a consequence, soluble materials and tinyparticles such as clay are leached (washed out) by percolating water. Lying immediately below the surface soil is the B horizon, or subsoil. It is in this zone that much of the material removed from the A horizon is deposited. Because of this, the B horizon is referred to as the zone of accumulation. Since the B horizon has an intermediate position in the soil profile, it may be considered, at least in part, a transitional zone. For example, living organisms and organic matter are more abundant in the B than in the C horizon, but considerably less so than in the A horizon. The A and B horizons together constitute the solum, or "true soil". It is in the solum that the soil-forming processes are active and that living roots and other plant and animal life are largely confined.

Below the solum is the C horizon, a layer characterized by partially altered parent material and little if any organic matter. While the parent material may be so dramatically al-

tered in the solum that its original character is not recognizable, it is easily identifiable in the C horizon.

The boundaries between soil horizons may be very sharp, or the horizons may blend gradually from one to another. Furthermore, some soils lack horizons altogether. Such soils are called immature, because soil building has been going on for only a short time. Immature soils are also characteristic of steep slopes where erosion continually strips away the soil, preventing full development.

Soil Type: In the discussion which follows we shall briefly examine some common soil types. As you read, notice that the characteristics of each of the soil types are primarily a manifestation of the prevailing climatic conditions.

The term pedalfer gives a clue to the basic characteristic of this soil type. The word is derived from the Greek pedon, meaning "soil", and the chemical symbols Al (aluminum) and Fe (iron). Pedalfers are characterized by an accumulation of iron oxides and aluminum-rich clays in the B horizon. In the mid-latitude areas where the annual rainful exceeds 63 centimeters (25 inches) most of the soluble materials, such as calcium carbonate, are leached from the soil and carried away by underground water. The less soluble iron oxides and clays are carried from the A horizon and deposited in the B horizon, giving it a brown to red brown color. These soil are best developed under forest vegetation where large quantities of decomposing organic matter provide the acid conditions necessary for leaching. In the United States pedalfers are found east of a line extending from northwestern Minnesota to south-central Texas. Pedocal is derived from the Greek pendon, meaning "soil", and the first three letters of calcite (calcium carbonate). As the name implies, pedocals are characterized by an accumulation of calcium carbonate. This soil type is found in drier western United States in association with grassland and brush vegetation. Here, rainwater percolating through the soil often evaporates before it can remove soluble materials, chiefly calcium carbonate. The result is a whitish accumulation called caliche. In addition, since chemical weathering is less intense in drier areas, pedocals generally contain a smaller percentage of clay mineral than pedalfers. In the hot and wet climates of the tropics soils called laterites develop. Since chemical weathering is intense under such climatic conditions, these soils are usually deeper than soils developing over a similar period of time in the mid-latitudes. Not only does leaching remove the soluble materials like calcite, but the great quantities of percolating water also remove much of the silica, with the result that oxides of iron and aluminum become concentrated in the soil. The iron gives the soil a distinctive red color. When dried, laterites are very hard. In fact, some people use this soil for making bricks. If the parent rock contained little iron, the product of weathering is an aluminum-rich accumulation called bauxite. Bauxite is the primary ore of aluminum.

Since bacterial activity is very high in the tropics, laterites contain practically no humus. This fact, coupled with the highly leached and bricklike nature of these soils, makes laterites poor for growing crops. The infertility of these soils has been borne out repeatedly

in tropical countries where cultivation has been expanded into such areas.

In cold or dry climates soils are generally very thin and poorly developed. The reasons for this are fairly obvious. Chemical weathering progresses very slowly in such climates, and the scanty plant life yields very little organic matter.

(*From Earth Science*, 1976, *pp*32—40)

New Words and Expressions

1. inanimate [in'ænimit] a. 无生命的
2. convert…to… 把…变为…
3. intermediary [ˌintə(:)'mi:djəri] n. 媒介（物）
4. assimilate [ə'simileit] v. 吸收
5. with few exceptions 极少例外
6. regolith ['regəliθ] n. 风化层；表土；浮土
7. disintegrate [dis'intigreit] v. （使）崩解；分裂
8. horizontal layer 水平层
9. collectively [kə'lektivli] ad. 共同地
10. label ['leibl] n., vt. 标记；符号；称号；把…称为；标明
11. surface soil 表土
12. as a consequence 因此
13. leach [li:tʃ] v. 淋滤
14. percolating water 渗透水；渗滤水
15. subsoil ['sʌbsɔil] n. 底土；心土
16. considerably less so than 比…少得多
17. solum ['səuləm] n. 土层
18. parent material 母岩物质
19. little if any 几乎没有
20. blend [blend] v. 混和；把…混成一体
21. furthermore ['fə:ðə'mɔ:] ad. 而且；此外
22. immature [ˌimə'tjuə] a. 幼年的；发育不全的；不完全的；未成熟的
23. strip away 剥离；剥去
24. prevailing [pri'veiliŋ] a. 占优势的；主要的；普遍的
25. pedalfer [pi'dælfə] n. 铁铝土
26. pedon ['pedɔun] n. （希腊语）土壤
27. mid-latitude areas 中纬度地区
28. annual rainfall 年降雨量
29. red brown color 褐红色
30. pedocal ['pedəkæl] n. 钙层土
31. in association with 与…联合；与…有关连
32. brush vegetation 灌丛植物
33. whitish ['waitiʃ] a. 带白色的
34. caliche [kə'li:tʃi] n. 钙结层；钙积层；生硝
35. tropics ['trɔpiks] n. 热带
36. laterite ['lætərait] n. 红土；砖红壤
37. with the result that… 结果；因而；从而
38. bauxite ['bɔ:ksait] n. 铝土矿
39. primary ore 原生矿石
40. humus ['hju:məs] n. 腐殖质
41. coupled with 和…联合；结合
42. bricklike nature 类似砖的性质
43. infertility [ˌinfə'tiliti] n. 贫瘠
44. bear out 证实，证明
45. cultivation [ˌkʌlti'veiʃən] n. 耕作；栽培
46. scanty ['skænti] a. 不够大的；很小的；缺乏的

Notes to the Text

1. Then, plants carry out their role as the great intermediary, assimilating the necessary elements and making them available to animals and people.

   然后，植物作为巨大的媒介来起到它应有的作用，它能吸收必要的元素，并能使这些元素适用于动物和人类。

   "as the great intermediary" 为主语补语；"assimilating…" 和 "making…" 为二个并列的分词短语，作方式状语或表示伴随情况，对主句作进一步解释。

2. However soil is more than an accumulation of loose rock debris. Soil is a combination of

mineral and organic matter, water, and air, that portion of the regolith that supports the growth of plants. 但是，土壤不只是一种疏松岩石碎屑的堆积物，而是矿物、有机物、水和空气的复合物，即支撑植物生长的那部分表层土。

"that portion…plants"是主语"soil"的同位语，他的前面省略了"that is"；"that supports …plants" 为定语从句。

Exercises

1. Questions for review:
   1) What is the difference between soil and regolith?
   2) Which of the horizons in a soil profile constitute the solum?
   3) Under what circumstances do soils lack horizons?
   4) Soils formed in the humid tropics and the Arctic both contain little organic matter. Do both lack humus for the same reasons?
   5) Why can the oxides of iron and aluminum become concentrated in the soil?
2. Choose the correct term given in brackets to complete each statement:
   1) With few exceptions, the earth's land surface is covered by _____.
      a. soil b. solum c. regolith
   2) The uppermost layer in a soil profile is often called _____.
      a. the subsoil b. the true soil c. the surface soil
   3) ____ are characterized by an accumulation of calcium carbonate.
      a. pedalfers b. pedocals c. caliches
   4) If the parent rock contained little iron, the product of weathering is an alumium-rich accumulation called _____.
      a. laterite b. bauxite c. clay
   5) _____ refers to the downward slipping of a mass or rock or unconsolidated material moving as a unit along a curved surface.
      a. slump b. rockslide c. mudflow
3. Write one complete sentence in English for each term listed below:

soil	**solum**	**pedalfer**
caliche	**laterite**	**pedocal**

4. Translating the following passage into Chinese:

One of the spheres of exploration activities that has received increasing attention in the context of environmental protection is pollution—its prevention, detection, control and monitoring. Studies related to pollutant transport, filtration and attenuation characteristics of the earth materials and isolation of the pollutant from the biosphere till its degradation or dilution to safe levels, require information on the hydrogeological environment. Hydrogeological evaluation of the feasibility of a site for safe and cost-effective disposal of wastes aims at determining the mineral composition, texture and perme-

ability of the materials involved, geology and structure of the formations, distribution of ground water heads, and the quality of interstitial formation water. Hydrogeological investigations of pollution problems rely on many of the same techniques adopted in ground water exploration. Whereas in normal ground water investigations the distribution of permeable zones is of importance, in problems of pollution the low permeability units, which can act as barriers to pollutant transportation, and the unsaturated zone, which can retain pollutants for long periods, can be very significant. An analysis of the ground water flow system will give an insight into the possible direction of pollutant movement and in identifying zones that are likely to be free from pollution. Such studies will also indicate zones that can serve as safe repositories of wastes.

5. Translate the following sentences into English:
   1) 在寒冷或干旱气候区，土壤层一般是很薄的，甚至是不发育的。
   2) 在热而潮湿的热带气候区，红土往往十分发育。
   3) 块体坡移指的是岩石、浮土和土壤在重力的直接影响下向坡下移动。
   4) 有些块体移动很快，其平均速度大约为每小时160公里；相反，有些类型的块体坡移非常慢，以致这种移动往往难以察觉。
   5) 就工程构造和地块的稳定性来说，地下水是一个不利因素。
   6) 酸性水不仅能扩大碳酸盐岩中存在的空洞，而且还能从胶结和固结集合体中淋滤出钙。

Reading Materials

(A) Mass Wasting

Periodically newspapers carry stories relating the terrifying and often grim details of land slides. On Friday, June28, 1974, the papers carried such an account when a massive landslide occurred along a steep hillside in the Andes Mountains of Columbia. A peasant described it this way: "The earth began to rumble like when thousands of horses gallop on the range." Witnesses said the rock and debris covered more than 875 meters (2400 feet) of the twisting high way at the base of the slope and "pushed around tractors and other heavy equipment like toys." Officials estimated the dead at more than 200. Since the land slide also dammed a river, there was also the threat of flooding. Certainly for those in the vicinity of the landslide it was a major catastrophe. Fortunately, mass movements such as this are infrequent and seldom affect many people.

Landslides are spectacular examples of a normal geologic process called mass wasting. Mass wasting refers to the downslope movement of rock, regolith, and soil under the direct influence of gravity. Once weathering breaks up rock, gravity pulls the material to lower elevations, where streams usually carry it away, eventually depositing it in the ocean. In this manner the earth's landscape is slowly being shaped.

Although gravity is the controling force of mass wasting, other factors play an impor-

tant part in bringing about the downslope movement of material. Water is one of these factors. When the pores in sediment become filled with water, the cohesion between the particles is destroyed, allowing them to slide past one another with relative ease. For example, when sand is slightly moist, it may stick together quite well. However, if more water is added, filling the openings between the grains, the sand will ooze out in all directions. Thus saturation reduces the internal resistance of materials, which are then easily set in motion by the force of gravity. When clay is wetted, it becomes very slick--another example of the "lubricating" effect of water. Water also adds considerable weight to a mass of material. The added weight in itself may be enough to cause the material to slide or flow downslope.

Oversteepening of slopes is another cause for many mass movements. There are many situations in nature where this takes place. A stream undercutting a valley wall and waves pounding against the base of a cliff are but two common examples. Furthermore, through their activities, people often create oversteepened and unstable slopes that become prime sites for mass wasting.

The various types of mass wasting have been classified using a number of schemes, some of them quite complex. For our purpose, we shall divide them into two categories based on the rate of movement. Some mass movements are rapid, as the landslide described earlier. An extreme example is a landslide that occurred at Elm, Switzerland, in 1881. The rock and debris in this slide moved over 2500 meters (800 feet) in less than one minute--a mean velocity of about 160 Kilometers (100 miles) per hour. In most instances, however velocities are considerably less than this. On the other hand, some types of mass wasting are so slow that the movement is imperceptible. These slow movements, which include creep and solifluction, are measured in terms of centimeters or meters per year.

Landslides: Landslides may be divided into two basic types: slump and rockslide. Slump refers to the downward slipping of a mass or rock or unconsolidated material moving as a unit along a curved surface. This movement usually results because a slope has been greatly steepened, either naturally or by people, and, as expected, the material reacts to the pull of gravity.

Rockslides occur when blocks of bedrock break loose and slide down a slope. Such events are among the fastest and most destructive of mass movements. Usually rockslides take place in a geologic setting where the rock strata are inclined, or joints and fractures exist, parallel to the slope. If the rock is undercut at the base of the slope it loses support, and the rock eventually gives away. Sometimes the rockslide is triggered when rain or melting snow lubricates the underlying surface to the point where friction is no longer sufficient to hold the rock unit in place. As a result, rockslides tend to be most prevalent during the spring, when heavy rains and melting snow are generally greatest. Earthquakes are another mechanism which often triggers rockslides and other mass movements. The 1811 earthquake at New Madrid, Missouri, for example, caused landslides in an area of more than 13,000 square kilometers (5000 square miles) along the Mississippi River valley.

Mudflow: Mudflow is a type of mass wasting which involves a flowage of debris containing a large amount of water. Mudflows are most characteristic of canyons and gullies in arid mountainous regions. When such an area experiences a heavy rain, large amounts of sediment are washed into the channel from the valley walls, which usually have little or no vegetation to anchor the loose material. The end product is a rapidly moving mass of mud having the consistency of wet concrete. Because of its high density the mudflow can carry large boulders with ease. Upon reaching the mouth of the canyon the mudflow spreads out.

Solifluction: In the frigid zones found at high latitudes solifluction is of major importance. In such regions only the ice in the upper few meters of regolith melts during the spring and summer, while the ground below remains permanently frozen. Since the water in the upper zone has nowhere to go, this layer remains saturated and slowly flows down even the gentlest slopes. In this manner the overburden is removed and the unweathered rock below is exposed. When the newly exposed rock is eventually weathered, it too will be removed by solifluction.

(*From Earth Science*, 1976, *pp*40--45)

New Words and Expressions

1. mass wasting 块体坡移；物质坡移
2. terifying ['terifaiiŋ] a. 极大的；可怕的
3. grim [grim] a. 严酷的；无情的；残忍的
4. landslide ['lændslaid] n. 山崩；塌方；滑坡
5. massive ['mæsiv] n. 块状的
6. hillside ['hil'said] n. 山腰；山坡
7. the Andes Mountains 安第斯山脉（南美州）
8. Columbia [kə'lʌmbiə] n. 哥伦比亚（美国城市）
9. rumble ['rʌmbl] v. （使）隆隆响
10. gallop ['gæləp] n. 飞跑；疾驰
11. range [reindʒ] n. 放牧区；山脉；区域
12. witness ['witnis] n. 证据；证言；证人；目击者
13. debris ['de'bri:] n. 碎片；碎石；岩屑；瓦砾堆
14. twisting ['twistiŋ] a. 旋转的
15. equipment [i'kwipmənt] n. 装备；设备
16. dam [dæm] n., vt. 水坝；抑制；阻碍（隔）
17. threat [θret] n. 威胁
18. catastrophe [kə'tæstrəfi] n. 大灾难；大祸；灾祸
19. infrequent [in'fri:kwənt] a. 稀罕的；不寻常的
20. spectacular [spek'tækjulə] a. 壮观的；惊人的；引人注意的
21. break up 破碎，破坏
22. play an important part in 在…方面起重要作用；对…起重要作用
23. cohesion [kəu'hi:ʒən] n. 粘性；凝聚力
24. slide [slaid] v. （使）滑动
25. stick [stik] v. 粘住
26. ooze [u:z] n., v. 淤泥；渗出；冒出
27. lubricate ['lu:brikeit] v. 使润滑
28. lubricating ['lu:brikeitiŋ] a. 润滑的
29. oversteepen ['əuvə'sti:pən] v. （使）变得更陡峭；变得过陡，oversteepening n. 削峭作用；过陡作用
30. undercut ['ʌndə'kʌt] v. 掏蚀；底切；暗掘；底部掏槽
31. pound [paund] v. 捣碎；猛击；冲击
32. Elm 埃尔姆（地名）
33. Switzerland ['switsələnd] n. 瑞士
34. on the other hand 另一方面
35. imperceptible [impə'septəbl] a. 难以察觉的；察觉不到的
36. creep [kri:p] n. 蠕变，蠕动
37. solifluction [səli'flʌkʃən] n. 泥流（作用）
38. slump [slʌmp] n. 滑塌；滑移；滑动沉陷

39. rockslide ['rɔk'slaid] n. 岩滑
40. as expected 不出所料；正如预料的一样
41. react to 对…起反应；对…起反应（作用）
42. destructive [dis'trʌktiv] a. 破坏（性）的
43. geologic setting 地质背景
44. incline [in'klain] v. n. 使倾斜；斜面；斜坡
45. give away 塌落
46. trigger ['trigə] v. 触发；激发起；引起
47. prevalent ['prevələnt] a. 普遍的；盛行的
48. mechanism ['mekənizəm] n. 机制；机理
49. New Madrid n. 新马德里（地名）
50. Missouri [mi'zuəri] n. 密苏里（美国州名）
51. Mississippi River 密西西比河
52. mudflow ['mʌdfləu] n. 泥石流
53. flowage ['fləuidʒ] n. 流动
54. canyon ['kænjən] n. 峡谷
55. gully ['gʌli] n. 冲沟
56. anchor ['æŋkə] v. 加固；使固定；粘连
57. consistency [kən'sistənsi] n. 稠性（度）；稳定；粘度
58. concrete ['kɔnkri:t] n. 混凝土；凝结物
59. frigid zone 寒带

(B) Geotechnical Investigations

Ground water is an unfavourable factor to the stability of engineering structures and landmass. Ascertaining disposition of permeable channels, potentiometric heads and engineering properties of subsurface materials when wet and dry is essential in understanding geotechnical problems related to hydrogeology. A brief mention of some of these aspects is made below; for a detailed treatment of the subject Krynine and Judd (1957) may be referred.

Sites for reservoirs and foundations of dams should be watertight. Pervious layers such as sandstone, buried channels, cavernous zones, faults and joints within the reservoir rim and dam site should be investigated as to their propensity for causing leakage and losses from the reservoir. Presence of springs, artesian conditions and below-normal ground water temperatures on the downstream side of dam site may indicate the existence of subterranean passages for leakage from the reservoir. Ground water divides within the reservoir rim will also ivdicate possible reservoir losses. Influent streams with deep water tables and permeable subsurface materials are not favourable for siting storage reservoirs as seepage losses will be heavy.

Shallow water tables should receive considerable attention if an engineering structure or a part of it extends to subsurface. A knowledge of ground water level fluctuations and positions is essential for determining uplift pressures on the floor and foundation of structures. The water levels can be measured at regular intervals in piezometers or existing water table wells. Investigations for achieving subsurface drainage should aim at establishing specific yield, permeability and thickness of saturated materials and the depth to which it must be drained, as also the source and direction of flow of ground water. Figure illustrates two types of drainage installations suitable for selected hydrogeological conditions. A battery of wells is required to lower potentiometric surfaces to great depths over wide areas. As large-scale ground water withdrawal from areas underlain by compactible sediments results in subsidence, the pumping pattern should be investigated as to its effect on engineering structures.

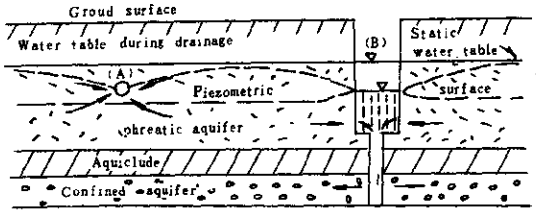


Figure Subsurface drainage installations (A) horizontally laid perforated pipe (tile drain) and (B) vertical drainage to a lower aquifer

In certain environments, it may be necessary to evaluate the chemical quality of water as it will determine whether the interstices in the rocks through which water moves are likely to be enlarged due to solution, or closed by cementation. Acid waters will not only enlarge existing cavities in carbonate rocks, but also leach calcium from cement and concrete aggregates.

(*From Hydrogeology*, *pp*230—232)

New Words and Expressions

1. geotechnical [dʒiau'teknikəl] a. 土工的；岩土的
2. unfavourable [ʌn'feivərəbl] a. 不利的；不适宜的
3. stability [stə'biliti] n. 稳定性
4. landmass ['lændmæs] n. 地块；陆块
5. ascertain [æsə'tein] vt. 确定；查明
6. disposition [dispə'ziʃən] n. 布局；处理；部署；排列
7. mention ['menʃən] v., n. 叙述
8. watertight ['wɔ:tətait] a. 不透水的；隔水的
9. pervious layers 透水层
10. rim [rim] n. 边缘
11. as to 就…而论；说到；至于
12. propensity [prə'pensiti] n. 倾向
13. leakage ['li:kidʒ] n. 渗漏
14. below-normal 标准以下的
15. downstream ['daun'stri:m] n., a. 顺流（的）；下游（的）
16. influent ['influənt] a. 流入的；注入的
17. uplift [ʌp'lift] n. 上升；隆起
18. piezometer [paiə'zɔmitə] n. 水压计
19. aim at 瞄准；指望
20. installation [ˌinstə'leiʃən] n. 装置；设备
21. battery ['bætəri] n. 蓄电池
22. compactible [kəm'pæktəbl] a. 可压实的
23. aggregate ['ægrigit] n. 集合体

Lesson Nineteen

Text

Geophysics

The consumption of mineral raw materials in the world is increasing year by year. Their scarcity is essentially responsible for the fuel and raw materials crisis which the world has faced since the seventies. This situation requires that geological surveys be undertaken to exploit raw materials from local sources as effectively as possible. These will concentrate on deposits at increasingly greater depths and in new, non-traditional areas. Classical geological survey methods are no longer sufficient, they must be supplemented by new progressive methods, among which applied geophysics has an important place.

Geophysics is a boundary scientific discipline which draws on new discoveries in geology and physics, and on the modern methods of mass data processing. It is closely associated with seismology, geothermics, tectonophysics, structural and general geology and other geological disciplines, whose findings it both exploits and supplements. *Applied geophysics* has the character of an applied science. It deals with those physical fields of the Earth which are important for determining the geological structure of the crust and upper mantle, for prospecting, for raw material deposits, or for other geological activities (engineering geology, environmental geology, hydrogeology, etc.). Applied geophysics is divided into individual disciplines depending on the physical principle and nature of the field which is being surveyed. The gravity field is studied by means of gravimetric methods, the magnetic field by means of magnetometric methods, the geoelectric field by means of geoelectrical methods, the field of elastic waves by means of seismic methods, the radioactive field by means of radiometric methods and methods of nuclear geophysics, and the thermal field by means of geothermic methods.

The Earth's crust is an inhomogeneous medium, formed by individual blocks and these, in turn, by rocks of various origins and geological ages. The different physical properties of the rocks, or of the tectonic blocks (density, magnetic susceptibility, resistivity, radioactivity and nuclear properties, thermal conductivity and elastic parameters) affect the physical fields of the Earth locally. We are thus able to use the changes in the physical fields of the Earth to determine inhomogeneities in the Earth's crust (structure, occurrence of raw-material deposits, etc.).

In interpreting geophysical data we frequently encounter the terms direct and inverse problems. In solving the *direct problem* we seek to determine the effect of a disturbing body of known size, shape, depth and physical properties on the corresponding physical field

(e. g. , the effect of a regular geometric body of known differential density and susceptibility on the gravity and magnetic field of the Earth). This problem is always unique. In solving the *inverse problem* we seek to determine the disturbing body corresponding to an anomaly in a physical field. This problem is usually ambiguous. To render it unique, it is necessary to use a combination of several geophysical methods or supplemental geological information.

Depending on the conditions and manner of surveying, several alternative forms of the geophysical methods may be used: airborne, ground, mining, drilling, submarine, etc. Each of these alternatives has its instrumental, methodical and interpretational peculiarities. From the point of view of the application of geophysical methods, we distinguish between methods for investigating the deep structure of the Earth's crust and problems of geological structure, geophysical methods for surveying raw-material deposits, geophysical methods for engineering geology and mining, geophysical methods for hydrogeology, etc.
(*From Introduction to Applied Geophysics*; *Introduction*, *pp*11—12)

New Words and Expressions

1. consumption [kən'sʌmpʃən] n. 消耗；消费量
2. raw [rɔ:] a. 生的；未加工的；处于自然状态的
3. scarcity ['skeəsiti] n. 缺乏；不足；稀少；罕见
4. geophysics [dʒi (:) ou'fiziks] [复] n. , a. [单数] 地球物理学；地球物理学的
5. discipline [disiplin] n. 纪律；风纪；训练；学科
6. draw [drɔ:] (drew [dru:], drawn [drɔ:n]) v. 引起；招来；获得；提取
   draw on 戴上；穿上；吸收；利用；凭；靠
7. seismology [saiz mɔlədʒi] n. 地震学
8. geothermics [dʒi (:) ou'θə:miks] [复] n. [单数] 地热学
9. tectonophysics [ˌtekˈtɔnəfiziks] [复] n. [单数] 构造物理学
10. findings ['faindiŋz] [复] n. 调查的结果
11. gravimetric [ˌgrævi'metrik] a. 测定重量的；重量分析的
12. magnetometric [mægnitou'metric] a. 测定磁力的；磁力分析的
13. geoelectric [dʒi (:) oui'lektrik] a. 地电的；地电测量的
14. geoelectrical [dʒi (:) oui'lektrikəl] a. 地电的
15. radioactive ['reidiouæktiv] a. 放射性的；放射引起的
16. inhomogeneous ['inhɔmə'dʒi:njəs] a. 不同类的；不同质的；非均匀的；不纯一的
17. susceptibility [səsepti'biliti] n. 磁化率；磁化系数
18. resistivity [rizis'tiviti] n. 电阻率
19. radioactivity [reidiouæk'tiviti] n. 放射性；放射（现象）
20. nuclear ['nju:kliə] a. 原子核的；原子能的
21. conductivity [kɔndʌk'tiviti] n. 传导率；传导性
22. parameter [pə'ræmitə] n. 参数；参项
23. inhomogeneity [inhɔmoudʒe'ni:iti] n. 不同类；不同质
24. direct [di'rekt] a. 直接的；正演的
25. inverse [in'vəs] a. 相反的；倒转的；反的；反演的
26. geophysical [dʒi (:) ou'fizikəl] a. 地球物理学的
27. encounter [in'kauntə] vt. 遭遇；遇到
28. disturb [dis'tə:b] vt. 打扰；干扰；弄乱
29. anomaly [o'nɔmoli] n. 异常
    gravity ～ 重力异常
30. submarine ['sʌbməri:n] a. 水下的；水底的；海下的
31. peculiarity [pikju:liæriti] n. 独特性；特色；特质
32. distinguish [dis'tiŋgwiʃ] vt. 区别；辨别；识别

33. borehole ['bɔ:houl] n. 钻孔
34. geochemist [dʒi (:) ou'kemist] n. 地球化学家
35. crisis ['kraisis] ([复] crises ['kraisi:z]) n. 危机
36. methodical [me'θɔdikəl] a. 有方法的；有条理的
37. ambiguous [æm'bigjuəs] a. 可能有两种或多种解释的；意义不明确的
38. render ['rendə] vt. 提出；作出；放弃；提供

Note to the Text

…, whose findings it both exploits and supplements.

…它既利用又补充了这些学科的研究成果。

Writing Guide

Abstract Writing (I)

1. 总体要求

科技论文摘要，不论用中文或英文，均应在正文之前，简明扼要地介绍论文的内容，说明研究的目的、方法、研究成果和最终结论。

书写科技论文英文摘要时应注意如下几点：

1) 要具有独立性，它是可以独立使用的一篇短文，其内容应保持论文报告的基本信息和格调。国外有的学术刊物规定摘要为1000个印刷符号或300～500个 words。国内各大学术刊物杂志一般要求300～500个印刷符号即可。

2) 应以第三人称书写，避免用第一人称作主语，因为使用第一人称往往具有个人感情色彩。

3) 英文摘要中出现俄、德、法、日等其它国家的人名时，应将它译成英文，不要夹杂使用。而中国的地名、人名均用汉语拼音字母书写。

4) 应避免使用公式、化学结构式、图表、参考文献标记、符号和人们不熟悉的缩写字。

5) 应与中文摘要内容一致，译文确切，无语法错误，并应注意包含3～8个外文关键词(key words)。

2. 论文题目的英译 (Title Writing)

1) 英文摘要题目的写作应注意以下几点：

a. 题目中除冠词、介词和连词外，其余所有实词的第一个字母都应大写。当介词、冠词在题目的开头时第一个字母也应大写。有些刊物规定题目的所有字母都大写。题目一般不超过20个字。在一行不够书写时，可分成两行，此时第二行的第一个字的第一个字母必须大写。

b. 科技论文题目通常不加标点符号，也不使用引号，但允许使用破折号。

c. 题目一般不必用完整的句子，大多数应该用名词短语，力求简、明、短。

2) 标题常用的英译形式：

为了使科技论文题目的英译工作规范化，现将几种常见的固定表达格式列举如下：

a. ××××的研究

A Study on…

The Study of…

A Study of the…

b. ××××××的初步研究

Preliminary Study of…

c. ××××××的新进展

Recent Advances in…

d. ××××××探讨

Exploration on…

A Study of…

Study on…

Investigation on…

e. ××××××的应用

The Application of…

Application of…to…

f. ××××××方法及其应用

Method of…and its Application

g. ××××××的几个问题

Some Problems of

h. ××××××的讨论

Discussions on…

i. ××××××简介

A Brief Description of…

j. ××××××的现状和今后的发展趋势

Present and Future Trends in (of) …

3）作者与工作单位的译法：

论文题目后写明作者全名及所在单位。作者姓名英译应按1958年2月11日第一届人大第五次会议上批准的《汉语拼音方案》的拼音字母正确书写。现在我国规定姓在前，名在后，姓和名的第一个字母均应大写，名中的第一、第二个字中间不必用短划线分隔。例如，吴勇强，应写为 Wu Yongqiang，不要写成 Wu Yong-qiang，也不要按欧美习惯写成 Yongqiang Wu。作者的姓名应在题目下面居中书写。作者的工作单位另起一行写。工作单位应从小至大依次书写，在高等院校工作，最基层单位可写至系，在厂矿、研究所，可写上厂矿及研究所名即可，不必再细分至教研室、科、室。下面给出几个不同的实例：

例1　　A Study on…（标题）

Su Pu

Department of Geology, Shanxi Mining College, China

例2　　Recent Advances in…（标题）

Wu Yongqiang

Geological Institute, The Chinese A cademy of Sciences, China

例3　　Preliminary Study…（标题）

Lei Fang

Yong Dingzhuang Colliery, Datong Bureau of Mines, China

Exercises

1. Questions for review:
   1) How many disciplines can applied geophysics be divided into?
   2) Why do we need to look for new progressive exploiting methods?
   3) What method can exploit the earth's field of elastic waves?
   4) Does the direct problem have unique solution?
   5) How can we render a unique solution for inverse problems?
2. Give the Chinese/English equivalents for the following:
   1) in response to　　6) 应用地球物理
   2) natural resources　　7) 非均匀介质
   3) both in performance and economy　　8) 磁异常
   4) to put to use in mining exploration　　9) 正演问题
   5) to be associated with inverse problems　　10) 放射性
3. Choose the correct form from the following adjective phrases:

   capable of　　typical of　　free of

   full of　　essential to　　proportional to

   responsible for　　good at　　dependent on

   1) He is…mathematics.
   2) This line is…that.
   3) This angle is…that.
   4) Oxygen is…life.
   5) Such compounds is…living things.
   6) When quartz in the earth's rocks wears away, or erodes, the small particles of quartz are very…the original quartz minerals.
   7) Sedimentation, in a strict sense, refers to the processed…the formation of sedimentary rocks
   8) Every particle in the universe attracts every other particle with a force that is directly …the product of their masses and inversely…the square of the distance between them.
4. Translate the following passage into Chinese:

   Investigations of the physical properties of the earth and internal processes are called geophysics. The geophysical techniques most widely employed for exploration work are the seismic, gravity, magnetic and electrical methods. Less common methods

involve the measurement of radioactivity and temperature at or near the earth's surface and in the air.

Some of these methods are used almost entirely in the search for oil and gas. Others are used primarily in exploring for solid minerals. Most of them may be employed for either objective. Seismic and gravity prospecting are main tools for oil exploration; electrical methods are predominantly used for coal and mineral exploration; magnetic methods are employed for both types of prospecting.

5. Choose the best answer:

1) Did you blame him for his mistakes?Yes, but _____it.
   a. I'd rather not do b. I'd not rather have done
   c. I'd better not done d. I'd rather not have done

2) You ought to have gone to see your uncle yesterday. Yes, I _____.
   a. should b. ought to c. would to d. should have

3) What are you taking next term? I don't know, but it's time _____something.
   a. I decide b. I decided c. I'll decide d. I'd decide

4) We can't go out now. It's too rainy. I wish the rain _____soon.
   a. stop b. will stop c. would stop d. to stop

5) What advice did your grandfather give you?He suggested that I _____ to learn from the people.
   a. am b. be c. was d. would be

6) Did you call to make you airline reservation?Not yet. but I _____.
   a. should have b. may have c. must have d. shall have

7) If only she could get her feet on something solid, she _____able to break out of the swift current.
   a. might have been b. might be c. were d. shall be

8) I _____by ship, but I didn't have enough times.
   a. would like to come here b. would like to have come here
   c. would rather come here d. would rather to come here

6. Translate the following sentences into English:

1) 为了满足对矿物资源的需要，地球物理学家正在改进地球物理测量技术
2) 地球物理反演问题通常是多解的。
3) 应用地球物理依据所探测的物理场的性质可分为几个分支。
4) 在解释地球物理资料时，我们经常会遇到正演问题和反演问题。
5) 传统的地质方法不再能满足勘探煤和石油等原材料的需要。

Reading Material

Principles of Applied Geophysics

Geophysics is the application of the principles of physics to the study of the earth. Strictly

speaking the subject includes meteorology, atmospheric electricity, or ionosphere physics; but in this monograph the word geophysics will be used in the more restricted sense, namely the physics of the body of the earth. The aim of pure geophysics is to deduce the physical properties of the earth and its internal constitution from the physical phenomena associated with it, for instance the geomagnetic field, the heat flow, the propagation of seismic waves, the force of gravity, etc. On the other hand, the object of applied geophysics, with which this monograph is concerned, is to investigate specific, relatively small-scale and shallow features which are presumed to exist within the earth's crust. Among such features may be mentioned synclines and anticlines, geological faults, salt domes, undulations of the crystalline bedrock under a cover of moraine, ore bodies, clay deposits and so on. It is now common knowledge that the investigation of such features very often has a bearing on practical problems of oil prospecting, the location of water-bearing strata, mineral exploration, highway construction and civil engineering. Often, the application of physics, in combination with geological information, is the only satisfactory way towards a solution of these problems.

The geophysical methods used in investigating the shallow features of the earth's crust vary in accordance with the physical properties of the rocks—the last word is used in the widest sense—of which these features are composed, but broadly speaking they fall into four classes. On the one hand are the *static methods* in which the distortions of a static physical field are detected and measured accurately in order to delineate the features producing them. The static field may be a natural field like the geomagnetic, the gravitational or the thermal gradient field, or it may be an artificially applied field like an electric potential gradient. On the other hand, we have the *dynamic methods* in which signals are sent into the ground, the returning signals are detected, and their strengths and times of arrival are measured at suitable points. In the dynamic methods the dimension of time always appears, in the appropriate field equations, either directly as the time of wave arrival, as in the seismic method, or indirectly as the frequency or phase difference, as in the electromagnetic method. There is a further, now considerably important, class of methods which lie in between the two just mentioned. These will be called *relaxation methods*. Their feature is that the dimension of time appears in them as the time needed for a disturbed medium to return to its normal state. This class includes the overvoltage or induced polarization methods. Finally there are what we may call *integrated effect methods*, in which the detected signals are statistical averages over a given area or within a given volume. The methods using radioactivity fall in this class.

The classification of geophysical methods into ground, airborne or borehole methods refers only to the operational procedure. It has no physical significance. Many ground methods can be used in the air, under water or in boreholes as well.

The magnetic, electromagnetic and radioactive methods have been adapted to geophysical measurements from the air. Airborne work has certain advantages. Firstly, on account

of the high speed of operations an aerial survey is many times cheaper than an equivalent ground survey, provided the area surveyed is sufficiently large, and secondly, measurements can be made over mountains, jungles, swamps, lakes, glaciers and other terrains which may be inaccessible or difficult for ground surveying parties.

Compared with ground work, airborne measurements imply a decrease in resolution which means that adjacent geophysical indications tend to merge into one another giving the impression of only one indication. Besides, there is often considerable uncertainty about the position of airborne indications so that they must be confirmed on the ground before undertaking further work such as drilling.

In a sense, applied geophysics, excepting the seismic methods, is predominantly a science suited to flat or gently undulating terrain where the overburden is relatively thin. The reason is that whenever the relief is violent, the data of geophysical methods need corrections which are frequently such as to render their interpretation uncertain. On the other hand, when the overburden is too thick the effects produced by the features concealed under it generally lie within the errors of measurement and are difficult to ascertain. There is, however, no general rule as to the suitability of any terrain to geophysical methods and every case must be considered carefully on its own merits.

The various methods of applied geophysics will be dealt with in turn in the following chapters.

(*From Principles of Applied Geophysics: Introduction*, *pp*1 3)

New Words and Expressions

1. meteorology [mi:tjə'rɔlədʒi] n. 气象学
2. ionosphere [ai'ɔnəsfiə] n. 电离层
3. monograph ['mɔnəgrɑ:f] n. 专题文章；专题著作
4. geomagnetic [dʒi (:) oumæg'netik] a. 地磁的
5. presumed [pri'zju:md] a. 假定的
6. anticline ['æntiklain] n. 背斜
7. dome [doum] n. 穹窿
8. undulation [ʌndju'leiʃən] n. 起伏；波浪
9. prospecting [prəspektiŋ] n. 探矿；勘探
10. bearing ['beəriŋ] n. 意义；关系
11. strata ['strɑ:tə] n. (复) 地层
12. moraine [mə'rein] n. 冰碛；冰碛层
13. gravitational [grævi'teiʃənəl] a. 引力的；重力的
14. gradient ['greidjənt] n. 梯度
15. relaxation [rilæk'seiʃən] n. 张弛；弛豫
16. radioactivity [reidiouæk'tiviti] n. 放射性；放射现象
17. airborne ['ɛəbɔ:n] a. 空中的；空运的
18. electromagnetic [ilektroumæg'netik] a. 电磁的
19. radioactive [reidiou'æktiv] a. 放射性的
20. aerial ['ɛəriəl] a. 航空的
21. undulate ['ʌndjuleit] v. 波动；起伏

Lesson Twenty

Text

Geoelectrical Methods

The study of electric fields and currents in the Earth is one of the youngest geophysical disciplines. Although the first steps in applying geoelectrical methods to geology were already made more than 100 years ago (prospecting for sulphide deposits using the self-polarization method), the study of geoelectricity only began to develop at the beginning of this century.

A large number of methods, some of which have a number of variations, are used to study geoelectricity. This fact is favourably reflected in the wide range of geological problems, solved by geoelectrical considerations. With the aid of geoelectrical methods we are able to differentiate between rocks according to their resistivity, permittivity and electrochemical activity.

Geoelectrical methods can be classified from a number of points of view. The field studied may be D. C. or A. C. (with a wide range of frequencies), harmonic or non-harmonic, natural of man-made, and measurements can be made on the ground, in an aircraft, in a borehole, as well as in a mine.

Geoelectrical methods which are used to investigate the distribution of the electrical potential or potential gradient of a direct current are referred to as D. C. methods. The most widely used D. C. method is the resistivity method. In field measurements, current I is passed through the ground by electrodes A and B, and the potential difference ΔV is measured between the electrodes M and N. The resistivity of the medium is calculated from the quotient of the values $\Delta V/I$ using a modified Ohm's law. If the distances between the electrodes do not change and we move the array along a profile, we speak of resistivity profiling. This is useful in mapping contacts of rocks with different resistivities, in locating conductors, thin non-conductors, etc. If the centre of the electrode array remains stationary we speak of vertical electrical sounding. This serves particularly for studying horizontally stratified media which we may expect, e. g., in sedimentary basins.

An important group of D. C. methods are the potential methods. As in resistivity methods, current is passed through the ground via current electrodes and the distribution of the potential or potential gradient on the Earth's surface is measured with the aid of the measuring or potential electrodes. These include, e. g., the charged body method (or mise-à-la-masse method) in which the conducting ore body, penetrated by a borehole or shaft, serves as one of the current electrodes.

Electrochemical methods have proved useful in searching for natural conductors of the lst order. In the self-polarization method we measure the natural D. C. electric fields generated spontaneously, e. g., above sulphide deposits as a result of oxidation reduction processes. If the conditions for the generation of a self-polarization field are not satisfied, e. g., due to the large depth of conducting bodies, or the unfavourable structure of conducting minerals (disseminated ore mineralization), the object we are looking for can be polarized artificially by intensive current pulses. We then speak of induced polarization.

Electromagnetic methods are very varied and numerous. In comparison to D. C. and electrochemical methods they have substantially more complicated theoretical foundations. They are used to investigate variable electromagnetic fields, natural and man-made, harmonic and non-harmonic and of low and high frequencies. Their great advantage is that they mostly do not require galvanic connection to earth and, therefore, they can be used for surveying from a mobile station. Electromagnetic methods are widely used in complex airborne geophysical surveys. For the sake of simplicity we shall divide electromagnetic methods in the same way as the resistivity methods into electromagnetic profiling and electromagnetic sounding.

(*From Introduction to Applied Geophysics: Geoelectrical Methods*, *pp*263—264)

New Words and Expressions

1. permittivity [ˌpəːmiˈtiviti] n. 介电常数；电容率
2. electrochemical [ˌilektrouˈkemikəl] a. 电化的；电化学的
3. harmonic [hɑːˈmɔnik] a. 谐波的 n. 谐波 non-harmonic a. 非谐波的
4. aircraft [ˈɛə-ˈkrɑːft] n. 航空器；飞机
5. electrode [iˈlektroud] n. 电极
6. quotient [ˈkwəuʃənt] n. 商
7. array [əˈrei] n. 排列
8. shaft [ʃɑːft] n. 竖井
9. self-polarization [ˈself-poulariˈzeiʃən] n. 自激极化；自激极化强度
   induced-polarization 激发极化
10. polarize [ˈpouləraiz] v. (使) 极化
11. galvanic [gælˈvænik] a. (电池) 电流的
12. sake [seik] n. 缘故
    for the ～ of 为…起见
13. profiling [ˈproufailiŋ] n. 剖面
    electromagnetic ～ 电磁剖面法
14. sounding [ˈsaundiŋ] n. 测深
    electromagnetic ～ 电磁测深
15. pulse [ˈpʌls] n. 脉冲
    intensive current ～ 强电流脉冲
16. unfavourable [ʌnˈfeivərəbl] a. 不适宜的；不顺利的；不利的
17. spontaneously [spɔnˈteinjəsli] ad. 自发地；自然发生地
18. sulphide [ˈsʌlfaid] n. 硫化物

Note to the Text

These include, e. g., the charged body method (or mise-a-la-masse method) in which the conducting ore body penetrated by a borehole or shaft serves as one of the current electrodes. 例如，这些包括充电法，在充电法中被钻孔或竖井穿过的导电矿体，充当其中的一个电极。

Writing Guide

Abstract Writing (Ⅱ)

4. 论文摘要主题句 (Topic Sentences of Abstracts)

论文摘要主题句常在摘要的开头。许多论文摘要常用一种固定的句式，现将常见的句式列出，以供参考。

1) In this paper the author deals with … (本文研究了)

2) In this paper the author analyses … (本文分析了)

3) In this paper the author discusses … (本文讨论了)

4) In this paper the author proposes … (本文提出)

5) In this paper the author introduces … (本文介绍了)

6) In this paper the author presents … (本文给出了)

7) In this paper the author studies and analyses … (本文研究和分析了)

8) In this paper the author describes … (本文描述了)

……

也可以将以上一些句子用下列被动语态来表达，例如：

1) … is discussed in this paper

2) … is studied

3) … is proposed …

5. 科技论文英文摘要的时态 (Tenses of Abstracts)

英文论文摘要中的动词时态反映研究过程中各种事实的时间关系，现将主要时态的一般原则归纳如下：

1) 现在时态

概述一般结论、真理、实验结果、方法描述，都用一般现在时表述。例如：

a. A method is presented for calculating…

b. The advantage offered by the method and scope of its application is outlined.

c. A series of examples for plate tectonics are analyzed…

2) 过去时态

实验经过，过去的研究工作，一些特定结论要用过去时态，例如：

a. The plate tectonic theory was first proposed by…

b. The structural analyses were carried out with…

c. The results were compared with…

3) 现在完成时态

叙述从某一时间开始，对现在有影响，用现在完成时态，例如：

a. His results have never been published.

b. Up to now, our main natural energy sources have been coal and oil.

c. Since World War Ⅱ, the use of the fast electronic computers has made…

4) 一般将来时

叙述今后研究及打算，予期的结果要用一般将来时，例如：

a. The results will be discussed further.

b. Some experiments will be carried out later.

c. The conclusion will be proved…

6. 结尾句（Concluding Sentences）

在英文摘要的结尾往往需写上作者的结论或建议，下面是一些常见的句式：

1) It is suggested that…

2) It is recommended that…

3) The results show that…

4) The results suggest that…

5) The author concludes that…

7. 英文摘要关键词（Key words）

英文摘要的最后，附有关键词（Key words）。关键词是论文的主题词，也是论文的精华。一般是将能反映论文中心议题的词和词组列出若干个（十个以内），直接写在 Key words 之后，词与词之间用分号分开，最后一个词后面，可不加标点。例如：

Key words: lithosphere; hydrosphere; atmosphere; crust.

关键词应力求简明、扼要，尽量选择能体现论文主题思想的文字，不要拖泥带水。

以上仅是撰写英文摘要的一般程序，供初次写作参考。当然，随着英语水平的提高及写作技巧的不断熟练，完全可以不拘泥上述形式，只要能抓住论文的中心以简练的语言综合扼要地概述即可。

8. 英文摘要实例

为了帮助大家了解掌握英文摘要的写作格式和要领，下面列举几个英语论文摘要实例。

例1

Plate Tectonic Reconstructions of the Cretaceous and Cenozoic Ocean Basins

CHRISTOPHER R. SCOTESE[1], LISA M. GAHAGAN[2] and ROGER L. LARSON[3]

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2. *The Department of Geological Sciences, The University of Texas, Austin, TX* 78713 (*U. S. A*)

and The Institute for Geophysics, University of Texas, Austin, TX 78759 (*U. S. A*)

3. *School of Oceanography, University of Rhode Island, Kingston, RI* 02881 (*U. S. A.*)

Abstract

In this paper the author present nine reconstructions for the Mesozoic and Cenozoic, based on previously published sea-floor spreading isochrons. The purpose of this study was (1) to determine if the isochrons could be refitted to produce accurate plate tectonic reconstructions. (2)to identify areas of further investigations, and (3) to test the capabilities and accuracy of interactive computer graphic methods of plate tectonic reconstruction. In general, Tertiary and Late Cretaceous isochrons could be refitted with little overlap and few gaps; however, closure errors were apparent in the vicinity of the Bouvet and Macquarie

triple junctions. It was not possible to produce Early Cretaceous reconstructions that were consistent with the previously published isochrons. In this paper the author also propose that the Late Cretaceous and Early Tertiary plate reorganizations observed in the Indian ocean were the result of the progressive subduction of an intra Tethyan rift system.

例2 **COAL MEASURES OF AN OROGENIC RECESS: LATE PERMIAN SYDNEY BASIN, AUSTRALIA**

J. GILBERT JONES, PATRICK J. CONAGHAN and KEVIN L. McDONNELL

School of Earth Sciences, Macquarie University, North Ryde, N. S. W. 2113 (Australia)

Abstract

Comparison of the Late Permian northeastern Sydney Basin with the Pliocene-Quaternary "Purari recess" of the Papuan Basin on the basis of gross lithology and lithologic sequence, sediment provenance, sedimentary environment and basin architecture confirms its tectonic context as an orogenic recess of closely similar character. This comparison, together with comparison to the Late Carboniferous Appalachian Basin of Pennsylvania, suggests that, under favourable climatic circumstances, orogenic recesses are optimum sites for thick coal accumulation.

例3 **Discovery of Blake Reversed Episode in China**

Liu Chun

Paleomagnetic Laboratory, Institute of Geology, Chinese Academy of Sciences, Beijing

Abstract

A reversed polarity event known as Blake Episode is first found at the Xujiayao Paleolithic site, Shanxi province, China.

This discovery has an important significance for further studying geomagnetic reversals during the Brunhes chron and the evolution of biological species.

In this paper, the Quatenary geology and chronology related to the Blake Episode are briefly discussed.

KEY WORDS: Blake; Brunhes; Reversed Episode; Paleolithic Site

Exercises

1. Questions for review:
   1) What do the geoelectrical methods study?
   2) How do you classify geoelectrical methods?
   3) What can we do by using resistivity profiling?
   4) What kind of problems can be solved by the self-polarization method?
   5) What can we differentiate between rocks according to?
2. Give the Chinese/English equivalents for the following:
   1) 自然电位法　　2) 充电法
   3) 激发极化法　　4) 电阻率剖面法
   5) 电磁测深　　6) electrochemical activity
   7) apparent resistivity　　8) with a wide range of frequencies

9) potential methods　　10) conducting minerals

3. Fill in the blanks with one of the following prepositions:

for　along　in　between　to　by　with

_____ resistivity profiling we use a certain pattern _____ moving the electrode array _____ a given profile or _____ neihbouring profiles. _____ most profiling all the electrodes move _____ the profile simultaneously, preserving the distances _____ them. _____ some cases the current electrodes remain stationary. The measured electric field. or the calculated apparent resistivity is referred _____ a single point which has a constant position relative _____ the electrodes. This point. the recording point. is denoted _____ the letter O. _____ symmetric arrays the recording point is usually _____ the middle of the array, _____ asymmetric arrays it is located _____ the center of the measuring dipole or it is identified _____ one of the measuring electrodes.

4. Translate the following passage into Chinese:

D. C. Resistivity Methods: D. C. resistivity methods have proved very useful in practice and serve to solve a whole series of geological problems. Various types of rocks differ from one another, e. g, in porosity, which is one of the main factors affecting resistivity. Resistivity methods can be used to investigate the boundary between crystalline and sedimentary rocks, compact quartzite rocks with schists or phyllites. etc. Where resistivity differentiation of rocks can be anticipated in the horizontal direction. i. e. in areas with steeply dipping rock contacts, resistivity profiling can be applied. If the maximum resistivity changes occur in the vertical direction. i. e. in areas with approximately horizontally deposited layers, vertical electric sounding is used.

5. Find the mistakes in sentences and correct it:

1) If he took (A) better care of his money, he will be (B) less (C) likely to lose (D) it.

2) They are the ones (A) who assert (B) that a better bridge could have (C) been built have (D) we had their assistance.

3) I recommend (A) that you all (B) are (C) diligent if you want (D) to pass the exam.

4) If these discoveries were made (A) by chance alone (B), many discoveries of this type would have been (C) made (D) by any inexperienced scientists like Bernard.

5) He insists (A) that you are (B) on time for (C) the appointment you made (D).

6) If I would have tried (A) to handle the heavy (B) case without Paul (C), I could never have moved (D) it.

7) Inside (A) the broken-down shed, which (B) could not be (C) more uncomfortable, the Curies (D) had worked out the most difficult experiments.

8) I would go to visit that beautiful lake but I couldn't got in touch with you while I was in Boston.
A B C D

6. Translate the following Chinese sentences into English:

1) 电阻率剖面法是基本的地电方法之一。

2) 岩石的电阻率受地质、水文因素的影响很大。

3) 地电方法能够从不同的观点进行分类。

4) 地电方法的多样性是由于岩石电性参数的各向异性 (heterogeneity)。

5) 电磁方法广泛地应用于复杂的航空地球物理勘探。

Reading Material

Electrical Resistivity and Electromagnetic Methods

The resistance of the rock strata to electric currents depends partly on the minerals involved and partly on the fluids present in the rock's pore spaces. Under laboratory conditions, sub-bituminous and bituminous coals are highly resistive. Shales, limestones and sandstones generally have lower resistivities, and such contrasts form the basis for the application of electrical resistivity techniques to coal exploration.

Measurement of the electrical resistivity of rock strata in the subsurface can be performed by relatively simple geophysical apparatus, described in standard texts on exploration geophysics (e. g. Telford et al 1976; Parasnis 1979). An array of four electrodes is normally used, two of which are connected to a generator or current source (the 'current electrodes') and two of which are connected to a separate voltmeter or potentiometer (the 'potential electrodes'). The apparatus ideally passes current through a roughly hemispherical zone beneath the current electrodes and the 'apparent resistivity' of this block is determined from the voltage across the potential electrodes in relation to the current flowing in the system.

If the electrodes are set up about a fixed point and their spacing is progressively expanded, the depth below the ground surface to which the current penetrates is likewise increased. The presence of a stratum of contrasting resistivity to those nearer the surface is indicated by a change in the 'apparent resistivity' of the block as the hemispherical zone encompasses the new bed. By plotting apparent resistivity against electrode spacing, the depth at which this change occurs can be determined.

Use of resistivity apparatus in this way is known as 'electrical sounding'. It can be used, in favourable situations, to give the depth to a coal bed or other resistivity change without the need for drilling. An alternative method is to maintain a constant electrode spacing but move the apparatus along an appropriate traverse line. This enables lateral changes in resistivity within a certain distance of the surface to be delineated. Known as 'electric trenching' or 'resistivity profiling', this technique may be used to determine the

position of the outcrop of dipping coal seams in areas where exposure is poor (Verma & Bhuin 1979). Connection of adjacent traverses may then be used to produce a map showing the outcrop zone.

Resistivity techniques can be used on a regional scale or as part of a detailed investigation in a small area. The regional application may be used to delineate the position of a coal-bearing formation, or any other formation with distinctive resistivity characteristics. In the detailed study, however, the coal seam itself is normally the target.

Resistivity surveys are strongly influenced by the geologic setting of the area in question. A blanket of highly resistive material, such as a thick, dry, weathered zone at the surface, can prevent penetration of the current to the strata below, and make resistivity contrasts undetectable. Not all high resistivity beds are coal seams, nor do all coal seams have significant resistivity contrasts with adjacent strata. The presence of water in pores and cleat fractures, in particular, can reduce the apparent resistivity of a coal bed in the field, while the presence of coals associated with coarse freshwater sandstone or conglomerate may be difficult to detect even in favourable conditions. The position of the water table and the salinity of the groundwater in the area can also have a marked effect on the results of a resistivity survey.

Electromagnetic methods of geophysical exploration are based on the production of a time-varying electromagnetic field by an alternating or pulsed electric current in a suitably laid out conductor at the ground surface or in the air above. As it builds up and collapses, this field generates a pattern of secondary currents in the subsurface strata due to the effects of electromagnetic induction. The secondary currents, in turn, produce secondary electromagnetic fields, and these act to distort the primary field generated by the conductor itself.

The combined effects of the primary and secondary fields can be measured from the currents produced in another conductor (a detecting loop or coil) suitably located with respect to the primary source. If the primary field is a transient pulse, the secondary currents and their associated field build up and decay gradually, rather than instantaneously, when the original current is turned on or off. Build-up and decay are more rapid if the resistivity of the subsurface rocks is high, and thus the inductive effects may be used to interpret the electrical properties and spatial arrangement of the strata involved. If a regularly oscillating field is used, on other hand, the secondary effects produce a combined field that is of different amplitude, phase and orientation compared to the field from the primary source. Depending on such factors as the geometric arrangement of source and detector loops in relation to the subsurface strata, as well as the frequency of the field that is used, these differences can also be analysed to interpret the resistivity and distribution of the beds beneath.

A comprehensive discussion of the use of electromagnetic methods in geophysical prospecting is given by Parasnis (1979). The technique has the advantage over the methods described in Section 6.4.3 that it does not require physical contact to be made with the

ground surface. This avoids the risk of difficulties due to poor electrode contact or variable soil conditions, and may enable more rapid surveys to be carried out in some cases. Electromagnetic methods can be applied even when the near-surface layer is of very high resistivity, such as in arid lands or permafrost terrain.

Although traditionally applied to the search for metallic mineral deposits, electromagnetic methods may also be used for evaluating subsurface geology in coalfield areas. Both transient pulse methods and multi-frequency oscillation techniques have been used to assess factors such as depth to basement, coalbearing rock units or individual coal seams and to indicate the location of seam subcrops, faults, intrusions and cinder zones.

(*From Coal Geology: Coalfield Exploration*, *pp*182—184)

New Words and Expressions

1. strata ['strɑtə] (复) n. 地层
2. resistance [ri'zistəns] n. 电阻；阻抗
3. resistive [ri'zistiv] a. 抵抗的；有抵抗力的；电阻的
4. apparatus [æpə'reitəs] n. 仪器；设备；装置
5. progressively [prə'gresivli] ad. 渐进地；逐渐地
6. encompass [in'kʌmpəs] vt. 围绕；环绕；包围；包含；包括
7. delineate [di'linieit] vt. 描绘；描出…的外形，划出…的轮廓
8. trench [trentʃ] n. 深沟；地沟 vt. 刻；挖 vi. 接近；近似
   electrical ~ 电剖面法
9. cleat ['kli:t] n. 煤的内生裂隙
10. lay [lei] vt. 布置；安排；放
    ~ out 摆开；展示
11. transient ['trænziənt] a. 瞬变的
12. instantaneously [instən'teinjəsli] ad. 瞬间地；即刻地
13. oscillate ['ɔsileit] vi. 振荡；振动；摆动
14. loop [lu:p] n. 圈；环
15. arid ['ærid] a. 干旱的；贫瘠的
16. permafrost ['pə:məfrɔ (:) st] n. 永久冻土
17. subcrop [sʌbkrɔp] n. 隐伏露头
18. cinder ['sində] n. 火山渣

Lesson Twenty-one

Text

Seismic Methods

Seismic prospecting—*seismics*—is a set of methods for investigating the geological structure of the Earth's crust, based on studying artificially excited elastic waves. These waves propagate omnidirectionally from their source and penetrate to great depths. At boundaries they are refracted and reflected and return to the Earth's surface, where the oscillations they generate are recorded. Measuring the time of propagation of the waves and studying their character enables us to determine the depths and shapes of the boundaries, from which the wave has been reflected back to the surface, and provides information about the rocks through which the wave has propagated along its path. Seismic prospecting plays an important part in solving various problems of structural geology, particularly in prospecting for oil and gas deposits. Seismic prospecting is also important in locating deposits of other raw materials and in solving problems in hydrogeology and engineering-geology.

In treating various geological problems, the waves which are reflected from the object being investigated back to the Earth's surface, i. e. reflected and head waves, are most important.

The main source of seismic energy is still the detonating of explosives, usually close to or on the surface. The explosion generates body waves as well as intensive surface waves. However, the latter only penetrate to depths of a few tens of metres and, therefore, cannot be used for prospecting at greater depths.

As the initial point of the travel-time curve of the head wave we shall define point M at which the ray of the head wave, generated directly at the point of incidence of the direct wave under the critical angle at boundary R, arrives. We are able to trace the head wave from this point onwards: the head wave does not physically exist between this point and the shotpoint.

Reflected waves exist along the profile close to the shotpoint, as well as at larger distances from it. However, they arrive there later than the head waves. For a given shotpoint, therefore, the seismic profile can be divided into two parts: the neighbourhood of the shotpoint, where the reflected waves are usually recorded and the more distant region, where the head (refracted) waves are usually observed.

In seismic prospecting we distinguish between two fundamental methods: reflection and refraction. Each of these methods has its specific properties which make it suitable for solving different geological problems.

Besides longitudinal reflected and head waves, the following waves may also arrive at the Earth's surface:

- *Direct longitudinal wave*, propagating along the Earth's surface. This usually involves a head wave, propagating along the surface of a rock layer at the base of a weathered layer.

—*Surface waves*, propagating at velocities of 200 to 1000ms $^{-1}$.

—*Acoustic waves* with velocities of about 340ms^{-1}.

—*Transverse waves* (reflected and head) and *transformed waves*.

—*Multiple reflections*, generated after the incidence of waves of different types (particularly of longitudinal reflected waves) at the Earth's surface or some boundarh within the geological section; they are reflected back to depth where they are again reflected and returned to the surface.

—*Diffracted waves*, generated by the incidence of seismic waves at discontinuous boundaries or other inhomogeneities.

—*Irregular waves* which appear in the neighbourhood of the shotpoint and are caused by dispersion of longitudinal waves on shallow inhomogeneities.

—*Microseisms*, irregular ground motions due to various agents (wind, rain, traffic, agricultural machines).

Only some of these waves can be used for investigating the geological structure of a given region. The waves which we wish to observe in prospecting are referred to as *useful waves* or as *the useful signal*. The waves which disturb the recording of useful waves are called *interfering waves*, *interference*, or simply *noise*. The latter can be divided into *regular (coherent) noise*, consisting of waves which can be represented by travel-time curves, and *random noise* which cannot be expressed in terms of travel-time curves. Microseisms and irregular waves belong to random noise, the other interference can be classified as regular noise.

For a seismic record to be sufficiently legible, it is necessary that the signal-to-noise ratio be at least 1.5:1. Since the ratio is in practice frequently worse, methods are used to improve it, both in the field measurements, and in later processing.

The possibility of using seismic methods is determined by the seismological conditions which are associated with the deep parts of the geological profile, as well as with its subsurface zone.

The most favourable conditions for seismic observations are created by:

—the existence of distinct seismic boundaries and their agreement with stratigraphic or lithological boundaries,

—large area of seismic boundaries without faults and facial changes, small angles of dip (2° to 10°),

—the presence of moist plastic rocks in the upper part of the geological profile,

—the small thickness of the low-velocity layer,

—the small depth of groundwater,

—the absence of shallow and sharp seismic boundaries,

· planar relief of the region being investigated.

(*From Introduction to Applied Geophysics; Seismic Methods, pp*401—403)

New Words and Expressions

1. omnidirectionally [ɔmnidi'rekʃənəli] ad. 全向地
2. refract [rif'rækt] vt. 折射
3. oscillation [ɔsi'leiʃən] n. 振荡
4. detonate ['detouneit] v. 起爆；使起爆
5. longitudinal [lɔndʒi'tju:dinl] a. 纵向的
6. acoustic [ə'ku:stik] a. 声的
7. incidence ['insidəns] n. 入射；入射角
8. irregular [i'regjulə] a. 不规则的；无规律的
   ~ waves 不规则波
9. legible ['ledʒəbl] a. 清楚的
10. seismological [saizmə'lɔdʒikəl] a. 地震的
11. facial ['feiʃəl] a. 表面的
12. head waves 首波
13. multiple ['mʌltipl] a. 多次的；多重的
    ~ reflections 多次反射
14. transverse waves 横波
15. microseism [maikrou'saizm] n. 微震
16. transformed waves 转换波
17. onwards ['ɔnwədz] ad. 向前；在前面

Note to the Text

As the initial point of the travel-time curve of the head wave we shall define point M at which the ray of the head wave, generated directly at the point of incidence of the direct wave under the critical angle at boundary R, arrives.

倒装句。句首的 As…作为 shall define 的宾语 point 的补足语。at which 引导定语从句。本句可译为："我们定义 M 点为首波旅行时曲线的始点，由边界 R 以临界角在入射点入射的直达波射线在这点到达。"

Exercises

1. Questions for review:
   1) What can we do by using seismic prospecting?
   2) How can we determine the depths and shapes of the boundaries?
   3) What is the main source of seismic energy?
   4) What are the most favourable conditions for seismic observations?
   5) What kinds of waves can we get at the Earth's surface in seismic prospecting?
2. Choose the correct answer from the alternatives:
   1) Seismic P-waves travel most rapidly through:
      a. Granite
      b. Unconsolidated sediments
      c. Alternating shales and sandstones
      d. Brown coal
   2) Which of the following can be determined from arrival times recorded at only one seismic station?
      a. Time of the earthquake
      b. Location of the earthquake

c. Magnitude of the earthquake d. Stress pattern of the earthquake

3) Seismic S-wave velocities are highest in:

a. Glacial gravel

b. The lithosphere above the Mohorovicic discontinuity

c. The lithosphere below the Mohorovicic discontinuity

d. The asthenosphere

4) The earth's outer core is thought to be in the liquid state because:

a. S-waves do not pass through it

b. P-waves do not pass through it

c. Neither P-and S-waves slow down sharply as they pass through it

d. Both P-and S-waves slow down sharply as they pass through it

5) Large earthquakes are caused predominantly by:

a. Volcanism and the intrusion of magma

b. Major landslides and avalanches

c. Horizontal movements of the earth's crust

d. The release of strains generated by tidal forces

6) First-motion studies of earthquakes have shown the tensional faults occur most frequently:

a. In and parallel to subduction zones

b. Perpendicular to subduction zones

c. In and parallel to middle-oceanic ridges

d. Perpendicular to mid-oceanic ridges offsetting them

3. Choose the correct word from the following lists:

reconstruct rearrange return regain reappear rewrite

a. Some objects are described as elastic because they _____ to their original size and shape after they have been bent.

b. Under the high temperature and greater pressure the minerals in the rock are _____.

c. Some of the rain may remain close to the surface and _____ to the air by evaporation.

d. An earthquake destroyed the town last year but it is being _____ now.

e. When the rocks rupture, abrupt movement takes place along a fault as rocks grind and slide past each other attempting to _____ their original position.

4. Translate the following passage into Chinese:

Body waves propagate omnidirectionally from the source at a certain velocity which depends on the physical properties of the medium and on the type of wave. Within a certain region, bounded by two closed surfaces, short-period oscillations of mass particles occur. The external surface separates a part of the elastic medium at a given time, in which the wave has already caused the particle to oscillate, from the

part which is still at rest. This surface is called the wavefront. The internal surface, which separates the part of the medium in which the oscillations are taking place from the parts where they have already terminated, is called the rear of the wave. The wavefront and rear of the wave change their position with time.

5. Fill in each blank with the letter of the word which best completes the passage:

It is estimated that in the last two thousand years the world has lost more than a hundred species of animals. A similar number of species of birds has also become extinct. The real significance of __1__ (this, world, thousand, these) figures, however, lies in __2__ (a, the, two, first) fact that almost three-quarters __3__ (of, from, with, since) all the losses occurred __4__ (then, perhaps, in, on) the past hundred years __5__ (plus, and, ago, then) as a direct result __6__ (because, of, since, the) man's activities on this __7__ (planets, worlds, planet, country). It is essential for __8__ (the, their, a, his) whole process of evolution __9__ (since, certainly, because, that) the extinction of certain species should occur over a __10__ (year, period, extinct, periods) of time.

6. Translate the following sentences into English:

1) 地震勘探是研究地壳地质构造的一种方法。

2) 测量波的传播时间并研究它们的特征，使我们能确定反射界面的深度和形状。

3) 地震波在界面折射并被反射回地表。

4) 应用地震方法的可能性取决于地震剖面深部的地震地质条件。

5) 要使地震记录足够清楚，信噪比至少要1.5:1。

Reading Materials

(A) Seismic Reflection

Seismic reflection studies involve the input of shock wave energy into the ground, reflection of that energy from an appropriate interface and recording of the reflected waves on suitably located receivers called geophones. The time that elapses, in milliseconds, between the generation of the energy pulse and the arrival of the reflected ray at each geophone, allowing for the lateral distance between source and receiver, can be used to determine the depth of the reflecting horizon below the ground surface. If the reflection data are obtained from one or more traverse lines, and processed to improve the record quality, a profile indicating the subsurface structure is obtained.

Reflection studies are an essential part of most programmes in petroleum exploration, but seismic reflection has also proved to be vital to many coalfield investigations, where it is used both to delineate the broad structural features of a relatively large area and to map

out individual small-scale structures, such as faults, splits and washouts, that may disrupt mining operations. There is a considerable difference in scale, however, between the features of significance in the coal and the petroleum industries. Petroleum exploration is generally concerned with structures that are tens of metres in size and several kilometres below the ground surface, while coalfield geology mostly involves studies of structures less than 10 m in size, occurring at depths of less than 1 km. The reflected ray travel time for the features relevant to the coal industry is usually less than 1 s, and the techniques must be adapted accordingly.

With the equipment used in most studies, the distance between source and receiver is usually no more than the approximate depth of the reflecting horizon involved. Any geophones outside this range receive useable data only from lower beds in the sequence. This means that more individual spreads are required to cover each traverse line in coalfield studies, especially with shallow seams. The locations of the individual shots are also usually closely spaced, to allow each point in the subsurface to be covered several times (common depth point shooting) and hence enable improvements to be made in the quality of the record during the subsequent processing operation.

For most studies, the energy pulse is derived by detonation of an explosive charge, but weightdropping techniques or a vibratory tamper may be used as an alternative in some cases. Where the coal lies beneath a body of water, such as a lake, estuary or the sea, an air gun or an electric sparker device may be necessary. Details of the main techniques involved for land-based studies, including an outline of methods for processing the data obtained from the field are given by Daly and Hageman (1976) and Peace (1979).

Where high resolution is required, such as in studies to aid detailed colliery planning, it is also necessary to use only the high frequency or short wavelength components of the energy spectrum. Small charges (about 50g) of explosive materials represent the best energy source in these circumstances, but these suffer the disadvantage that the strength of the signal is relatively low compared to the level of ambient noise inherent in the seismic system. Special high frequency geophones and appropriate recording filters are used in this type of survey as well, to enhance the signal desired.

One of the main problems with any shallow seismic survey, and one that is of particular significance in high resolution studies, is the effect on the total travel time when the waves have to pass through a low velocity weathered zone near the ground surface. Variations in the thickness or velocity characteristics of this zone for each geophone station cause variations in the arrival time of the reflected ray. If not adequately allowed for by 'static corrections' in the processing operations, these variations may he misinterpreted as structural anomalies, such as folds or faults, in the reflecting horizon.

(*From Coal Geology and Coal Technology: Coalfield Exploration*, *pp* 184—187)

New Words and Expressions

1. shock [ʃɔk] n. 震动
2. input ['input] n. 输入
3. elapse [i'læps] n. (时间的) 过去；消失
4. washout ['wɔʃaut] n. 冲蚀地段
5. disrupt [dis'rʌpt] vt. 爆破；冲破
6. accordingly [ə'kɔ:diŋli] ad. 相应地；因此
7. detonation [detou'neiʃən] n. 爆炸
8. weight-dropping [weit-dʒɔpiŋ] n. 落锤法
9. tamper ['tæmpə] n. 夯；夯具
10. sparker ['spɑ:kə] n. 火花发生器；电火花震源
11. ambient ['æmbiənt] a. 周围的
12. inherent [in'hiərənt] a. 内在的；固有的
13. static ['stætik] a. 静态的；静的
    ~ corrections 静校正

(B) Seismic Field Operations

Field operations are conducted by a seismic crew, 2 to 3 in number where the refraction method for small depths is involved and running to several tens if the CDP method is being used. The operations follow a plan prepared in advance. The seismic profile is marked out by a survey team so that it is accessible to vehicles with drilling rigs and other equipment or vibrators. The profile must be marked on maps with sufficient accuracy to enable subsequent prospecting work to go ahead.

If the energy is provided by explosives, the charges are usually placed in boreholes, drilled below the low-velocity layer to depths of as much as 40 m. A safe distance must be kept between the shotpoints and certain objects (buildings, roads, mains, etc.). This problem is avoided if impacts, vibration methods or Dinoseis are used. In prospecting at shallow depths, surface blasting and impacts are used.

The geophones are distributed according to the measuring system being used and connected by cables with the station; the geophones are stuck into the ground, sometimes placed in shallow pits. If the geophone cannot be placed at a predetermined point. It can be moved perpendicular to the profile by a small distance; this relocation must be recorded.

The explosive charge is fired by the blaster under instruction from the observer; if vibrators are being used, or in surveys at sea. the energy excitation is controlled by the observer himself. With many seismic stations the shot moment and commencement of the motion of the carrier of the seismic record (magnetic tape) are synchronized. In the refraction method each geophone spread usually yields 4 to 6 records, in the reflection method 2 records. In the CDP method the spread is shifted forward by 1 to 4 geophone groupings after each shot and, therefore, there are 6 to 24 records per length of the spread.

After recording with one spread has finished, the geophones are relocated in the neighbouring spread. In the CDP method a larger number of geophone groupings is usually prepared along the profile, of which only n groupings are then used. After shooting, the last groupings of the spread (m groupings, usually 1 – 4) are disconnected and the same number is connected at the beginning. If a total of q shots (usually 1—2) is fired per set of n groupings, the *multiplicity of the coverage* P is determined by the equation

$$P=\frac{nq}{2m}$$

After recording, the seismic records are numbered and the most important data about them are included in the observer's log (pegging of the shotpoints and geophones, weight and depth of charge, degree of amplification, filtering and the other recording parameters, the data, number of records, etc.). These data are essential for further processing of the seismic records.

In seismic measurements conducted for studying shallow depths, direct digital recording of the arrival time of the signal with an accuracy of 10^{-4} s is sometimes used. The energy is provided by the impact of a hammer and the point of impact is gradually moved along the profile, whereas the recording geophone is kept stationary; this is a practical application of the interchangeability principle between the source and receiver. At other times a 12-or 24-channel station is used with a similar measuring procedure as in the standard refraction method.

In *seismic observations at sea* the hydrophone spread is usually pulled behind the ship on floats. The ship is kept to the profile by various semi-automatic or automatic navigation systems (e. g., radar, Shoran, Loran), operating ship-to-shore, or navigation satellites may be used. If the ship is moving at constant speed, the sources of seismic energy are used at regular intervals. Measurements at sea are very quick and several records can be obtained per minute. Sonar alone is used sometimes to record the times t_0 of the reflected waves. At sea we can use refracted (head) waves, besides the CDP method; in this case special buoys are employed to record the refracted waves.

(*From Introduction to Applied Geophysics: Seismic Methods*, *pp*440—441)

New Words and Expressions

1. crew [kru:] a. 成员（一组）
2. refraction [rɪf'rækʃən] n. 折射
3. CDP (common depth point) 等深度点
4. accessible [æk'sesəbl] a. 能进去的；易接近的
5. rig [rig] n. 钻架；装置；设备
6. vibrator [vaib'reitə] n. 振动器；振子
7. charge ['tʃɑ:dʒ] n. 炸药
8. main [mein] n. 管道（自来水，煤气）；干线（电，铁路）
9. impact ['impækt] vt. 冲击；碰撞；撞击
10. blast [blɑ:st] vi. 爆炸；爆破
11. stick [stik] vt. 钉入；插入；放置到
12. pit [pit] n. 坑；洼
13. commencement [kə'mensmənt] n. 开始
14. carrier ['kæriə] n. 载波
15. geophone ['dʒi (:) oufoun] n. 检波器（地震）
16. multiplicity [mʌlti'plisiti] n. 多倍；复合度；多重
17. coverage ['kʌvəridʒ] n. 所包括的范围；覆盖
18. log [lɔg] n. 工作记录
19. peg [peg] vt. 定界
20. amplification [æmplifi'keiʃən] n. 扩大；放大
21. filter ['filtə] vi. 滤波
22. interchangeability ['intə (:) tʃeindʒə'biliti] n. 可交换性；可交替性；互换性
23. sonar ['sounɑ:] n. 声纳
24. buoy [bɔi] n. 浮标
25. Dinoseis [dai'nəsaiz] n. 气爆震源
26. hydrophone ['haidrəfoun] n. 水中地震检波器
27. synchronize ['siŋkrənaiz] vt. 同时发生；同步

Lesson Twenty-two

Text

Geophysical well Logging

Geophysical well logging comprises a set of geophysical methods applied to the assessment of the physical properties of rocks and of fluids filling the borehole and pores and fractures of the rock, to the technical inspection of boreholes, and to the recognition of basic geological conditions in the rock complexes penetrated by drilling. Various technical and blasting operations are also often carried out by logging services. These operations are, for example, sampling of well fluids, testing of potentially productive zones, lateral core sampling, perforating of casing and cutting of casing, tubing and drill pipes.

Well logging is a young branch of applied geophysics; the first measurements of this kind were conducted in 1927 by Marcel and Conrad Schlumberger on an oil field in France. Since that time the methods and instruments applied have undergone intensive development. It can be said without exaggeration that well logging is the most comprehensive field of applied geophysics. It uses the principles of almost all methods used in geophysical surface surveys (magnetic, nuclear, geothermal, electrical and seismic) and additionally some procedures particular to drilling research. The latter involve measurement of borehole diameter, bearing and deviation of the borehole from vertical, the strike and dip of beds, the volumetric flow rate, and the like. Compared with geophysical surface survey, well logging has the advantage that the measuring devices contact the medium either directly (measurement of physical properties and movement of fluids in a borehole) or almost directly, i. e. the physical properties of rocks are examined through the drilling mud. The relatively precise data on the physical parameters of rocks and fluids thus obtained may then be used for the assessment of further data on mineral deposits (such as the content of the mineral or element studied, porosity of rock, hydrocarbon saturation, the volume of movable hydrocarbon); hydrogeological conditions (porosity, permeability, the content of dissolved solids in ground water, the yield of an aquifer); or geological features (e. g. the lithology of rocks, thickness of beds and their strike and dip).

No less significant is the contribution of well logging to correct interpretation of geophysical surface measurements on the basis of physical properties of rocks in natural conditions.

To carry out well log measurement, an exploratory borehole must be available. Since the measurement conditions in a borehole differ from ideal conditions (when the probe is

lowered into the rock itself), they will be discussed here in some detail.

An exploratory borehole is a hole, usually vertical (occasionally oblique), sunk into the upper part of the Earth's crust. The holes are made by percussion drilling (at present only exceptionally) or by the rotary method combined with continuous or intermittent coring. Any drilling intervenes with natural conditions of the rock, because the physical properties of the drilling mud differ greatly from those of the rock environment. A borehole is thus a factor which is prerequisite for well logging but which makes it difficult to determine the physical properties of rocks, the more so the larger its *diameter*. Therefore, nearly all well logs need to be complemented by caliper logs, i. e. by measurement of the true hole diameter. In sedimentary, jointed and tectonically disturbed rocks the conditions are still more complicated; the drilling mud, usually having a higher hydrostatic pressure than the ground water, penetrates ("invades") the permeable rocks and alters their physical properties in the immediate vicinity of the borehole walls.

As the electrical properties of permeable rocks change most markedly, they deserve particular attention. Let us suppose that the borehole met a permeable bed with resistivity ρ_s lying between two impermeable beds having a resistivity ρ_i. Since the hydrostatic pressure of the drilling mud is higher than that of ground water, the overpressure developed on the borehole wall forces the mud to enter the permeable bed. The wall behaves as a porous filter which only lets through the mud filtrate with resistivity ρ_{mf}; this expels ground water with resistivity ρ_w from the rock pores near the borehole wall (in the so-called *flushed zone*) and partly displaces the ground water from the pores in the more distant part of the formation, called the *invaded zone*. Thus the resistivity of the rock changes from the original value ρ_i to ρ_{xo} in the flushed zone and to ρ_i in the invaded zone. A mud cake having a resistivity ρ_m and a thickness h_m develops simultaneously on the borehole wall. The spatial distribution of the media and their resistivities and the geological factors are shown in Figure 337. It is to be noted that in *rocks saturated with hydrocarbons* only a part of pore space S_i in the uncontaminated zone is filled with ground water, the remaining part being filled with liquid or gaseous hydrocarbons. In the flushed zone the hydrocarbons are also not forced out from all pores of the rock (so-called residual oil saturation remains); water saturation in this part of the zone is labelled S_{xo}.

In the pelitic formations (claystones, siltstones) the changes in elastic properties occur along the borehole walls. Under the influence of drilling mud the clay mineral swell and the cohesion of the rock is reduced; a low-velocity zone forms along the borehole wall, being the more marked the longer the time interval between drilling and the moment of velocity measurement.

The electrical logging cannot be used in boreholes provided with casing and double-casing or in boreholes with cemented-in space between casing and borehole wall. In such an event other logging procedures also give strongly distorted results (e. g. different nuclear logs), which require corrections to obtain true values.

(*From Introduction to Applied Geophysics: Geophysical Well Logging*, pp474 -476)

New Words and Expressions

1. recognition [rekəg'niʃən] n. 识别
2. perforate ['pə:fəreit] vt. 穿孔；打眼
3. casing ['keisiŋ] n. 套管
4. tubing ['tju:biŋ] n. 管筒；敷设管道
5. cutting ['kʌtiŋ] n. 切；割；掘
6. drilling [driliŋ] n. 钻孔；钻井
7. percussion [pə:'kʌʃən] n. 冲击
8. prerequisite [pri:'rekwizit] n. 先决条件；前提
9. well-log [wel-lɔg] n. 测井
10. hydrostatic [haidrou'stætik] a. 流体静力学的
11. expel [iks'pel] vt. 排出
12. invade [in'veid] vt. 侵入
    invaded zone 侵入带
13. pelitic ['pelitik] a. 泥质的
14. uncontaminated [ʌnkən'tæmineitid] a. 没有污染的；未沾染的
15. swell (过去式 swelled，过去分词 swollen) vt. 增长；膨胀
16. siltstone ['siltstoun] n. 粉砂岩
17. claystone ['kleistoun] n. 粘土岩
18. filtrate ['filtreit] n. 滤液
19. permeability [pə:mjə'biliti] n. 渗透；渗透率

Note to the Text

No less significant is the contribution of well logging to correct interpretation of geophysical surface measurements on the basis of physical properties of rocks in natural conditions. 测井对在天然条件下，以岩石的物理特性为基础，对地面地球物理测量所做出的解释结果进行校正方面，也具有重要意义。

倒装句，主语为 the contribution of well logging。

Exercises

1. Questions for review:
   1) What can you do by using well logging?
   2) When were the first well-logging measurements made?
   3) What advantage does well-logging have compared with geophysical surface survey?
   4) What is the prerequisite factor for well logging?
   5) How many methods does geophysical well logging have?
2. Fill in the blank with the suitable conjuctives chosen from the following:
   as long as, as soon as, as well as, no matter, whatever, as if
   1) Concretions (结核) commonly show a concentric structure _____ made up of a series of concentric sphere.
   2) _____ the velocity of the stream is increasing, the load may also be increased.
   3) All metals, _____ many important nonmetals, are obtained from minerals in the rocks.
   4) _____ how the earth originated, it seems probable that either it was once much smaller than at present.
   5) _____ weather is, we will go out for field practice.

3. Give the Chinese/English equivalents for the following:

1) self-potential
2) lateral electric
3) resistivity logging with guard electrodes
4) microresistivity logging
5) logging cable
6) 渗透参数
7) 测井设备
8) 电流测井法
9) γ射线测井
10) 放射性同位素

4. Translate the following passage into Chinese:

The logging spectrometers have at present much wider application than mentioned above. In principle they can be used for all nuclear logs recording the gamma radiation, i. e. particularly for the gamma-gamma log both density and selective forms, neutron-gamma log, pulsed neutron log and the like. The use of logging spectrometers is a prerequisite in X-ray fluorescence logging. For this method, however, proportional counter are used as detectors because measurement is made in a region of very low energies.

5. Identify the one underlined word or phrase A, B, C or D that should be corrected or rewritten.

1) Little do (A) scientists know (B) about conditions on Uranus (C) and Neptune, two giant planet (D) in the solar system.

2) Only after local residents became (A) sick and publicly voiced (B) their displeasure the chemical company began (C) to clean up its (D) dump sites.

3) So far is Pluto (A) from the sun that it (B) has not completed a full revolve (C) around it since being discovered (D) in 1930.

4) Few inventors (A) have to their (B) credit as much (C) useful inventions as (D) Thomas Alva Edison.

5) Not until (A) recent (B) has interest in (C) synthetic fuels been (D) rivived.

6) Some teachers (A) always have (B) time enough (C) to answer their students (D) questions.

7) Scarcely (A) the injured man had arrived (B) at the hospital when (C) he rushed into the operation room (D).

8) The receptionist (A) inquired (B) whether I wanted (C) a magazine to read while I being waited (D).

6. Translate the following sentences into English:

1) 测井是用来确定岩石物理性质的一种地球物理方法。
2) 毫不夸张地说，测井是应用地球物理中最综合性的领域。
3) 测井在检验地面物探测量结果方面有着重要的意义。
4) 进行测井工作，必须具备勘探钻孔。
5) 和地面物探相比，测井的优势在于测量装置同介质直接或几乎直接接触。

Reading Materials

(A) The Method of Electrode Potentials (Eplog)

Minerals possessing electron conductivity (most sulphides except for sphalerite; magnetite, graphite and anthracite) behave similarly to noble metals, i.e. as metals having a positive self-potential. When such a mineral is inserted into electrolyte together with a metal electrode having a sufficiently negative self-potential (e. g. Fe, Zn), a considerable potential difference, called electrode potential, exists between them since a galvanic cell has developed with the electrode acting as cathode and the sulphide or oxide as anode.

This phenomenon is utilized for the identification of conductive minerals occurring in the borehole wall. A logging tool for measuring electrode potentials has two electrodes made of the same metal (Zn is most appropriate). One of them (M) in the form of a brush electrode slides over the borehole wall and the other, the reference electrode, consists of two rings (N_1, N_2) which do not contact the walls of the hole. The two rings are located symmetrically relative to the brush electrode and virtually exclude the effect of spontaneous potentials. The potential difference is measured between electrodes M and N. As long as the brush electrode touches the barren rock during the motion of the probe, there is only a very small constant potential difference between the electrodes, which is due to the heterogeneity of the electrode material. Once the brush electrode contacts an electron-conductive mineral (e. g. a sulphide), a marked potential difference arises. It is essentially a potential difference between the mineral and the reference electrode because the brush electrode merely provides a conductive connection. The drilling mud acts as an electrolyte. The electrode potentials measured in a borehole attain values of several hundreds of mV, and they are greater and more distinct in certain cases; the higher the negative self-potential of the electrode metal; the lower the ratio of the two electrode surfaces; the lower the pH of water in the borehole; and the lower the tool velocity ($v=0.04\text{ms}^{-1}$). The potential value is also controlled by the type of the conductive mineral, but this relation is of no practical use as most of the ore bodies are polymictic aggregates.

The EP curve outlines well a layer containing conductive minerals (predominantly ore minerals) and makes it possible to determine the thickness and structure of the ore body.

The possibilities for the measurement of natural electric fields are limited. This has led to the development of a number of logging methods based on the measurement of artificial electric fields on rocks penetrated by drilling. These methods are divided into five groups:

1. current logging which uses the differences in the rock conductivity;
2. resistivity logging which determines the formation resistivity.

This group comprises several variations, such as the resistivity log using a simple electrode arrangement including lateral electric sounding, focused-current logs, and analogous methods (laterolog 7 or laterolog-3, guard log), and microresistivity logs (microlog, micro

laterolog, proximity log);

3. induced polarization logging;

4. induction logging; and

5. dielectrical logging.

The theory of artificial electric fields is basically consistent with the theory of fields applied in surface geoelectrical surveys. It must be kept in mind that in downhole measurement the potential of a point current source will be at a given distance equal to half the potential of the same point source measured at the surface. This is because in well logging the whole space is involved, whereas a half-space is involved in a surface survey.

(*From Introduction to Applied Geophysics: Geophysical well Logging*, pp483- 485)

New Words and Expressions

1. sphalerite ['sfælərait] n. 闪锌矿
2. graphite ['græfait] n. 石墨
3. anthracite ['ænθrəsait] n. 无烟煤
4. electrolyte [i'lektroulait] n. 电解质；电解液
5. cathode ['kæθoud] n. 阴极；负极
6. anode ['ænoud] n. 阳极；正极
7. symmetrically [si'metrikəli] ad. 对称地；匀称地
8. spontaneous [spɔn'teinjəs] a. 自发的；自然的
9. distinct [dis'tiŋkt] a. 明显的；清楚的；与其它不同的
10. polymictic ['pɔlimiktik] a. 多级的；复成分的；复碎屑的；复矿的
11. aggregate ['ægrigit] n. 集合体
12. predominantly [pri'dɔminəntli] ad. 占优势地；突出地；最显著地
13. logging ['lɔdʒiŋ] n. 测井
    current ～ 电流测井
    induction ～ 感应测井
    resistivity ～ 电阻率测井
    dielectrical ～ 电介质测井
14. laterolog ['lætərəlɔg] n. 侧向测井
15. focuse ['foukəs] vt. 聚焦
    focused-current log 聚焦电流测井
16. analogous [ə'næləgəs] a. 类似的；相似的
17. guard [gɑ:d] n. 屏蔽
    ～ log 屏蔽测井
18. proximity [prɔk'simiti] n. 接近；邻近
    ～ log 邻近侧向测井

(B) Nuclear Logging Methods

The importance of nuclear logging methods is recently steadily increasing. Although they do not yet involve the whole series of methods used in laboratory, even the more sophisticated procedures are carried out increasingly in borehole conditions. The methods of nuclear logging are based on the same theoretical principles as those of nuclear physics, and most of the terms modes of nuclear radiation detection and the principles of individual methods have been explained in Chapter 3. We can therefore confine ourselves to the peculiarities of logging methods and chiefly discuss their application. The particular character of nuclear logging is given by the following factors:

The logging tool which carries a detector of nuclear radiation (of a natural field or of

the artificial field created by a source of nuclear radiation in the borehole) is virtually surrounded by the medium whose parameters are measured. In contrast to the surface field measurement, we make measurements in a medium where information is gathered equally from all directions.

The existence of a borehole and the presence of drilling mud in it as well as the change in borehole diameter and various types of casing produce considerable effects on the results of nuclear logging. Although many nuclear methods can be applied in cased boreholes, some of the measurements must be made in uncased boreholes, particularly where chemical or mineral composition of rocks is to be determined. Besides, almost all nuclear logging methods need to be complemented by a caliper log. In order to reduce the effect of disturbing inhomogeneities to a minimum, particularly the influence of drilling mud and of the change in borehole diameter, special measurements are made using probes pressed to the formation wall, either along their whole length or at least that of the detector and source of nuclear radiation (in active and activation methods). At the same time both the detector and the radiation source are effectively shielded against the mud. In some cases the nuclear radiation from an inset source is intentionally collimated into a given space along the borehole wall, and then towards the detector after interaction with the rock. This geometry of uncollided flux refines the accuracy of information and guarantees a better vertical resolution of the parameter studied, but the volume of the measured part of the formation and thus also the representativeness decrease.

The goal of nuclear logging is to provide a continuous documentation of physical properties and chemical composition of the rocks and pore fluids, of physical properties and chemical composition of the fluid filling the borehole, of the physical state of the borehole, the quality of casing, cementation and the like. Most of the measurements are carried out with a moving probe, point measurements (e. g. neutron activation analysis for some elements) are used exceptionally. The nuclear logging methods are at present applied either by themselves or combined with other logging techniques in drilling research of the most varied types (for oil, gas ores and non-metallic deposits, in regional, engineering-geological and hydrogeological investigations).

The basic instruments for nuclear logging are radiometers for the detection of gamma-rays or neutrons. They consist of a downhole probe and a surface panel. The downhole probe contains a detector of gamma radiation (GM tube, proportional counter or a NaI (Tl) crystal with a photomultiplier), a source of high voltage and an initial amplifier or a neutron detector (proportional boron counters or crystals or, recently, highly effective corona tubes filled with ^{3}He at a pressure of 0.4MPa) with associated electrical circuits. In addition, most downhole probes are provided with a special part to place the isotope source of gamma rays or of neutrons at various distances from the detector; the detector in a probe is effectively shielded against this source according to the type of radiation. It is time saving to measure at least two or even more parameters at one probe lowering. There

fore multi-channel probes are constructed, which enable a measurement of, e.g., three curves of gamma radiation in different energy regions, one curve of gamma radiation and one of neutron flux density, or two curves of neutron flux density with two different distances between the source and detector.

Further electric circuits for adjustment of the parameter measured are located in the surface panel. If total activity is measured, it holds one more amplifier, a circuit for pulse shaping and an integrator, the output of which is connected to a recording galvanometer. In instruments for spectral measurement the amplifier must maintain the ratio between the amplitudes of individual pulses. The next part of the electric circuit is then an amplitude analyser which makes it possible to choose the energy window, a pulse counter or again the integrating circuit with output to a galvanometer recorder.

There are three main types of nuclear logs: a) logs that detect natural gamma radiation of rocks, b) logs using artificial gamma ray sources, and c) logs employing artificial neutron sources.

(*From Introduction to Applied Geophysics: Geophysical Well Logging*, *pp*507 508)

New Words and Expressions

1. steadily ['stedili] ad. 稳定地
2. peculiarity [pikju:li'æriti] n. 独特性；特色；特质
3. detector [di'tektə] n. 探测器
4. radiation [reidi'eiʃən] n. 放射；辐射
5. gather ['gæðə] vt. 搜集；采集；使聚集；使聚拢
6. caliper ['kælipə] n. 测径器；井径
7. collimate ['kɔlimeit] vt. 瞄准；校准
8. uncollide ['ʌnkə'laid] vt. 不接触；不冲突；不抵触
9. flux [flʌks] n. 流量；通量
10. refine [ri'fain] vt. 精炼；提纯
11. documentation [dɔkjumen'teiʃən] n. 文件；文献
12. probe [proub] n. 探针；探头
13. exceptionally [ik'sepʃənli] ad. 特殊地；罕见地
14. inset ['in'set] n. 插入
15. intentionally [in'tenʃənli] ad. 有意地；故意地
16. interaction [intə'rækʃən] n. 相互作用；相互影响
17. photomultiplier [foutou'mʌltiplaiə] n. 光电倍增管
18. galvanometer [gælvə'nəmitə] n. 电流计
19. amplifier ['æmplifaiə] n. 放大器
20. panel ['pænl] n. 板面

Lesson Twenty-three

Text

Magnetic Methods

When placed in a magnetic field of given intensity, rocks develop a varying degree of magnetic polarization. The strength of this polarization depends principally on the magnetic susceptibility of the material concerned, which is in turn largely related to the abundance of specific components, such as magnetite or ilmenite, among the minerals present. Most sedimentary rocks have relatively low magnetic susceptibilities. The susceptibility of crystalline basement rocks tends to be somewhat higher, while mafic and ultramafic igneous bodies usually exhibit particularly high susceptibility values.

Except for rare examples of materials that have been struck by lightning, magnetic rocks have almost always acquired their polarization from the earth's magnetic field. In many cases, the effects have been induced by the field in existence at the present time, but if the rock was formed at a time when the field was differently oriented, or even reversed, the effects of that field may remain as 'remnant magnetism' in the material as well.

Differences in polarization of different rock masses give rise to local and regional anomalies in the earth's magnetic field. Magnetic methods are based on mapping out these anomalies, using ground-based, shipboard or aerial equipment to measure either the total intensity or the vertical component of the field at points across the study area. Allowance must be made for fluctuations or 'drift' in the earth's field with time, which may be the result of long-term (secular) or daily (diurnal) variations as well as short-term disturbances due to magnetic storms.

An airborne magnetic survey can be used in coalfield studies to map out the broad structural framework of a large exploration area. Such a survey depends on the existence of a contrast in magnetic properties between the basement rocks and the overlying sedimentary strata, and, if all else is equal, the results will generally reflect variations in the depth to crystalline material. It will not detect coal, but if a sedimentary or tectonic model is applied to the sequence in question, it may assist in delineating those sectors likely to have significant coal accumulations at a reasonable depth.

Ground or vehicle-borne magnetic surveys are more commonly used for closer investigations in coalfield exploration. They may be used to provide further information on basement-controlled geological structures, or to map out any bodies of mafic igneous materials, such as sills, dykes and lava flows, that occur within the area. The igneous bodies may act as markers for the sequence under investigation, and help to delineate the outcrop pattern

of the coalbearing units, or they may act as intrusions that locally increase the rank of the coal and, in some circumstances, increase the value of the material. More commonly, however, igneous intrusions form barriers to mine development, and even render seams completely unworkable over large areas due to replacement and cinder formation.

Broad, low-intensity anomalies in this case were found to be related to structural features, while smaller, more intense anomalies were associated with igneous intrusions.

Magnetic anomalies, usually of a smaller magnitude, may also be associated with the presence of fractured strata in joint zones and fault planes. The fractured rock may be preferentially mineralized by material of different susceptibility to surrounding strata, or else be leached of magnetic material, such as a ferruginous cement, by deeper weathering. In either event, they may show up as anomalies in detailed magnetic surveys. Like the igneous bodies, these structures can provide a barrier to mining, and their significance should be further evaluated as the programme proceeds.

In some areas, ground magnetic techniques can be used for the delineation of burnt zones that may develop due to *in situ* combustion of coal seams in their outcrop area. The burned-out coal bed, as well as some of the surrounding non-coal strata, may become strongly magnetized during the cooling process, and produce a significant local anomaly. This can be used to trace the outcrop of such seams, even where they have been heavily obscured by soil, talus or vegetation, and hence provide valuable data for field mapping studies. The technique can also be used to determine the extent of the burnt-out zone away from the outcrop, and assess the amount of otherwise mineable coal that has been destroyed in the combustion process.

Ground magnetic surveys for regional studies may be based on traverses along existing roads and other access routes in the area. For more detailed studies, however, especially over critical parts of colliery holdings, a surveyed system of intersecting traverse lines is necessary, with points of observation spaced 10—50m apart. Care should be taken in all cases to avoid observations at points where objects such as metal fences, railway tracks, power lines etc. are in the vicinity, as these can cause spurious results. Surficial ferruginous deposits such as laterite must also be taken into account. Magnetic surveying can be used in underground mines (Henderson 1967), but problems of interference from metallic features and electrical equipment may be significant limiting factors in these circumstances.

Because the number of corrections to be made is relatively small, the recording of magnetic data is a relatively simple process. However, the recognition and interpretation of individual anomalies is complicated by the fact that the orientation of the magnetic polarization in the rock, as well as its intensity, can play a part, and by the possibility that several anomalies from different sources may overlap in the field. As with gravity studies, the incorporation of all relevant geological data is vital to the success of the operation.

(*From Coal Geology and Coal Technology: Coalfield Exploration*, *pp*180—182)

New Words and Expressions

1. polarization [poulərai'zeiʃən] n. 极化
2. ilmenite ['ilminait] n. 钛铁矿
3. allowance [ə'lauəns] n. 允许；准许
4. fluctuation [flʌkrju'eiʃən] n. 波动；起伏
5. framework ['freimwə:k] n. 框架
6. diurnal [dai'ə:nl] a. 每日的；白天的
7. dyke [daik] n. 岩墙；岩脉
8. talus ['teiləs] n. 山麓；堆积
9. leach [li:tʃ] vt. 滤去；沥滤
10. ferruginous [fe'ru:dʒinəs] a. 铁的；含铁的

Note to the Text

…but if the rock was formed at a time when the field was differently oriented, or even reversed, the effects of that field may remain as remnant magnetism in the material as well. 但是，如果岩石是在地磁场方向不同，甚至倒转时形成的，则该地磁场的效应可能以剩磁的形式被保留下来。

Exercises

1. Questions for review:
   1) What does the strength of magnetic polarization depend on?
   2) What give rise to local and regional anomalies in the earth's magnetic field?
   3) What are the differences in the susceptibilities for different kinds of rocks?
   4) What can the magnetic method be used for?
   5) Why are the recognition and interpretation of individual anomalies complicated?
2. Choose the correct answer from alternatives:
   1) The earth's magnetic field is thought to be generated by which of the following:
      a. Electrical currents generated by convection in the core.
      b. Electrical currents generated by convection in the asthenosphere.
      c. Permanent magnetism of the mantle.
      d. Permanent magnetism of the core.
   2) Linear magnetic anomalies, which are observed to parallel the mid-oceanic ridges, have been correlated with the magnetic reversal time scale by:
      a. The directions of their magnetization.
      b. The sequence and relative widths of the individual anomaly bands.
      c. Matching of symmetrical bands on either side of the ridge.
      d. The intensities of their magnetization.
   3) In which of the following environments would a piece of basalt, cooled from 600℃, not acquire remanent magnetization:
      a. In a simple furnace, on the equator.
      b. In a simple furnace, at the north magnetic pole.
      c. Inside a coil through which DC tcurrent is flowing.

d. Inside a coil through which AC current is flowing.

4) Which of the following rocks would not retain remanent magnetism recording the direction of an ancient magnetic field:

a. Basalt b. Magnetite c. Quartzite d. Shale

5) Determination of the inclination and declination of remanent magnetism in rocks of a single age from one continent yields which of the following paleogeographic data:

a. Paleolatitude and paleolongitude.

b. Paleolatitude and evidence of rotation of the continent.

c. Paleolongitude and evidence of rotation of the continent.

d. Paleolongitude only.

3. Give the Chinese/English equivalents for the following:

1) 磁极方向 6) natural remanent magnetization

2) 磁异常 7) susceptibility

3) 磁化 8) ferromagnetic

4) 磁倾角 9) magnetic property of rock

5) 资料解释 10) direct problem of magnetometry

4. Translate the following paragraph into Chinese:

Magnetic property of rocks: A knowledge of the magnetic properties of rocks from the region in which a geophysical survey is to be carried out, is usually important for three reasons. First of all, it forms a basis for deciding whether it is expedient to use magnetic methods for solving a given problem and, if so, also forms a basis for selecting a suitable method of working. Secondly the interpreter draws the knowledge in evaluating the causes of observed magnetic anomalies. Finally, a more detailed study of the magnetic properties may in itself disclose important facts, e. g., about tectonics, structural geology, stratigraphy, the age of rocks and ores, about the conditions under which they were formed, about their genetic interrelationships, mineral composition, etc.

5. Rewrite the following sentences by putting the words in parentheses into the right order like the example:

Example: Seldom (you come across) bargain.

Seldom do you come across bargains.

1) Little (I expect) to meet you here.

2) Only in summer (it be) warm enough to swim in the sea.

3) Not until a long time afterwards (I find out) the truth.

4) Only by practicing every day (you can hope) to improve your English.

5) No sooner (the bell ring) than everyone rushed out of the room.

6) Hardly (you will find) such hospitable people in any other country.

7) Never again (I will stay) at that awful hotel.

8) Only if the weather stays fine (we will go) on a picnic.

5. Translate the following sentences into English:

1）磁场的规律变化或多或少是周期性的。

2）岩石的磁化率取决于铁磁性矿物颗粒的大小。

3）反演分析可直接应用于观察资料。

4）在有些情况下，有经验的解释人员可根据等值线的形态估计异常体的形状，

5）计算机技术被广泛应用于地面磁法的资料处理和解释。

Reading Materials

(A) Interpretation of Magnetic Anomalies

The essence of interpretation is the solution of the inverse problem of magnetometry: given the distribution of the anomalous potential or of its derivatives over a given surface we want to find the shape, position and dimensions of the disturbing body. However, the interpretation of anomalies does not mean just the solution of the inverse problem, but also determining the rock types and structures which are the cause of the anomalies. In interpreting, therefore, it is necessary to know not only the results of purely geophysical observations, but also the geology of the region and the magnetic properties of the rocks which occur in it. In contrast to gravimetry, where even quite extensive sections of gravity maps can he interpreted as a whole to obtain the required geological information because of the relatively low variability of densities (this is particularly the case in the geophysical study of the relief of the crystalline basement of sedimentary basins), the high degree of variability of the magnetic properties of rocks usually forces us to individual evaluation of magnetic anomalies.

In general, the solution of the inverse problem of magnetometry is ambiguous, as in gravimetry. With a view to the nature of real geological bodies it is , nevertheless, possible to determine some positional parameters, e. g., the distance from the Earth's surface to some of the characteristic points of the body, without making any assumptions about it.

The possibility of obtaining an optimum and likely determination of all required parameters (position, depth, shape, dimensions, magnetization) depends on the quality of existing geological and geophysical data on the body, which enter the solution as known constants, e. g., the shape, the depth of the upper or lower boundary, magnetization, data on penetrating bodies, etc. The more of these supporting data available, the smaller the number of unknown variables and the smaller the degree of ambiguity of the solution. In ordinary practical interpretation homogeneous magnetization is assumed as a basis. (The differential magnetization of the body M, defined in comparison with the ambient medium to which the normal field corresponds, is, of course, decisive for the generation and interpretation of the anomaly.)

A fast evaluation of a magnetic image (map), extensive in area, can be achieved by qualitative interpretation in which the situation of magnetically distinguishable geological

bodies is determined approximately in the map; by means of simple methods and rules, some characteristic elements of these bodies are estimated (approximate depth, direction, dip, depth range) and an opinion of their geological importance may also be presented. ') Quantitative interpretation, in which more detailed data on the determining parameters of the disturbing geological body are derived, sometimes using quite complicated procedures and computations, requires a detailed and accurate knowledge of the corresponding magnetic anomaly.

The simultaneous determination of the shape and other parameters (e. g., depth) using an analytical method causes difficulties; it is, therefore, usual to solve the problem of shape first and then solve the other problems.

In some cases an experienced interpreter may estimate the shape according to the configuration of the isoanomalies in the map of isolines or according to the curves of Z_a, H_a or $\triangle T$ in the profile map, considering also the geology of the region. The problem of finding a shape which fits can be solved by comparing the observed anomaly with the magnetic fields of bodies of a regular shape. The atlas of theoretical curves may serve this purpose. The probable shape of the body and the determining parameters can be established by finding the theoretical curve which agrees best with the curve observed along the characteristic profile.

Besides this method, which is based on the principle of best fit, there exist a number of other ways of solving the inverse problem, each of which has its advantages and disadvantages. Here, we shall only mention some of the better known methods, applied particularly to the simple anomalies.

(*From Introduction to Applied Geophysics: Magnetometric Methods*, *pp*130--133)

New Words and Expressions

1. interpretation [intəːpri'teiʃən] n. 解释；阐明
2. essense ['esns] n. 本质；实质
3. anomalous [ə'nɔmələs] a. 不规则的；异常的
4. derivative [di'rivətiv] a., n. 被引出的；派生的；导数；微商
5. gravimetry [græ'vimitri] n. 重力测定法
6. variability [vɛəriə'biliti] n. 变化性；变异性
7. relief [ri'lif] n. 地势的起伏
8. magnetometry [mægni'tɔmitri] n. 磁力测定法；磁法
9. optimum ['ɔptiməm] n. 最适条件；最佳条件
10. ambiguity [æmbi'gju (:) iti] n. 意义不明确；可作两种（或多种解释）
11. qualitative ['kwɔlitətiv] a. 定性的
    ~ interpretation 定性解释
12. quantitative ['kwɔntitətiv] a. 定量的
    ~ interpretation 定量解释
13. analytical [ænə'litikəl] a. 分析的；解析的
14. isoanomaly [aisouə'nɔməli] n. 等异常
15. isoline ['aisoulain] n. 等值线
16. atlas ['ætləs] n. 地图册
17. magnetization [mægnitai'zeiʃən] n. 磁化；磁化强度
18. characteristic [kæriktə'ristik] a. 特有的；独特的；表示特性的

(B) Field Measurement Procedures

Aeromagnetometry has been perfected technically to such a degree that it is capable of replacing land surveys on a regional scale in full. Because of its speed, resolution, economy, continuity of measurements, independence of accessibility of a region and of the possibility of filtering local magnetic effects by changing the flight altitude, it has become a highly efficient method in ore-mineral and oil prospecting, as well as in basic geological research. The high sensitivity of the modern airborne magnetometers, which allow anomalies with amplitudes of less than 1 nT to be recorded, has turned aeromagnetometry into a universal method usable in nearly all geological terrains, because the required differences in magnetization (larger than 10^{-2} A m^{-1}) can be measured even in sedimentary rocks.

The scale of the airborne survey is roughly determined by the geological purpose it is to be used for. In selecting the interval between the profiles and the flight altitude, we draw on certain assumptions about the size and depth of the magnetized bodies which are the objects of interest. For example, a survey on a scale of 1:500 000 (distance between profiles is 5 km) serves to delineate regional geological structures, a survey on a scale of 1:200 000 (distance between profiles is 2km) is conducted with the purpose of obtaining more accurate structural shapes and data on the relief of basin basements. The flight altitude depends on the circumstances and filtration intentions and, as a rule, varies between 1000 and 100 m; sometimes a constant flight altitude is preferred, at other times a constant relative altitude above the terrain is adopted. In more detailed and complex surveys, usual in ore prospecting, the flight is made as low as possible, respecting flight safety regulations (around 50 m). The largest scale which has been used in operation is 1:10 000 (distance between profiles is 100 m).

Marine magnetic measurements are mostly carried out within the scope of global geophysical research or prospecting for oil or natural gas, usually together with other kinds of measurements, e. g., gravimetric, seismic, bathymetric. Flux-gate, proton, atomic magnetometers as well as various types of gradiometers are used. The sensor, in a non-magnetic container, is fixed to a cable 150—300 m long (depending on the tonnage of the ship) and is trailed behind the vessel, most frequently at a depth of about 20m (fish).

The method of measuring and processing the data is analogous to that used in airborne surveys. Various systems of radiolocation, the Doppler-sonar system or satellite signals are used for navigation and determining the position. Detailed data on the variations of the geomagnetic field can be obtained if a variation recording buoy is set up in the middle of the surveyed region; otherwise, the variation pattern can be derived from simultaneous measurements with a magnetometer and a horizontal gradiometer. In general, magnetic measurements on seas are more tedious and as a rule provide less accurate maps of the anomalous field than airborne magnetic survey.

Magnetic land surveys now mostly involve detailed measurements. They are often conducted in areas, discovered by airborne surveys or anticipated geologically, where deposits may be expected, and for purposes of detailed geological mapping. The work is carried out using large map scales of 1∶1000 to 1∶10 000 according to a detailed project plan.

Two factors have the most disturbing effect on magnetic measurements: time variations of the geomagnetic field and the instrument drift.

A. If the demands on the accuracy of the measurements are not stringent, the approximate pattern of variations is usually determined together with the drift of the instrument (if any) by repeating observations at regular time intervals at a selected base station (BS), which must be located in an undisturbed magnetic field. If an extensive detailed survey is being conducted, it is useful to establish a network of base stations, suitably distributed over the surveyed area.

B. If high accuracy is required in the resultant magnetic maps, it is expedient to use a sensitive instrument with no drift and to record the variations at a variation station (VS) in the surveyed area with another instrument. Another good basis for corrections for variations are the variation records from magnetic observatories which, however, should not be too distant.

(*From Introduction to Applied Geophysics: Magnetometric Methods*, *pp*120—122)

New Words and Expressions

1. aeromagnetometry [ˈɛəroumægniˈtɔmitri] n. 航空磁测
2. sensitivity [sensiˈtɪviti] n. 灵敏度
3. accessibility [æksesiˈbiliti] n. 易接近性
4. bathymetric [bæθiˈmetrik] a. 测深法的；等深的
5. flux gate [ˈflʌks-geit] n. 磁通门
6. proton [ˈproutɔn] n. 质子
7. gradiometer [greidiˈɔmitə] n. 梯度仪
8. sensor [ˈsensə] n. 传感器，探头
9. radiolocation [reidioulouˈkeiʃən] n. 无线电定位
10. Doppler-sonar [ˈdoplə-sounə] n. 多普勒声纳
11. tedious [ˈtiːdjəs] a. 冗长乏味的；使人厌烦的
12. tonnage [ˈtʌnidʒ] n. 吨位；排水量
13. vessel [ˈvesl] n. 船
14. expedient [iksˈpiːdjənt] a. 有利的；方便的；便利的
15. stringent [ˈstrindʒənt] a. 严格的
16. anticipate [ænˈtisipeit] vt. 预期，期望

Lesson Twenty-four

Text

Gravity Anomalies

The values of the acceleration of gravity g include the effects of all masses within the Earth. The geometric figure of the Earth, the uneveness of its surface, as well as its composition and geological structure are responsible for the fact that the acceleration of gravity differs from place to place on its surface. In studying the structure of the Earth we are primarily interested in the effects of masses (rock complexes) distributed irregularly within the Earth, in particular in the Earth's crust. However, the effects of these masses on the values of the acceleration of gravity are obscured by effects due to other factors.

In applied geophysics, in order to emphasize the gravity effects of the irregular distribution of masses, we look at gravity anomalies, generally defined as the difference between the actual acceleration of gravity (observed at the Earth's surface) and its computed theoretical value. In calculating the theoretical value we adopt the normal acceleration of gravity g_n, the gravity effect of the reference ellipsoid with the same centre of gravity, total mass, axis and angular velocity of rotation as the Earth, as the basis. The values of the normal acceleration of gravity g_n are referred to the surface of the reference ellipsoid. However, the acceleration of gravity g is usually observed above (or, exceptionally, below) the surface of the reference ellipsoid (on the real Earth's surface). In order to be able to calculate the gravity anomaly both quantities must be referred to the same height. That is why we reduce the values of the normal acceleration of gravity g_n to the heigt of the point at which the gravity anomaly is being calculated.

The gravity anomaly Δg at point P may then in general be defined as

$$\Delta g\ (P) = g\ (P) - [g_n\ (P_o) + R\ (P)] = g\ (P) - g_n\ (P)$$

where $g\ (P)$ is the acceleration of gravity observed at point P, $g_n\ (P_o)$ is the value of the normal acceleration of gravity at point P_o which is located below (above) point P (on the surface of the reference ellipsoid at zero height above sea level), $R(P)$ is the gravity reduction, and $g_n(P) = g_n(P_o) + R(P)$ is the value of the normal acceleration of gravity reduced to the height of point P.

In applied geophysics we most frequently use the Faye reduction (free-air correction), the Bouguer reduction and the isostatic reduction. Depending on the reduction used, we distinguish between Faye anomalies, Bouguer anomalies and isostatic anomalies. The anomalies most frequently used in investigating the geological structure of the Earth's crust are

Bouguer anomalies.

If we are to reduce the normal acceleration of gravity $g_n \equiv g_n(P_0)$ to the height of point p, located at elevation h as if there were no masses (rocks) but only air between the surface of the reference ellipsoid and point P, the reduction term R_F (P) would be equal to the change of the acceleration of gravity δg. The Faye anomaly Δg_F will then be defined by the relation

$$\Delta g_F = g - g_n + 3.086h,$$

where $-3.086h - R_F$ represents the Faye reduction.

Thus, the Faye anomaly reflects the effect of anomalous masses within the reference ellipsoid and of all masses outside the reference ellipsoid (above the surface of reduction sea level).

The Faye reduction neglects the effect of all masses (rocks) located between the topographical surface of the Earth and the reference ellipsoid. The effect of these masses (its magnitude dependsion the distance of the topographical surface of the Earth from the reference ellipsoid), however, is contained in the value of the observed acceleration of gravity g. If we eliminate the effect of normal masses, located between the topographical surface and the reference ellipsoid (sea level-surface of reduction), from the Faye anomalies. We obtain Bouguer anomalies.

The Bouguer reduction does not eliminate the effect of masses which are located above the Bouguer plate but below the topographical surface, and which diminish the anomaly. Also we should subtract the effect of any non-existent masses between the upper surface of the Bouguer plate and the topographical surface, where the latter is below the level of point p, and thus diminish the anomaly further. If the area around point p is level, the error in calculating the Bouguer anomaly is negligible. If the topographical surface is uneven, however, We will find apparent negative anomalies in places where there are hills or valleys. That is why we introduce topographic corrections into the calculations of Bouguer anomalies, which eliminate the gravity effects of the uneven topographical surface——the terrain. The anomalies are then referred to as complete Bouguer anomalies or Bouguer anomalies with topographic correction.

(*From Introduction to Applied Geophysics; Gravimetric Methods, pp*9 11)

New Words and Expressions

1. uneveness [ˌʌn'i:vənis] n. 不平坦；崎岖
2. obscue [əbs'kjuə] vt. 使模糊；使不分明；遮掩
3. ellipsoid [i'lipsɔid] n. 椭面；椭球
4. Faye (free-air-correction) 自由空气校正
5. reduction [ri'dʌkʃən] n. 校正
6. Bouguer ['bugə] n. 布伽
   ～ anomaly 布伽异常
7. isostatic [aisou'stætik] a. 均衡的
   ～ reduction 均衡校正
8. diminish [di'miniʃ] vt. 减少；减小；缩减
9. uneven [ʌ'ni:vən] a. 不平坦的；崎岖的

Note to the Text

That is why we reduce the values of the normal acceleration of gravity g_n to the height of the point at which the gravity anomaly is being calculated. 这就是我们为什么把正常重力加速度值换算到计算重力异常的高度的原因。

Exercises

1. Questions for review:
   1) How many factors affect the values of the acceleration of gravity?
   2) What are the Faye anomalies?
   3) What are the Bouguer anomalies?
   4) What are the complete Bouguer anomalies?
   5) What are the normal acceleration of gravity?
2. Choose the correct answer from each alternatives:
   1) Recent uplifted, young mountain belts exhibit:
      a. Large positive Bouguer anomalies.
      b. Large negative Bouguer anomalies.
      c. Large negative free air anomalies.
      d. Zero Bouguer anomalies.
   2) Large positive Bouguer anomalies are typical of:
      a. Abyssai plains of the oceans.
      b. Continental shelves
      c. Deeply eroded, old mountains belts.
      d. Deep sediment-filled basins.
   3) The attraction of plumb bob toward the Himalayas is not as strong as the mass of these mountains would lead one to expect. Which of the following hypotheses could not explain this observation:
      a. The mountains consist of lighter-than-average crustal material.
      b. The mountains consist of light crustal material, and the crust is exceptionally thin.
      c. The asthenosphere beneath the mountains is hotter and less dense than elsewhere.
      d. Crustal material extends to great depths, displacing denser mantle material.
   4) Gravitational attraction at New Orieans is 979.324 gal, while at Minneapolis, almost 15°the north, gravity is 980.597 gal, which of the following factors cannot be said to contribute to this difference:
      a. Centrifugal force of earth's rotation is greater at New Orleans.
      b. Earth's radius (to sea level), is greater at New orleans.

c. The station at Minneapolis is 256 meters above sea level, the one at New Orleans is 2 meters above sea level.

d. 256 meters of rock stand above sea level at Minneapolis.

5) Which of the following does not play any part in the erosion of the moon's surface:

a. Cosmic rays　　b. Meterites

c. Gravity　　d. Wind blown sand

3. Put a check (√) beside sentenecs with correct word order and an (×) beside sentences with incorrect word order and correct the part that is wrong:

_____1) Such behaviour is not permitted in this classroom.

_____2) So tired the boy was that he fell asleep almost immediately.

_____3) Only at dusk on warm summer nights fireflies appear.

_____4) On the beach were large globs of oil lying.

_____5) So old the book was that its page had turned yellow.

_____6) Little do teenagers realize how much they have to learn.

_____7) Had the motorist been stopped by the police, he would surely have received a stiff fine.

_____8) Few and far between the gas stations are on this stretch of road.

4. Translate the following passgae into Chinese:

By observing the acceleration of gravity at various points on the earth's surface, it was found that systematic deviations in the values of the Bouguer anomalies occur in some regions. In ocean areas the values of the Bouguer anomalies are usually larger than one would expect from mass deficits in the earth's crust and, in contrast, in regions of extensive mountain ranges the Bouguer anomalies are smaller than expected. These deviations can only be explained by irregular distribution of masses in the upper layers of the earth. Consequently, two hypotheses of isostatic compensation of masses in the earth's crust were developed nearly simultaneously.

5. Give the Chinese/English equivalents for the following:

1) the acceleration of gravity　　6) 布伽异常

2) isostatic correction　　7) 绝对重力观测

3) gravimetric survey　　8) 扭力矩

4) processing of gravity measurements　　9) 平均密度

5) prior to commencing field measurements　　10) 重力基点

6. Translate the following sentences into Chinese:

1) 重力强度的变化可归之于若干种原因。

2) 地球物理方法可以分为五种主要方法。

3) 假如没有重力，地球周围就没有空气。

4) 重力观测能够在地下、钻孔和矿井中进行。

5) 重力异常地质解释的目的是给出异常的地质意义。

Reading Materials

(A) Field Measurements and Their Processing

Gravimetric surveys may essentially be divided into three stages. The first stage covers the preparatory work, the second stage the field measurements and the third the interpretation or the geological explanation of the observed gravity anomalies.

As part of the preparation for gravity observations it is necessary to become acquainted with the geological problem to be solved, with the geological structure of the area of interest. We must study in detail the results (including information on the physical properties of rocks) of all geophysical projects which have already been undertaken in the area of interest, evaluate them with regards to the task to be undertaken and prepare proposals for geophysical (gravimetric) measurements.

The preparation of gravity observations itself includes the preparation of suitable topographic data, data on the reference points of the national levelling net and gravity acceleration data at points of the national gravimetric net. An important part of the preparatory work is the preparation of geodetic instruments and particularly of the gravity meter, which must be adjusted and calibrated at the beginning and end of the observation season.

Prior to commencing field measurements it is necessary to inform the landowners and the appropriate authorities of the type and purpose of the planned geophysical work in the appropriate area and to request permission for access.

In field measurements either individual gravity stations (regional survey), or stations on gravity profiles or nets (detailed survey-microgravimetry) are decided upon in the area of interest and their positions are plotted on topographical maps on a scale of 1:10 000, 1:5000, or on even smaller scales. Each point is surveyed for gravity, as well as altitude and sometimes position.

The heights of gravity points are determined by levelling. Each levelling traverse must be connected at each end either to the national levelling network, or to the points of an auxiliary altitude network, surveyed by accurate levelling. The admissible mean error of altitude measurements in regional gravity survey is $m = \pm 0.1$m, in detailed survey $m = \pm 0.02$m.

Gravity measurements carried out by gravity meters must be connected to points of the national gravimetric network. Each gravity traverse must be connected at the beginning and end of the measurements to the same gravity base point. If the measurement is to take longer than 5 hours, it is necessary also to connect the gravity traverse to the gravity base point in the middle of the traverse. Should the density of the points of the fundamental (national) gravimetric network be insufficient for the gravity measurements being carried out, it is necessary to survey an auxiliary supporting gravimetric network. In order to keep a record of the gravity meter drift, measurements at 10% to 15% of the points are repeated

at 2 to 3 hour intervals. In very accurate and detailed surveys (miciogravimetry) it is advisable to repeat these measurements every half hour.

In order to determine the mean error of the measurements, independent observations are carried out at check points (at least at 10% of all surveyed gravity points). This error must not exceed $\pm 0.5\mu m\ s^{-2}$ in regional surveys and $\pm 0.2\mu m\ s^{-2}$ in detailed surveys.

Data on the gravity measurements are recorded in a gravity log book or on a special form. The heading of each gravity traverse record must give the survey area, the date, the type and manufacturer's number of the gravity meter used, its constant and the name of the operator. The number (stationing) of the point, the height of the stand (provided it was measured), the time of the observation and at least two readings of the gravity meter, possibly also the average of the readings (in detailed and accurate gravity surveys at least three) must be recorded at each point.

By processing of gravity measurements we mean the computation used to convert the initial data recorded in the field, into a graphical representation of the anomalous gravity field (profile or map of complete Bouguer anomalies, or a map of derived fields). In the course of the processing, therefore, we convert the reading of the gravity meter, in divisions, by multiplying it by the gravity meter constant into a reading in $\mu m\ s^{-2}$, we eliminate the effect of tidal variations and of the gravity meter drift and calculate the acceleration of gravity at the individual points. Using Equation (1.21) we then calculate the value of the complete Bouguer anomalies Δg.

The processing of gravity measurements is very demanding and the manual processing very tedious. All computational operations are now being carried out by suitable desk calculators or computers.

(*From Introduction to Applied Geophysics: Gravimetric Methods, pp*35—36)

New Words and Expressions

1. levelling ['levəliŋ] n. 水准测量；测平；整平 national ~ net 国家水准测量网
2. geodetic [dʒi:ou'detik] a. 大地测量学的
3. calibrate ['kælibreit] vt. 校准；使标准化；使合标准
4. commence [kə'mens] vt. 开始；倡导
5. altitude ['æltitju:d] n. 高；高度
6. auxiliary [ɔ:g'ziliəri] a. 辅助的；附属的；从属的
7. admissible [əd'misəbl] a. 可采纳的；可接受的
8. initial [i'niʃəl] a. 最初的；开始的
9. acceleration [ækselə'reiʃən] n. 加速度；加速作用
10. stationing ['steiʃəniŋ] n. 测站
11. advisable [əd'vaizəbl] a. 适当的；可取的
12. microgravimetry ['maikrougrævimitri] n. 微重力测量

(B) Interpretation of Gravimetric Observations

The interpretation of the anomalous field is a process by which we determme the causes or sources of the individual anomalies. The purpose of geological interpretation is to give a ge-

ological meaning to the anomalies with due regard to the geological structure of the area under investigation. In applied gravimetry we distinguish between two ways ofinterpreting the anomalous gravity field: qualitative and quantitative.

Qualitative interpretation consists in simply describing and explaining the anomaly geologically on the basis of geological and geophysical knowledge and particularly on the basis of experience as to what anomaly (shape and magnitude) a certain object (anomalous body, density boundary, etc) may generate. In this way we obtain an idea of the pattern of geological structures and tectonic lines as well as of the places where rocks with a high or low density are concentrated. Reduction using accurate rock densities is required for this purpose, however, practically no further calculations are required with this method of interpretation.

In quantitative interpretation the dimensions, shape, depth and mass of an anomalous object are determined from the observed gravity anomalies. The data we obtain are, understandably, only approximate, because we are deriving several unknown quantities which, as we shall see later, are inter-related from a single quantity, the gravity anomaly. In quantitative interpretation we introduce the terms direct and inverse problems of gravimetry.

By the direct problem of gravimetry we understand the calculation of the gravity effects (the first and higher derivatives of the gravity potential) of a model of an anomalous body of known dimensions, shape, density and depth (position). If a homogeneous body (ρ=const) of regular geometric shape (sphere, cylinder, plate, step) is involved, the direct problem is solved by means of precise analytical methods. With bodies of irregular shape we use approximate integration procedures on which graphical aids or computer programs have been developed. The direct problem is unique.

By solving the inverse problem of gravimetry we seek to determine the shape, dimensions and depth (position) of a disturbing body responsible for a known anomaly. This problem is not unique. The ambiguity of its solution lies in the realization that various combinations of the spatial distribution of anomalous masses and their densities can generate the same anomalous gravity field. In the interpretation we usually make certain assumptions about the geometric shape of the anomalous body (we compare it, for example, with a sphere) and about its density, which need not conform to reality.

The observed anomalous field is an image of the effects of all masses. Individual anomalies differ in magnitude, they have different wavelengths. Extensive anomalies, with large wavelengths, correspond to extensive and frequently deep-seated geological structures, whereas anomalies of small areal extent, with small wavelengths, correspond to small and subsurface bodies. Quantitative gravimetric interpretation can only yield good results if the anomaly being interpreted is caused by a single disturbing body, or at least by anomalous masses of one type. It is, therefore, convenient to separate the individual anomalous components for purposes of interpretation. By separating the individual components, i. e. by filtering the observed anomalous field we obtain derived fields.

In geophysics it is usual to refer to three-and two-dimensional bodies. A three dimensional body is a body which has finite dimensions in all directions (in the directions of the co-ordinate axes x, y, z) A two-dimensional body has an infinite dimension in the direction of the horizontal y-axis and, therefore, two dimensions in the vertical xz-plane are sufficient to describe it. Practically every body whose dimension in the direction of the y-axis is 3 to 5 times larger than its depth may be considered a two-dimensional body. The solutions of the direct and inverse problems for two-dimensional bodies are substantially simpler and, therefore, more useful in many cases of interpretation.

(*From Introduction to Applied Geophysics, Gravimetric Methods, pp*37—38)

New Words and Expressions

1. graphical ['græfikəl] a. 图解的；图示的
2. unique [ju (:) 'nik] a. 唯一的
3. dimensional [di'menʃənəl] a. 维的
   two ～ 两维的
4. conform [kən'fɔ:m] vt. 使一致；使符合
5. investigation [investi'geiʃən] n. 调查；研究

Vocabulary

A

abate [ə'beit] v. 减少 3T
abrasive [ə'breisiv] a. 研磨的 n. 磨料 2R
abstract [æb'strækt] vt. 抽出，取出，提取 16RA
abstraction [æb'strækʃən] n. 退流，提取，引出 16RA
abyssal ['əbisəl] a. 深渊的，深不可测的 ~ plain 深海平原 1R
accelerate [æk'seləreit] v. 加速，促进，加快 17RA
acceleration [ækselə'reiʃən] n. 加速度；加速作用 24RA
accessible [æk'sesəbl] a. 能进去的；易接近的 21RB
accessibility [æksesi'biliti] n. 易接近性 23RB
accessory mineral [æk'sesəri minərəl] 副矿物 3R
accordingly [ə'kɔ:diŋli] ad. 相应地；因此 21RA
accretion [ə'kri:ʃən] n. 增加，增大 16RA
accuracy ['ækjurəsi] n. 精确，准确度 5R
acidity [ə'siditi] n. 酸度，酸性 3T
acoustic [ə'ku:stik] a. 声的 21T
act as 充当，起…作用 15RB
actinomycete [æktinou'maisi:t] n. 放线菌类 9RB
adaptation [ædæp'teiʃən] n. 适应，适应性的变化 4T
addition to 增加 16T
admissible [ədmisəbl] a. 可采纳的；可接受的 24RA
admixture [əd'mikstʃə] n. 混合；混合物 10T
advancing [əd'vɑ:nsiŋ] n. a. 前进式开采 12RA
adventitious [ædventiʃəs] a. 外来的；不一定的 10T
adverse ['ædvə:s] a. 逆的，相反的 17RA
advisable [əd'vaizəbl] a. 适当的；可取的 24RA
aeration [eiə'reiʃən] n. 通风；通气；充气 7T
aerial ['ɛəriəl] a. 航空的；空气的
aerial photograph 航摄照片 11RA
aerobic [ɛə'rəubik] a. 喜氧的 9T
aeromagnetometry ['ɛəroumægni'tɔmitri] n. 航空磁测 25RB
afforestation [æfɔris'teiʃən] n. 造林 17RA
agate ['ægət] n. 玛瑙 2T
aggregate ['ægrigit] n. 集合体 18RB
agronomist [ə'grɔnəmist] n. 农业专家，农学家，农艺师 13R
agronomy [ə'grəunəmi] n. 农（艺）学，作物学 17RB
aim at 瞄准，指望 18RB
airborne ['ɛəbɔ:n] a. 空中的；气载的；空运的 11T
aircraft [ɛə-'krɑ:ft] n. 航空器；飞机 20T
alabaster ['æləbɑ:stə] n. 雪花石膏 2R
albite ['ælbait] n. 钠长石 2T
algae ['ældʒi] n. (alga ['ælgə] 的复数) 藻类 4T
alginite [ælginait] n. 藻类体 10RA
alicyclic [æli'saiklik] a. 脂环族的 9RB
alien ['eiljən] a. 相异的；不相容的 6R
aliphatic [æli'fætik] a. 脂肪族的 9RB
alkalinity ['ælkə'liniti] n. 碱度，碱性 3T
allochthonous [ə'lɔkθənəs] a. 外来的；移置的 7T
allowance [ə'lauəns] n. 允许；准许 23T
alluvial [ə'lu:viəl] a. 冲积的 7T
alluviate [ə'lu:vieit] v. 冲积 7T
alluvium [ə'lu:viəm] n. 冲积物；冲积层 12T
almandite ['ælməndait] n. 铁铝榴石 2R
alter ['ɔ:ltə] vt. 改变；改动 1T
altitude ['æltitju:d] n. 高；高度 24RA
aluminophosphate [ə lju:minəu'fɔsfeit] n.

铝磷酸盐 10RB
aluminosilicate [əˈluːminəu silikit] n. 铝硅酸盐 2T
ambient [ˈæmbiənt] a. 周围的 12RA
ambiguity [æmbiˈgjuiti] n. 多义性；二重性 10T
ambiguous [æmˈbigjuəs] a. 可能有两种或多种解释的；意义不明确的 19T
ameliorate [əˈmiːljəreit] v. 改良；改善；变好 12T
ammonia [əˈməuniə] n. 氨 9T
amorphous [əˈmɔːfəs] a. 无定形的，非晶质的 2R
amphibian [æmˈfibiən] n.，a. 两栖动物，两栖类的 5T
amphibole [ˈæmfibəul] n. 闪石 2T
amphibolite [æmˈfibəulait] n. 闪石 16T
ample [ˈæmpl] a. 足够的；充分的；宽大的 1T
amplification [æmplifiˈkeiʃən] n. 扩大；放大 21RB
amplifier [ˈæmplifaiə] n. 放大器 22RB
anaerobic [ə neiəˈrɔbik] a. 厌氧的 9T
analogy [əˈnælədʒi] n. 比拟；类推 1R
analogous [əˈnæləgəs] a. 类似的；相似的 22RA
analytical [ænəˈlitikəl] a. 分析的；解析的 23RA
anastomose [əˈnæstəməuz] v. 网结 8R
ancestor [ˈænsistə] n. 祖先 4R
anchor [ˈæŋkə] v. 加固，使固定，粘连 18RA
Andes [ˈændiz] n. 安第斯山脉（南美洲） 6R
andesine [ˈændiziːn] n. 中长石 3R
andesite [ˈændizait] n. 安山岩 3R
angiosperm [ˈændʒiəuspəːm] n. 被子植物 9RB
anhydrite [ænˈhaidrait] n. 硬石膏 10RB
anisotropy [ænaiˈsɔtrəpi] n. 各向异性 9RB
ankerite [ˈæŋkərait] n. 铁白云矿 10RB
annual rainful 年降雨量 18T
anode [ˈænoud] n. 阳极；正极 22RA
anomaly [əˈnɔməli] n. 异常 9RB
anomalous [əˈnɔmələs] a. 不规则的，异常的 23RA
anomalously [əˈnɔmələsli] ad. 异常地 9RB
anorthite [əˈnɔːθait] n. 钙长石 2T
anorthosite [æˈnɔːθəsait] n. 斜长岩 3R
Antartica [ænˈtɑːtikə] n. 南极洲 4R
anthracite [ˈænθrəsait] n. 无烟煤 9T
anticipate [ænˈtisipeit] vt. 预期；期望 23RB
anticlinal [ˈæntiˈklainl] a. 背斜的
～ limb 背斜翼 15T
anticline [ˈæntiklain] n. 背斜 19R
antique [ænˈtiːk] a. 自古就有的；古时的 6R
apatite [ˈæpətait] n. 磷灰石 10RB
aphanitic [æfəˈnitik] a. 隐晶质；非显晶质的 3R
apparatus [æpəˈreitəs] n. 仪器；设备；装置 20R
appreciable [əˈpriːʃiəbl] a. 可估计的 14T
aquatic [əˈkwætik] a. 水生的；水的 7T
aquiclude [ˈækwiklu:d] n. 隔水层 15T
aquifer [ˈækwifə] n. 含水层 14T
aquifuge [ˈækwifjuːdʒ] n. 不透水层 14T
aquitard [ˈækwitəd] n. 弱含水层 15T
arbitrary [ˈɑːbitrəri] a. 任意的；随机的；不定的 13R
Archaeozoic [ɑːkiəˈzəuik] n.，a. 太古代（的），太古界（的） 5
arenite [ˈærənait] n. 砂岩 8R
argon [ˈɑːgɔn] n. 氩 1T
arid [ˈærid] a. 干旱的；贫瘠的 20R
aridity [æˈriditi] n. 干旱 2R
arise [əˈraiz] vi. 发（产）生，上升，出现 17RA
aromatization [ərəumətaiˈzeiʃən] n. 芳香化 9RB
array [əˈrei] n. 排列 20T
artesian [ɑːˈtiːzjən] a. 自流的
～ aquifer 自流水含水层；承压含水层 15T
articulate [ɑːˈtikjulit] v.（用铰链）连接
articulated roof bar 铰链顶梁 12RA
as a consequence 因此 18T
as expected 不出所料；正如预料的一样 18RA
as to 就…而论；说到；至于 18RB
ascertain [æsəˈtein] vt. 确定，查明 18RB
assess [əˈses] vt. 估价；评定 16RB
assign [əˈsain] vt. 确定，给定 16T
assimilate [əˈsimileit] v. 吸收 18T
assimilation [ə simiˈleiʃən] n. 吸收；同化融合 11RB
asthenosphere [æˈθenəsfiə] n. 软流圈 1R
astronaut [ˈæstrənɔːt] n. 宇宙航行员 1T

asymmetric [æsɪ'metrɪk] a. 不对称的 8T
at right angles to 与…成直角；与…垂直 16T
atlas ['ætləs] n. 地图册 23RA
atmosphere ['ætməsfɪə] n. 大气；大气层；空气 1T
attain [ə'tein] v. 达到，获得 15RB
attrital layers 杂质层 10RA
auger ['ɔ:gə] n. 麻花钻；螺旋钻 9RA
augite ['ɔ:dʒait] n. （普通）辉石 2T
augment [ɔ:g'ment] v. 增长；增加；扩大 7T
aulacogen ['ɔ:ləkədʒən] n. 断陷槽 8T
aureole ['ɔ:rɪəul] n. 接触变质带 9RB
authigenic [ɔθi'dʒenik] a. 自生的 7T
autochthonous [ɔ:'tɔkθənəs] a. 原地的 9RA
auxiliary [ɔ:g'ziliəri] a. 辅助的；附属的；从属的 24RA
availability [əveilə'biliti] n. 可用性，使用价值，有效率 17RB
avenue ['ævinju:] n. 通道 17T
awesome ['ɔ:səm] a. 可畏的 1R
azure ['æʒə] a. 天蓝色的；蔚蓝的；无云的；晴空的 1T

B

back-barrier ['bæk-'bærɪə] n. 坝后 7R
backboned animals 脊椎动物 4T
bacteria [bæk'tɪərɪə] n. 细菌，bacterium 的复数 16RB
bacteriological [bæk-tɪərə'lɔdʒikəl] a. 细菌（学）的 16RB
barometric [bærə'metrik] a. 气压（计）的 1RA
basalt ['bæsɔ:lt] n. 玄武岩 3R
base flow 底流，基流，基本径流 16RA
base map 底图；工作草图 11RA
basinwise ['beisn'waiz] a. 盆地内的 17RB
bassanite ['bæsənait] n. 烧石膏 10RB
batholith ['bæθəliθ] n. 岩基 3R
bathymetric [bæθi'metrik] a. 测深法的；等深的 3RB
bauxite ['bɔ:ksait] n. 铝土矿 18T
be marked by… 以…为标志；以…为特征 5T
be overlain by 上覆为 15RA
be related to … 与…有关（的） 16RA
be restricted to… （只）限于…，被限制在… 16RA
be worn away 被剥蚀掉 5T
bear out 证实；证明 18T
bearing ['beəriŋ] n. 意义；关系 19R
bedding-plane ['bediŋ'plein] n. 层面 12T
bedrock ['bedrɔk] n. 基岩 12T
bedsets ['bed'sets] n. 岩层组 5R
below-normal 标准以下的 18RB
biblical ['biblikəl] a. 圣经的；出于圣经的 6R
biearbonate [bai'kɑ:bənit] n. 碳酸氢盐 3T
bifurcate ['baifə:'keit] v. 分流；分叉；分枝 8R
biochemical ['baiou'kemikəl] a. 生物化学的 3T
biogenic ['baiou'dʒenik] a. 生物所产生的，生命活动所必需的 3T
biotite ['baiətait] n. 黑云母 2T
bit [bit] n. 钻头
roller bit 牙轮钻头
blade bit 翼状钻头 11T
bituminite [bi'tju:minait] n. 沥青质体 10RA
bivalve ['bai'vælv] n. 双壳类动物 11RA
bizarre [bi'zɑ:] a. 希奇古怪的，异乎寻常的 17T
Black Hills 布莱克山（美国） 15RB
blast ['blɑ:st] vi. 爆炸；爆破 21RB
block [blɔk] n. 块，断块，岩块，块段，地块 5R
blowout ['blou'aut] n. 井喷；爆裂 12RB
bog [bɔg] n. 沼泽；沼地 4T
boggy ['bɔgi] a. 沼泽的 3T
boghead ['bɔghed] n. 藻煤 10RA
boom miner 悬臂式联合掘进机 12RA
bord and pillar method 房柱采矿法 9RA
borehole ['bɔ:həul] n. 钻孔 11T
boron ['bɔ:rɔn] n. 硼（B） 16RB
Bouguer ['baugə] n. 布伽
~ anomaly 布伽异常 24T
bouhd by 以…为界，受…限制 5R
brackish ['brækiʃ] a. 稍咸的 7R
break [breik] n. 间断，断裂
break apart 裂开 5T
breccia ['bretʃə] n. 角砾岩 6T

bricklike nature 类似砖的性质 18T
brine [brain] n. 盐水，咸水 2R
bring on 引起 5T
bring under 控制，纳入（…之下） 16RA
brush vegetation 灌丛植物 18T
bulk [bʌlk] n. 容积（量），大部分 13T
bulldozing [bul'douziŋ] n. 推土 6R
bump [bʌmp] n. 岩石突出
pressure bumps 岩爆
shock bumps 冲击地压 12RB
buoy [bɔi] n. 浮标 21RB
burst [bə:st] v. 爆炸，爆发 13R

C

cable-tool drilling 钢绳冲击式钻进 11T
calcite ['kælsait] n. 方解石 2R
calibrate ['kælibreit] vt. 校准；使标准化；使合标准 24RA
caliche [kə'li:tʃi] n. 钙结层，钙积层，生硝 18T
caliper ['kælipə] n. 测径器；井径 22RB
calorific [kælə'rifik] a. 热量的；生热的 9RB
Cambrian ['kæmbriən] n.，a. 寒武纪（的），寒武系（的） 5T
cannel [kænl] n. 烛煤 10RA
canopy ['kænəpi] n. 顶梁；顶盖 12RA
canyon ['kænjən] n. 峡谷 18RA
capillary [kə'pilərɪ] n.，a. 毛细管，毛细作用的
capillary fringe 毛细作用带 14T
capture stream-flows 袭夺河 17RA
carbonaceous [kɑ:bə'neiʃəs] a. 碳质的；含碳的 12T
carbonic [kɑ:'bɔnik] a.（含）碳的
～ acid 碳酸 17T
Carboniferous [kɑ:bə'nifərəs] n.，a. 石炭纪（的）；石炭系（的） 5T
Carlsbad Cavern 卡斯巴洞穴 17T
carrier ['kæriə] n. 载波 21RB
casing ['keisiŋ] n. 套管 22T
catalyze ['kætəlaiz] v. 催化 9RA
catastrophe [kə'tæstrəfi] n. 大灾难；大祸；灾祸 18RA
catchment ['kætʃmənt] n. 汇集；汇水
catchment area 汇水面积；集水面积 16RA
cathode ['kæθoud] n. 阴极；负极 22RA
cation ['kætaiən] n. 阳离子；正离子 2T
cavern ['kævən] n. 洞穴；山洞 2R
caving ['keiviŋ] n. 崩落；崩落采矿法 12RA
CDP (common depth point) 等深度点 21RB
cellular ['seljulə] a. 细胞状的；多孔的；蜂窝状的 7T
cementation [si:men'teiʃən] n. 胶结作用 3T
cementing [si'mentiŋ] a. 胶结的；粘结的 16
Cenozoic [ˌsi:nə'zəuik] n.，a. 新生代（的）；新生界（的） 5T
chalcedony [kæl'sedəni] n. 玉髓 2T
characteristic [kæriktə'ristik] a. 特有的；独特的；表示特性的 23RA
charge ['tʃɑ:dʒ] n. 炸药 21RB
chart ['tʃɑ:t] vt. 用图表表示 6R
chasm ['kæzəm] n. 断层；裂口；峪谷；深渊 6R
chert [tʃə:t] n. 燧石；黑硅石 2T
chloride ['klɔ:raid] n. 氧化物 16RB
chlorite ['klɔ:rait] n. 绿泥石 2R
chronostratigraphic [ˌkrɔnəstrætigræfik] a. 年代地层的 5R
cinder ['sində] n. 火山渣 20R
circulate ['sə:kjuleit] v.（使）循环，环流 15RB
cite [sait] vt. 引用；引证；引述；列举 17RB
clam [klæm] n. 蛤 1R
clan [klæn] n. 宗派；族；类 3R
clarian ['klærin] n. 亮煤 9T
clast [klæst] n. 碎屑 8R
clastic ['klæstik] a. 碎屑状的 3T
clayey ['kleii] n.，a. 亚粘土；粘土质的 9T
claystone ['kleistoun] n. 粘土岩 22T
cleat [kli:t] n. 割理（煤层）；内生裂隙 7R
cleavage ['kli:vidʒ] n. 解理，劈理，劈开 2T
cleave [kli:v] vt. 劈；劈开 1R
coal-bearing ['kəul'beəriŋ] a. 含煤的 11RA
coalification [kəulifi'keiʃən] n. 煤化作用 9T
coalification jump 煤化作用跃变 10T
cobble ['kɔbl] n. 大砾 8R
coeval [kəu'i:vəl] a. 同时代的；同时期的 3R

coexist [ˌkəuigˈzist] v. 共存；共处 7R
coherent [kouˈhiərənt] a. 紧凑的；连贯的；表达清楚的 6R
cohesion [kəuˈhiːʒən] n. 粘性，凝聚力 18RA
coin [kɔin] vt. 造（新词等） 15RB
coliforms [ˈkɔlifɔːmz] n. 大肠杆菌 16RB
collectively [kəˈlektivli] ad. 共同地 18T
collide [kəˈlaid] vi. 冲突；相撞 5T
colliery [ˈkɔliəri] n. 煤矿 7R
collimate [ˈkɔlimeit] vt. 瞄准；校准 22RB
Columbia [kəˈlʌmbiə] n. 哥伦比亚（美国城市） 18RA
column [ˈkɔləm] n. 柱；圆柱 15RB
come to be known as… 从此称为… 4R
commence [kəˈmens] vt. 开始；倡导 24RA
commencement [kəˈmensmənt] n. 开始 21RB
compactible [kəmˈpæktəbl] a. 可压实的 18RB
concentration [ˌkɔnsenˈtreiʃən] n. 浓度；富集 16RB
concentric [kənˈsentrik] a. 同一中心的；同轴的 1R
conchoidal [kɔŋˈkɔidl] a. 贝壳状的 2R
concomitantly [kənˈkɔmitəntli] ad. 相伴地 9RB
concordant [kənˈkɔːdənt] a. 一致的；协调的；整合的 11RA
concrete [ˈkɔnkriːt] n. 混凝土；凝结物 18RA
condensation [kɔndenˈseiʃən] n. 冷凝作用，凝结（作用） 13R
condense [kənˈdens] v. 冷凝，凝结 13R
conducive [kənˈdjuːsiv] a. 有助于…的，有益于…的
conducive to 有益于 3T
conductivity [kɔndʌkˈtiviti] n. 传导率；传导性 19T
conduit [ˈkɔndit] n. 水道；管道；排水渠 15T
cone of depression 沉陷锥；下降漏斗 15RA
configuration [kənˌfigjuˈreiʃən] n. 轮廓；构型；位形；组态 14T
confined aquifer 承压含水层 15T
confinement [ˈkɔnfainmənt] n. 边缘；区域；范围；境界 15T
conform [kənˈfɔːm] vt. 使一致；使符合 24RB
conformable [kənˈfɔːməbl] a. 一致的；相似的；（地层）整合的 5R
conformity [kənˈfɔːmiti] n. 整合 5R
congeal [kənˈdʒiːl] v. 凝结 2R
conglomerate [kənˈglɔmərit] n. 砾岩 8R
conglomeratic [kənˈglɔməˈrætik] a. 砾岩状；含砾的 8T
conical [ˈkɔnikəl] a. 圆锥形的 15RA
coniferous [kouˈnifərəs] a. 针叶树的 9RB
connate [ˈkɔneit] a. 同生的，同源的，先天的
～ water 原生水 14T
consequently [ˈkɔnsikwəntli] ad. 因而；所以 15RB
conservation [kɔnsəˈveiʃən] n. 保存，保持，储备，守恒 16T
considerably less so than 比…少得多 18T
consistency [kənˈsistənsi] n. 稠性（度）；稳定；粘度 18RA
consolidation [kənˌsɔliˈdeiʃən] n. 固结（作用） 17RB
conspicuous [kənˈspikjuəs] a. 明显的；显著的 1R
constant temperature 恒温 16RB
consumption [kənˈsʌmpʃən] n. 消耗；消费量 19T
contaminant [kənˈtæminənt] n. 污染物 11RB
contaminate [kənˈtæmineit] v. 弄脏；污染 3T
contamination [kənˌtæmiˈneiʃən] n. 污染 14R
contemporaneous [kənˌtempəˈreinjəs] a. 同时的；同生的 5R
continental [kɔntiˈnentl] a. 大陆的
～ shelves 大陆架；陆棚
～ slopes 陆坡
～ rises 陆隆 1R
continuity [ˌkɔntiˈnju (:) iti] n. 连续性 16T
convert…to… 把…变为… 18T
converting [kənˈvəːtiŋ] n. 转换，变换 16T
coquimbite [kəˈkimbait] n. 针绿矾 10RB
coral [ˈkɔrəl] n. 珊瑚 4R
core-drilling [ˈkɔːˌdriliŋ] n. 岩心钻进 11T
costean [ˈkɔstiːn] n. 探槽 11RA
coupled with 和…联合；结合 18T
coupling [ˈkʌpliŋ] n. 结合，匹配，联接 5R
coverage [kʌvəridʒ] n. 所包括的范围；

覆盖 21RB
crassispore [kræsi'spɔ:] n. 厚壁孢子 10RA
cratonic [krei'tɔnik] a. 克拉通（稳定地块）的 8T
creep [kri:p] n. 蠕变 12RA
Cretaceous [kri'teiʃəs] n., a. 白垩纪（的）；白垩系（的） 5T
crevasse-splay [kri'væs-splei] n. 决口扇（冰川）；决口扇形滩 7R
crew [kru:] a. 成员（一组） 21RB
crisis ['kraisis]（[复] crises ['kraisi:z]）n. 危机 19T
cross-linkage ['krɔs-'liŋkidʒ] n. 交链；交联 2T
cross sectional area 横断面积 16T
cross-stratified ['krɔs'strætifaid] n. 具交错层的 12T
crumble ['krʌmbl] vt. 弄碎； 4T
crumple ['krʌmpl] vt. 把…弄皱；扭弯 6R
crust [krʌst] n. 地壳 1R
crystalline ['kristalain] a. 结晶状的 2R
cultivation [ˌkʌlti'veiʃən] n. 耕作；栽培 18T
curtail [kə:'teil] v. 削减；削弱 9T
cutting ['kʌtiŋ] n. 切；割；掘 22T
cycad ['saikæd] n. 苏铁（科） 10RA
cylindrical [si'lindrikəl] a. 圆柱体的 11T

D

dam [dæm] n. vt. 水坝；抑制；阻碍（隔） 18RA
Darcy's law 达西定律 16T
date back 追溯（到） 15RA
dating ['deitiŋ] n. 年代测定 5T
debris ['debri:] n. 岩屑，碎石 3T
decent [di'sent] n. 血统，遗传，下降 4T
decimal ['desiməl] a. 十进位的，小数的 ~ fraction（十进制）小数；十进分数 16T
decimate ['desimeit] vt. 毁灭…的大部分 17RA
decipher [di'saifə] vt. 解释 1T
decline [di'klain] v., n. 下降 16RA
decompose [ˌdi:kəm'pəuz] v.（使）腐败；分解 4T
decomposition [ˌdi:kɔmpə'ziʃən] n. 分解（作用） 16RB
decoupling [di'kʌpliŋ] n. 不匹配；分离 5R
deduce [di'dju:s] vt. 推断 4R
deflect [di'flekt] v. 使偏斜 12RB
deforestation [di:ˌfɔris'teiʃən] n. 毁林；砍伐森林 17RA
degradation [ˌdegrə'deiʃən] n. 降解（作用）；退化；恶化；降级；降低 13R
degradofusinite ['digreidəu'fju:zinait] n. 氧化丝质体 10RA
dehydration [di:hai'dreiʃən] n. 脱水作用 10RA
deleterious [deli'tiəriəs] a. 有害的；有毒的 9T
delicate ['delikit] a. 灵敏的；精密的 6R
delineate [di'linieit] v. 叙述；描写 7R
delta ['deltə] n. 三角洲 3T
deluge ['delju:dʒ] n. 洪水；大雨；暴雨 6R
demarcation [di:mɑ:'keiʃən] n. 分界；界限 3R
denudational [di:nju:'deiʃənəl] a. 剥蚀的 3T
depict as 描绘成；画成 17RB
deplete [di'pli:t] vt. 耗尽；使枯竭；贫乏 17RA
deploy [di'plɔi] v., n. 部署；配置；使采用 17RB
depression [di'preʃən] n. 洼地；凹陷 15RA
depth [depθ] v., n. 变深；深度 16RA
derivative [di'rivətiv] a., n. 被引出的；派生的；导数；微商 23RA
derrick ['derik] n. 井架；钻塔 11T
desaturation [di:sætʃə'reiʃən] n. 减饱和（作用） 16RA
descendant [di'sendənt] n. 子孙后代 4R
desmocollinite [dezmə'kɔlinait] n. 基质镜质体 10RA
destructive [dis'trʌktiv] a. 破坏（性）的 18RA
detector [di'tektə] n. 探测器 22RB
deteriorate [di'tiəriəreit] v. 使恶化；使变质 12T
deterioration [ditiəriə'reiʃən] n. 损坏；恶化；变质 12T
detonate ['detouneit] v. 起爆；使起爆 21T
detonation [detouneiʃən] n. 爆炸 21RA
detrital [di'traitəl] a. 碎屑的 7T
devegetation [divedʒi'teiʃən] n. 毁掉植物；无植被 17RA

dew [dju:] n. 露（水） 13R
dewatering [di:'wɔ:təriŋ] n. 抽水；排水 15RA
diatom [ˌdaiətəm] n. 硅藻 4T
diatomaceous [ˌdaiətə'meiʃəs] a. 硅藻的
～ earth 硅藻土 4T
diffraction [di'frækʃən] n. 衍射 2R
diffuse [difju:z] v., a. 扩散（的）；分散（的） 16RA
dilute [dai'lju:t] v. 稀释；冲淡 2R
dimension [di'menʃən] n. 范围；方面 6R
dimensional [di'menʃənəl] a. 维的
two ～ 两维的 24RB
diminish [di'miniʃ] vt. 减少；减小；缩减 24T
dinosaur ['dainəsɔ:] n. 恐龙 5T
Dinoseis ['dainəsaiz] n. 气爆震源 21RB
diorite ['daiərait] n. 闪长岩 3R
direct [di'rekt] v. 引导；控制；指向 16RA
direct [di'rekt] a. 直接的；正演的 19T
discharge [dis'tʃɑ:dʒ] n. 流量；涌水量；排泄 14T
discipline [disiplin] n. 纪律；风纪；训练；学科 19T
discontinuity [diskənti'nju:iti] n. 不连续性；间断 5R
disfiguration [disfigə'reiʃən] n. 毁形；变形 9RA
disintegrate [dis'intigreit] v. 使瓦解；使分裂 11RB
dislocation [dislə'keiʃən] n. 断层；断错 6T
disparate ['disparit] a. 根本不相同的；无联系的 9RA
disposal [dis'pəuzəl] n. 处理，配置 13R
disposition [dispə'ziʃən] n. 布局，处理，部署，排列 18RB
disrupt [disrʌpt] vt. 爆破；冲破 21RA
disseminate [di'semineit] v. 散布 2R
dissolve [di'zɔlv] v. 分解，（使）溶解 17T
dissolver [di'zɔlvə] n. 溶剂 15RB
distinct [dis'tiŋkt] a. 明显的；清楚的；与其它不同的 22RA
distinguish [distiŋgwiʃ] vt. 区别；辨别；识别 19T
distort [dis'tɔ:t] v. （使）变形 4R
distributary [dis'tribjutəri] a. 分流的；支流的 7R
disturb [dis'tə:b] vt. 打扰；干扰；弄乱 19T
disturbance [dis'tə:bəns] n. 干扰；扰动 17T
diurnal [dai'ə:nl] a. 每日的；白天的 16RA
divorce [di'vɔ:s] vt. （使）脱离 13R
document ['dɔkjumənt] vt. 证明
to be well documented 有许多资料证明 17RA
documentation [dɔkjumen'teiʃən] n. 文件；文献 22RB
dolomite ['dɔləmait] n. 白云石 2R
dolostone [dɔlə'stəun] n. 白云岩 2R
domain [də'mein] n. 领域，范畴（围） 16RB
dome [dəum] n. 穹隆 19R
domestic [də'mestik] a. 民用的 16RB
Doppler-sonar ['dɔplə-sounə] n. 多普勒声纳 23RB
double refraction 双折射 2R
downstream ['daun'stri:m] n., a. 顺流（的）；下游（的） 18RB
downwarp [daun'wɔ:p] v. 向下弯曲；下沉 8T
drab [dræb] a. 黄褐色的 3R
drain [drein] vi. 排水；流掉（off） 5T
drainage ['dreinidʒ] n. 排水；放水
～ divide 分水岭 14T
draw [drɔ:] (drew [dru:], drawn [drɔ:n]) v. 引起；招来；获得；提取 17RB
～ on 戴上；穿上；吸收；利用；凭；靠
draw from 据…得出…；据…推断 17RB
drench [drentʃ] vt. 使浸透；使淋透 14R
drilling [driliŋ] n. 钻孔；钻井 22T
drilling rig 钻井装置；钻机 17RB
dripstone ['drip'stəun] n. 钟乳石，石笋 2R
droplet ['drɔplit] n. 小（水）滴；液滴 13R
dropping ['drɔpiŋ] n. 下降；落下 15RA
dub [dʌb] vt. 授与；给…起名（绰号） 6T
dune [dju:n] n. 沙丘 8R
dunite ['dju:nait] n. 纯橄榄石 16
durability [djuərə'biliti] n. 持久性；耐久性 11RB
durain ['djuərein] n. 暗煤 9T
dwelling ['dweliŋ] n. 居住；住处 5T
dye [dai] v., n. 染（色）；染料 16RB
dyke [daik] n. 岩墙 9T

dynamic [dai'næmik] a. 能动的；动态的 1T
dynamothermal [dainəməu'θə:ml] a. 热动力的 9T

E

echo ['ekou] n. 回声；反响 6R
effective porosity 有效空隙度 16T
effervesce [efə'ves] v. 冒气泡；起泡沫 2R
effervescence [efə'vesns] n. 起泡；冒泡 2R
eject [i (:) 'dʒekt] vt. 逐出；驱逐；排斥 15RB
elaborate [i'læbərit] a. 复杂的；精心制作的 17T
elapse [ilæps] n. (时间的) 过去；消失 21RA
elastic [i'læstik] a. 弹性的 16RA
electrochemical [i'lektroukemikəl] a. 电化的；电化学的 20T
electrode [i'lektroud] n. 电极 20T
electrolyte [i'lektroulait] n. 电解质；电解液 22RA
electromagnetic [ilektroumæg'netik] a. 电磁的 19R
elevation [ˌeli'veiʃən] n. 高处；高地；高度；海拔 13T
ellipsoid [i'lipsɔid] n. 椭面；椭球 24T
Elm 埃尔姆 (地名) 18RA
elucidate [ilju:sideit] v. 阐明；解释 11RA
emanation [ˌemə'neiʃən] n. 喷气；发射；流 (排) 出 (物) 17RA
embankment [im'bæŋkmənt] n. 堤防；堤坝 10RB
embed [im'bed] vt. 埋入；埋置 4T
embrace [im'breis] vt., n. 拥抱；包含；n. 包围 4T
emerge [i'mə:dʒ] vi. 出现；形成 15RB
emit [i'mit] v. 喷出；发射 15RB
emphases ['emfəsi:z] n. 强调；加强 (单数 emphasis) 13R
Empire State Buildings 帝国大厦 5T
employing [im'plɔiiŋ] n. 使用；雇用 17RB
encompass [in'kʌmpəs] vt. 围绕；环绕；包围；包含；包括 15T
encounter [in'kauntə] vt. 遭遇；遇到 15RB
encrust [in'krʌst] vt. 包外壳于 6R
energetic [enə'dʒetik] a. 精力旺盛的 6R
enhance [in'hɑ:ns] vt. 提高；增强 (加) 17RA
enlarge [in'lɑ:dʒ] v. 扩大 17T
enrichment [in'ritʃmənt] n. 富集；浓缩；加浓 16
entirety [in'taiəti] n. 整体；总体；全部；全面 6R
entomb [in'tu:m] vt. 埋葬 4
entrap [in'træp] vt. 诱捕；圈闭 14T
Eocene ['i:əsi:n] n., a. 始新世 (的)；始新统 (的) 5
epeirogenic [ipairəu'dʒenik] a. 造陆的 8T
episode ['episəud] n. 幕；期 8T
epoch ['i:pɔk] n. 世；时期 5T
equation [i'kweiʃən] n. 方程 (式) 16T
equidimensional [i:kwidi'menʃənəl] a. 等大的；等尺度的 2R
equipment [i'kwipmənt] n. 装备；设备 18RA
equivalent to 等于；相当于 15RA
era ['iərə] n. 代；时代 5T
erode [i'roud] v. 侵蚀；腐蚀 2R
erupt [i'rʌpt] v. 喷出 15RB
escarpment [is'kɑ:pment] n. 悬崖；急斜面 6T
essense [esns] n. 本质；实质 23RA
estuary ['estjuəri] n. 河口湾 3T
euhedral [ju:'hedrəl] a. 自形的 10RB
euxinic [ju:k'sinik] a. 静海的 10RA
evaporite [i'væpəsait] n. 蒸发岩 2R
evapotranspiration [iˌvæpəˌtrænspi'reiʃən] n. 蒸发蒸腾 (作用) 13R
evolve [i'vɔlv] v. (使) 发展；(使) 演化；(使) 进化 5T
excavation [ekskə'veiʃən] n. 掘进，挖掘 7R
exceedingly [iksi:diŋli] ad. 极端地；非常地 1T
exceptionally [iksepʃənli] ad. 特殊地；罕见地 22RB
excess [ik'ses] n. 超越；越过；过量；过剩 in ~ of 超过 1T
excessive [ik'sesiv] a. 极度的；过多的 16RA
exinite ['eksinait] n. 壳质组 10T
exotic [ig'zɔtik] a. 外来的 8R
expand [iks'pænd] v. 扩大；发展 5T

expedient [iks'pi:djənt] a. 有利的；方便的；便利的 23RB
expel [iks'pel] vt. 排出 22T
exploitation [ˌeksplɔi'teiʃən] n. 开发；开采 15RB
exploration [ˌeksplɔ:'reiʃən] n. 勘探；勘测；探查 17RA
expulsion [iks'pʌlʃən] n. 驱逐；开除 3T
extensive [iks'tensiv] a. 广泛的 5T
extinct [iks'tiŋkt] a. 灭绝的 5T
extraction [iks'trækʃən] n. 抽出，提取 14T
extrude [eks'tru:d] v. 使喷出 3R
extrusive [eks'tru:siv] a. 喷出的 3R
exudatinite [eksjudə'tinait] n. 渗出沥青体 10RA

F

facial ['feiʃəl] a. 表面的 21T
facies associations 相组合 5R
faecal ['fi:kəl] a. 粪便的 16RB
fate [feit] n. 命运；结局；毁灭 17T
fault [fɔ:lt] n. 断层
～ plane 断层面；normal ～ 正断层；reverse ～ 逆断层；thrust ～ 逆掩断层；strike-slip ～ 走向滑动断层 6T
fault troughs 地堑 15T
faunal succession 动物群顺序（律） 4R
Faye. (free air-correction) 自由空气校正 24T
feasibility [fi:zə'biliti] n. 可行性；可比性；现实性 17RB
federally ['fedərəli] ad. 在全联邦范围 6R
feed [fi:d] v. 补给；供水 16RA
feldspar ['feldspɑ:] n. 长石 2T
fernlike ['fə:nlaik] a. 像蕨类植物的 7T
ferruginous [fe'ru:dʒinəs] a. 铁的；含铁的 23T
ferromagnesian [ferəumæg'ni:ʃən] a. 含铁镁的 2T
fertility [fə:'tiliti] n. 肥沃 17RA
fibrous ['faibrəs] a. 纤维状的 2R
filtrate [filtreit] n. 滤液 22T
findings ['faindiŋz] 复 n. 调查的结果 19T
first and foremost 首先；第一；首要 17RB
fissile ['fisail] a. 易剥裂的 12T
fissure ['fiʃə] n. 裂缝；裂隙 3R
fissured ['fiʃəd] a. 具裂隙的 11T
filter ['filtə] vi. 滤波 21RB
flaggy ['flægi] a. 板状的；薄层的 12T
flake [fleik] n. 薄片 2T
flank [flæŋk] n. 翼；侧 2R
flat-lying ['flæt'laiiŋ] a. 平的；平伏的 11RB
fleshy ['fleʃi] a. 多肉的；肥胖的 1R
flexible ['fleksəbl] a. 易弯曲的；灵活的 12RA
flint [flint] n. 燧石；打火石；（打火机用的）电石 2T
flora ['flɔ:rə] n. 植物群；植物区系 7T
flourish ['flʌriʃ] vi. 繁荣；兴旺 5T
flow back to 流回到 13R
flowage ['fləuidʒ] n. 流动 18RA
fluctuate ['flʌktjueit] v. 波动；动摇 15RA
fluctuation [ˌflʌktju'eiʃən] n. 变动；波动 16RA
fluoride ['flu:əraid] n. 氟化物 16RB
fluvial-deltaic ['flu:viəl-del'teiik] a. 河流三角洲的 8T
flux [flʌks] n. 流量；通量 22RB
flux-gate ['flʌks-geit] n. 磁通门 23RB
focuse ['foukəs] vt. 聚焦 22RA
focused-current log 聚焦电流测井
fold [fould] n. 褶皱 6T
foldbelt [fouldbelt] n. 褶皱带；造山带 8T
footwall ['futwɔ:l] n. 下盘 6T
foraminifera [fə'ræmi'nifərə] n. 有孔虫 4T
foredeep ['fɔ:di:p] n. 前渊；陆外渊；俠窄深海槽 8T
foreset ['fɔ:set] n. 前积层 12T
formula ['fɔ:mjulə] n. 公式 16T
formulate ['fɔ:mjuleit] vt. 系统阐述 4R
fossil ['fɔsl] n. 化石 3T
fountain ['fauntin] n. 喷泉；自流井 15RB
fragment ['frægmənt] n. 碎块；碎屑；碎片 1
fragmentation [frægmenteiʃən] n. 分裂；裂成碎片 6R
framboidal ['fræmbɔidəl] a. （草）莓状结核的 7R
framework ['freimwə:k] n. 框架 23T
formidable ['fɔ:midəbl] a. 可怕的；令人生畏的；难对付的；难克服的 6R

friction ['frikʃən] n. 摩擦力 15RB
frigid zone 寒带 18
frost [frɔst] n. 霜；霜冻 13R
frozen ['frəuzn] a. 冰冻的；冻结的 4T
fume [fju:m] n. 烟；气 9T
function as 起…的作用 15T
fungal ['fʌgəl] a. 如真菌的；真菌的 7T
funnel ['fʌnl] n., vt. 漏斗；使成漏斗形 17T
furthermore ['fə:ðə'mɔ:] ad. 而且；此外 18T
fusian ['fju:zein] n. 丝炭 9T
fusinitic ['fju:znaitik] a. 丝质体的 10T
Fusulinid [fusu'linid] n. 纺缍虫类 4R

G

gabbro ['gæbrou] n. 辉长岩 3R
gabbroic ['gæbrɔik] a. 辉长岩的 3R
galena [gə'li:nə] n. 方铅矿 10RB
gallop ['gæləp] n. 飞跑；疾驰 18RA
galvanic [gæl'vænik] a. (电池) 电流的 20T
galvanometer [gælvə'nɔmitə] n. 电流计 22RB
ganister ['gænistə] n. 致密硅岩 9T
garnet ['gɑ:nit] n. 石榴石 2R
gasification [gæsifi'keiʃən] n. 气化作用 9RA
gas outburst 瓦斯突出 12RA
gate road 平巷；层内巷道 12RA
gather ['gæðə] vt. 搜集；采集；使聚集；使聚拢 2RB
gelifiction [dʒi lifi'keifən] n. 胶凝作用 10RA
gemstone ['dʒemstəun] n. 宝石 2T
geochemist [dʒi (:) ou'kemist] n. 地球化学家 19T
geodetic [dʒi (:) ou'detik] a. 大地测量学的 24RA
geoelectric [dʒi (:) oui'lektrik] a. 地电的 19T
geoelectrical [dʒi (:) oui'lektrikəl] a. 地电的 19T
geohydrology [ˌdʒi:əuhai'drɔlədʒi] n. 水文地质学 13R
geologic [dʒiə'lɔdʒik] a. 地质的
~ agent 地质营力 1T
geologic columns 地质柱状 (图) 5T
geologic setting 地质背景 18RA
geologic work 地质作用 17T
geomagnetic [dʒi (:) oumæg'netik] a. 地磁的 19R
geomechanical [dʒioumi'kænikəl] a. 地质力学的 11RB
geophone ['dʒi:əufəun] n. 地震检波器 12RB
geophysical [dʒi:əu'fizikəl] a. 地球物理的 8R
geophysicist [dʒi (:) ou'fizisist] n. 地球物理学家 1R
geophysics [dʒi (:) ou'fiziks] [复] n., a. [用作单] 地球物理学；地球物理学的 19T
geosyncline [dʒi:ou'sinklain] n. 地槽；地向斜 3R
geotechnical [dʒi:əu'teknikəl] a. 土工的 11T
geothermics [dʒi (:) ou'θə:miks] [复] n. [用作单] 地热学 19T
geyser ['gaizə] n. 间歇喷泉 15RB
geyserite ['gaizərait] n. 硅华 15RB
gigantic [dʒai'gæntik] a. 巨大的 13T
give away 塌落 18RA
glacial ['gleisjəl] a. 冰的；冰川的 3T
glacier ['glæsjə] n. 冰川 5T
gleam [gli:m] n. 闪光；微光 3R
goaf [gouf] n. 采空区；老塘 12RA
Gondwanaland 冈瓦纳大陆 6R
gouge ['gaudʒ] n. 断层泥
fault ~ 断层泥 6T
govern ['gʌvən] v. 控制；统治 16T
goyazite [gɔjəzait] n. 磷铝锶石 10RB
graben ['grɑ:bən] n. 地堑 6T
gradient ['greidjent] n 梯度 19R
gradiometer [greidi'ɔmitə] n. 梯度仪 23RB
granite ['grænit] n. 花岗岩；花岗石 1R
granitoid ['grænitɔid] a. 花岗质的；花岗状 9RB
granodiorite ['grænə'daiərait] n. 花岗闪长岩 3R
granular ['grænjulə] a. 颗粒状的；粒面的 14T
graphical ['græfikəl] a. 图解的；图示的 24RB
graphite ['græfait] n. 石墨 22RA
grave ['greiv] n. 坟墓 6T
gravel ['grævəl] n. 砾；砾石 1R
gravimetric [grævi'metrik] a. 测定重量的；重量分析的 19T
gravimetry [græ'vimitri] n. 重力测定法 23RA

gravitational [grævɪ'teiʃənəl] a. 引力的；重力的 19R
gravity ['græviti] n. 重力；引力；地球引力
specific ~ 比重 1T
Greenish ['gri:niʃ] a. 略呈绿色的 1T
grim [grim] a. 严酷的；无情的；残忍的 18RA
grossularite ['grɔsjulərait] n. 钙铝榴石 2R
ground checking 地面检查；地面验证 17RB
guard ['gɑ:d] n. 屏蔽
~ log 屏蔽测井 22RA
gully ['gʌli] n. 冲沟 18RA
gusher [gʌʃə] n. 自喷井；喷出 15RB
gymnosperm ['dʒimnəuspə:m] n. 裸子植物 10RA
gypsum ['dʒipsəm] n. 石膏 2R

H

ha. =hectare ['hektɑ:] n. 公顷 17RA
hail [heil] n. 雹；冰雹 13R
halite ['hælait] n. 岩盐；石盐 2R
hanging ['hæŋiŋ] n. 悬；挂
~ wall 上盘；顶壁 6T
haphazard ['hæp'hæzəd] a. 任意的 4R
haphazardly [hæphæzədli] ad. 任意地 1R
harmonic [hɑ:'mɔnik] a., n. 谐波的；谐波
non-harmonic a. 非谐波的 20T
haulage ['hɔ:lidʒ] n. 运输；牵引 12RA
Hawaiian [hɑ:'waii-ən] a. 夏威夷的
~ Islands 夏威夷群岛 1R
head difference 水头差 16RA
head loss 水头损失 16T
head waves 首波 21T
hematite ['hemətait] n. 赤铁矿；红铁矿 2R
herbaceous [hə:'beiʃəs] a. 草本的；草质的 7T
heterogeneous ['hetərəu'dʒi:njəs] a. 非均质的 10T
hierarchy ['haiərɑ:ki] n. 体系；系统；层次；阶层 5R
high specific yield 高流量；高单位流水量
low specific yield 低流量；低单位流水量 16RA
hillside ['hil'said] n. 山腰；山坡 15RA
Hilt's law 希尔特定律 9T
histogram ['histəgræm] n. 直方图 8R
homogeneous [hɔmə'dʒi:njəs] a. 均质的；均匀的 10T
horizontal layer 水平层 18T
hornblende [hɔ:n'blend] n. 角闪石 2T
horst [hɔ:st] n. 地垒 6T
hot spring 热泉 15RB
hue [hju:] n. 颜色；色彩；形式；样子 1T
humate ['hju:meit] n. 腐殖酸盐（脂） 10T
humic ['hju:mik] a. 腐殖的 9T
humin [hju:min] n. 腐殖酸等不溶性物质 9RB
humus ['hju:məs] n. 腐殖质 18T
hydraulic [hai'drɔ:lik] a. 水力的；水压的 15T
hydraulic conductivity 渗透系数；水力传导率 16T
hydraulic gradient 水力梯度 16
hydrochloric ['haidrə'klɔrik] a. 盐酸的 2R
hydroelectric power 水电站 13R
hydrogeology ['haidrəudʒi'ɔlədʒi] n. 水文地质学 5R
hydrologic cycle 水（文）循环 13T
hydrology [hai'drɔlədʒi] n. 水文学 5R
hydromechanical ['haidrəumi'kænikəl] a. 流体力学的 9RA
hydrometeorological ['haidrə,mi:tjərə'lɔdʒikəl] a. 水文气象（学）的 17RB
hydrophone ['haidrəfoun] n. 水中地震检波器 21RB
hydrosphere ['haidrəsfiə] n. 水圈 1T
hydrostatic ['haidrou'stætik] a. 流体静力学的 22T
hydrous ['haidrəs] a. 含水的；水合的；水化的 2R
hydroxide [hai'drɔksaid] n. 氢氧化物 2R

I

ICCP (international committee for coal petrology) 国际煤岩学委员会 10T
ice age 冰期 5T
icecap ['ais'kæp] n. 冰帽；冰盖 13T

icicle ['aisikl] n. 冰柱 17T
igneous ['igniəs] a. 火成的 2T
Illinois [ili'nɔi (z)] n. （美国）伊利诺斯（州） 15RB
illite ['ilait] n. 伊利石 10RB
illustrative of 说明…的；作为…的例证 17RB
imaginary [i'mædʒinəri] a. 假想的；虚构的
~ surface 理想水面 15T
immature [ˌimə'tjuə] a. 幼年的；发育不全的；不完全的；未成熟的 18T
immense [i'mens] a. 巨大的；无限的 13T
immobile [i'moubail] a. 不动的；不变的；静止的 1T
impact ['impækt] vt. 冲击；碰撞；撞击 21RB
impart [im'pɑ:t] v. 给与；分给 16RB
imperceptible [impə'septəbl] a. 难以察觉的；察觉不到的 18RA
impermeable [im'pə:mjəbl] a. 不渗透的；不透水的 9T
impervious [im'pə:vjəs] a. 不透水的；不渗透的 15RA
imply [im'plai] vt. 意思是；暗指；包含 1T
imposing [impouziŋ] a. 给人深刻印象的 6R
impoundment [im'paundmənt] n. 蓄水；贮水 17RA
imprint ['imprint] n. 印痕 1T
in a large measure 大部分 14T
in accordance with 根据；按照；和……一致 16T
in addition to 除…之外 15RB
in metric units 在公制单位中 16T
in terms of 按照 16RA
inadequate [in'ædikwit] a. 不适当的；不妥当的 17RA
inanimate [in'ænimit] a. 无生命的 18T
incidence ['insidəns] n. 入射；入射角 21T
inclination [inkli'neiʃən] n. 倾斜；倾角 11RB
incline [in'klain] v. n. 使倾斜；斜面；斜坡 15RB
inconsistency [inkən'sistənsi] n. 不一致；矛盾 11RA
incursion [in'kə:ʃən] n. 进入；流入 7T
index (guide) fossil 标准化石 4R
Indiana [ˌindi'ænə] n. 印第安纳（美国州名） 17T
indices ['indisiz] n. 标志；系数；索引；（单数 index） 17RB
indurate ['indjuəreit] v. 使硬化；变硬 3T
inertinite [i'nə:tinait] n. 惰性组 7T
inertodetrinite [inə:tə'detrinait] n. 碎屑；惰性体 10RA
infertility [ˌinfə'tiliti] n. 贫瘠 18T
infilter ['infiltə] v. 渗入（into） 13R
infiltrate [in'filtreit] vt. （使）渗入；透过；渗透 13T
infiltration [ˌinfil'treiʃən] n. 渗入 13T
infiltration capacity 渗水量 17RA
infinitesimal [ˌinfini'tesiməl] a. 无限小的；无穷小的 18T
inflow ['infləu] n. 进水量；入流 11RB
influent ['influənt] a. 流入的；注入的 18RB
influx [inflʌks] n. 流入量；流入 [illegible]
infrequent [in'fri:kwənt] a. 稀罕的、不寻常的 18RA
ingress ['ingres] n. 侵入；海侵 7R
inherent [in'hiərənt] a. 内在的；固有的 21RA
inhomogeneity [inhəmoudʒe'niiti] n. 不同类；不同质 19T
inhomogeneous [i'nhəmə'dʒi:njəs] a. 不同类的；不同质的；非均匀的；不纯一的 19T
initial [i'niʃəl] a. 最初的；开始的 21RA
injection [in'dʒekʃən] n. 注入 17RA
input ['input] n. 输入 21RA
inseparable [in'sepərəbl] a. 不可分离（割）的；分不开的 13R
inset [inset] n. 插入 22RB
instability [instə'biliti] n. 不稳定性 11RB
installation [ˌinstə'leiʃən] n. 装置；设备 18RB
instantaneously [instən'teinjəsli] ad. 瞬间地；即刻地 20R
insure [in'ʃuə] vt. 给…保险；保证（使…得到）；为…提供保证 15RA
intact [in'tækt] a. 未扰动的；原状的；完整（无缺）的 1T
intake ['inteik] n. 吸入；垂直补给
~ area 受水区；垂直补给区 17T
integral ['intigrəl] a. 整体的；完整的 16RB

ntegrate ['intigreit] v. (使) 结 (综; 总) 合 (成整体); 汇集
~ with 使…与…结合… 5R
ntentionally [in'tenʃənli] ad. 有意地; 故意地 22RB
nteraction [intə'rækʃən] n. 相互作用; 相互影响 22RB
nterchange [intə (:) 'tʃeindʒ] v., n. 交换; 交替 13T
nterchangeability ['intə (:) tʃeindʒə'biliti] n. 可交换性; 可交替性; 互换性 21RB
nterconnect ['intə (:) kə'nekt] vt. 使互相联系; 使互相结合 14T
nterdisciplinary [intə'disiplinəri] a. (各) 学科 (之) 间的 13R
nterdistributary [intə'dis'tribjutəri] a. 分流间的 7R
nterface ['intəfeis] n. 分界面 14T
nterfinger [intə'fiŋgə] n. v. 指状交错 8T
nterfluve ['intəflu:v] n. 河间地; 江河分水区 16RA
nter-glacial age 间冰期 5T
ntergrowth ['intəgrouθ] n. 共生 3R
nterlock [intə'lɔk] v., n. 联锁; 连结 3T
ntermediary [intə (:) 'mi:djəri] n. 媒介 (物) 18T
ntermediate transition zone 中间过渡带 16RA
ntermittent [intə'mitənt] n. 间歇性; 周期性 15RB
ntermontane [intə'məntein] a. 山间的 8T
nterplay ['intəplei] n., v. 相互影响; 相互作用 12T
nterpretation [intə:pri'teiʃən] n. 解释; 阐明 23RA
nterrelationship n. 相互关系 (联系) 13R
ntersect [intə'sekt] v. 横切; 贯穿; 交叉; 交会 15RA
ntersperse [intə'spə:s] v. 散布 3R
nterstice ['intə:stis] n. 空隙; 间隙 14T
nterstitial [intə'stiʃəl] a. 空隙的; 填隙的 9T
nterval ['intəvəl] n. (时间的) 间隔 5T
ntestines [in'testinz] n. 肠 16RB
ntracontinental [intrəkənti'nentl] a. 陆间的 8T
ntrusion [in'tru:ʒən] n. 侵入; 侵入体 9T
nundation [inʌn'deiʃən] n. 泛滥; 淹浸 7T
nundate ['inʌndeit] v. 淹没; 泛滥; 使充满 7T
nvade [in'veid] vt. 侵入
nvaded zone 侵入带 22T
nventory ['invəntri] n. 清单, (…) 总数 13T
nverse [in'vəs] a. 相反的; 倒转的; 反的; 反演的 19T
nvertebrate [in'və:tibrit] n. 无脊椎动物 2R
nvestigation [investi'geiʃən] n. 调查; 研究 21RB
nvestment [in'vestmənt] n. 投资, 投入 17RB
onization [aiənai'zeiʃən] n. 电离 3T
onosphere [ai'ɔnəsfiə] n. 电离层 13R
ridescent [iri'desnt] a. 晕彩的; 虹彩的 3R
rregularity [iregju'læriti] n. 不规则; 不整齐 1T
rrespective of 不管; 不论; 不考虑; 与…无论 15T
rrigated land 水浇地 17RA
soaonmaly [aisoua'nɔməli] n. 等异常 23RA
soline ['aisoulain] n. 等值线 23RA
isometamorphic [aisəumetə'mɔ:fik] a. 等变质的 16T
isometric [aisou'metrik] a. 等轴的; 等轴晶的; 立方的 2R
isostatic [aisoustætik] a. 均衡的
~ reduction 均衡校正 21T
isotope ['aisoutoup] n. 同位素 2R
issue ['iʃ (j) u:] v., n. 流出; 出口 16RA

J

jarosite [dʒə'rəusait] n. 黄钾铁矾 3RB
jasper ['dʒæspə] n. 碧玉; 暗绿色 2T
jellyfish ['dʒelifiʃ] n. 水母, 海蜇 1T
jet [dʒet] v. 喷射出 15RB
joint ['dʒɔint] n., vt. 节理; 裂隙; 连接; 接合; 使成节理 (裂隙) 17T
justify ['dʒʌstifai] v. 证明…是; 正确的; 认为…有理由 17RB

juvenile ['dʒu:vinail] a. 幼年的；初生的
~ water 初生水 14T

K

kaolin ['keiəlin] n. 高岭土 9T
kaolinite ['keiəlinait] n. 高岭石 9T
karst topography 岩溶地形；喀斯特地形 17T
Kentucky [ken'tʌki] n. 肯塔基（美国州名） 17T
kindred ['kindrid] n. 宗族；类 3R
kinematic [kaini'mætik] a. 运动的；运动学的
~ viscosity （运）动粘滞性；动粘滞度 16T

L

label ['leibl] n., vt. 标记；符号；称号；把…称为；标明 18T
labradorite ['læbrədɔ:rait] n. 拉长石 3R
laccolith ['lækəliθ] n. 岩盖 3R
lagoon [lə'gu:n] n. 泻湖 7R
laminae（单数 lamina）['læmini:] n. 薄层；细层 5R
laminasets ['læminə'sets] n. 细（纹）层组 5R
laminated ['læmineitid] a. 层纹的；页状 12T
landform [lændfɔ:m] n. 地形 6R
landmass ['lændmæs] n. 地块；陆块 18RB
landslide ['lændslaid] n. 山崩；塌方；滑坡 18RA
lateral ['lætərəl] a. 侧面的；旁边的 6T
laterite ['lætərait] n. 红土；砖红壤 18T
laterolog ['lætərəlɔg] n. 侧向测井 22RA
lathlike ['lɑ:θlaik] a. 板晶的 3R
launch [lɔ:ntʃ] vt. 着手进行；开始 6R
Laurasia n. 劳亚古陆 6R
lava ['lɑ:və] n. 火山岩；熔岩 2T
lay [lei] vt. 布置；安排；放
~ out 列开；展示 20R
leach [li:tʃ] vt. 滤去；沥滤 18T
leakage ['li:kidʒ] n. 渗透；渗流；越流 15T
leaky aquifer 越流含水层（半承压含水层） 15T
legible ['ledʒəbl] a. 清楚的 21T
lethal ['li:θəl] a. 致死的；致命的 1T
levee ['levi] n. 天然堤 7R
leveling ['levəliŋ] n. 水准测量 11RA
barometric leveling 气压测高；气压高程测量
lignite ['lignait] n. 褐煤 9T
ligno-cellulosic ['lignəu seljʊ'ləusik] a. 本质纤维素的 10RA
limnic ['limnik] a. 湖沼的 7T
limonite ['laimənait] n. 褐铁矿 2R
linear ['liniə] a. 线性的；（直）线的 16T
linkage ['liŋkidʒ] n. 连接；交连；耦合；连合；接合 5R
lipoid ['lipɔid] a., n. 类脂的；类脂物 10RA
liptinitic [liptinitik] a. 壳质组的 10T
liquefaction [likwi'fækʃən] n. 液化作用 9RA
listric ['listrik] a. 铲状的 8T
lithification [liθifi'keiʃən] n. 成岩作用 3T
lithofacies [liθə'feiʃi:z] n. 岩相（沉积岩） 7R
lithosphere ['liθousfiə] n. 岩石圈 1R
lithostatic [liθəst'ætik] a. 地压的 9RB
lithostratigraphic [liθəstræti'græfik] a. 岩石地层的 8R
little if any 几乎没有 18T
lizard ['lizəd] n. 蜥蜴 5T
locate [ləu'keit] vt. 探明…位置；查出…位置 17RB
lofty ['lɔfti] a. 高耸的；极高的 1R
log [lɔg] n. 工作记录 21RB
logging ['lɔdʒiŋ] n. 测井 8R
current ~ 电流测井
induction ~ 感应测井
resistivity ~ 电阻率测井
dielectrical ~ 电介质测井 22RA
longitudinal [lɔndʒi'tju:dinl] a. 纵向的 21T
longwall mining 长壁式开采 9RA
loop [lu:p] n. 圈；环 20R
lopolith ['lɔpəliθ] n. 岩盆 3R
lubricate ['lu:brikeit] v. 使润滑 18RA
lubricating ['lu:brikeitiŋ] a. 润滑的 18RA
luster ['lʌstə] n. 光泽；光彩 2R
lutite ['lu:tait] n. 细屑岩；泥质岩 10RB
lycopod ['laikəpɔd] n. 石松 10RA

M

maceral ['mæsərəl] n. 煤岩显微组分 7T
macrinite ['mækrinait] n. 粗粒体 10RA
macropetrographic ['mækrau'petrəgræfik] a. 宏观岩石学的 11RB
mafic ['mæfik] a. (火成岩的) 镁铁质 3R
magnetite ['mægnitait] n. 磁铁矿 2R
magnetization [mægnitai'zeiʃən] n. 磁化；磁化强度 23RA
magnetometer ['mægni'tɔmitə] n. 地磁仪；磁强计 6R
magnetometric [mægnitou'metrik] a. 测定磁力的；磁力分析的 19T
magnetometry [mægni'tɔmitri] n. 磁力测定法；磁法 23RA
magnitude ['mægnitju:d] n. 大小；数量；幅度 16RA
main [mein] n. 管道 (自来水；煤气)；干线 (电；铁路) 21RB
majestic [mə'dʒestik] a. 庄严的；威严的；崇高的 6R
mammal ['mæməl] n. 哺乳动物 5T
Mamnoth Cave 猛犸洞穴 17T
mangrove ['mæŋgrəuv] n. (热带沿海生长的) 红树林 7T
manifestation ['mænifes'teiʃən] n. 形式；现象；表明；表现 1R
mantle ['mæntl] n. 地幔 1R
mapgazer ['mæp'geizə] n. 凝视地图者 6R
maple ['meipl] n. 枫树 5T
marble ['mɑ:bl] n. 大理石 2R
marcasite ['mɑ:kəsait] n. 白铁矿 10RB
Mariana [mæəri'ænə] n. 马里亚纳 ~ trench 马里亚纳海沟 1R
marker ['mɑ:kə] n. 标记；标示物 11RA
marker bed 标准层；标志层 11RA
maroon [mə'ru:n] a. 栗色的；酱紫色的 8R
marsh ['mɑ:ʃ] n. 沼泽 7T
marvelous ['mɑ:viləs] a. 奇异的；奇迹般的；惊人的；不可思议的 6R
mass [mæs] n. 物质；质量 16T
mass wasting 块体坡移；物质坡移 18RA
massive ['mæsiv] n. 块状的 18RA
matrix ['meitriks] n. 基质；填隙物 3T
matte [mæt] a. 无光泽的 9T
maturation [mætju'reiʃən] n. 成熟 9T
meander [mi'ændə] n. 河曲；曲流 7R
mechanism ['mekənizəm] n. 机制；机理 18RA
media (单数 medium) ['mi:diə] n. 介质；中间 16T
megascopic [megə'skɔpik] a. 肉眼识别的 8R
mention [menʃən] v., n. 叙述 18RB
Mercury ['mə:kjuri] n. 水星 1T
Mesozoic [mesəu'zəuik] n., a. 中生代 (的)；中生界 (的) 5T
metallurgical [metə'lə:dʒikəl] a. 冶金的 9RA
metamorphic [metə'mɔ:fik] a. 变质的；变性的 2T
meteoric [ˌmi:ti'ɔrik] a. 大气的，气象的 ~ water 雨水 14T
meteorite ['mi:tjərait] n. 陨石 2T
meteorology [mi:tjə'rɔlədʒi] n. 气象学 19R
methane ['mi:θein] n. 甲烷；沼气 9T
methodical [me'θɔdikəl] a. 有方法的；条理的 19T
mica ['maikə] n. 云母 2T
micrinite ['maikrinait] n. 微粒体 10RA
microgravimetry ['maikrougrævimitri] n. 微重力测量 24RA
microlithotype ['maikrəu'liθətaip] n. 显微煤岩类型 8T
micro-organisms 微生物 16RB
micropaleontology ['maikrəuˌpæliən'tɔlədʒi] n. 微体古生物学 4T
microscope ['maikrəskəup] n. 显微镜 4T
microseism ['maikrou'saizm] n. 微震 21T
microseismic ['maikrəu'saizmik] a. 微震的；脉动的 12RB
mid-latitude areas 中纬度地区 18T
milieu ['mi:ljə:] n. 环境；周围 10RA
mineability ['mainəbiliti] n. 可采性 8T
mined [maind] v. 开采 15RA
mineralize ['minərəlaiz] vt. 使矿化；使矿物化 6T

minute [mai'nju:t] a. 微小的；微细的；不足道的 1T
Miss.ssippi River 密西西比河 18RA
Missouri [mi'zuəri] n. 密苏里（美国州名） 18RA
mist [mist] n. 雾；烟雾 13RA
Mohorovicic [mouhou'rɔvisik] n. （人名）莫霍罗维奇
～ discontinuity 莫霍罗维奇不连续面 1R
Mohs' scale 莫氏硬度 2T
moisture ['mɔistʃə] n. 湿气；水分；湿度；潮湿 13T
molecular [məu'lekjulə] a. 分子的 14T
monocline ['mɔnəklain] n. 单斜构造 15T
monograph ['mɔnogrɑ:f] n. 专题文章；专题著作 19R
montmorillonite [mɔntmə'rilənait] n. 蒙脱石 10RB
moraine [mə'rein] n. 冰碛；冰碛层 19R
morphology [mɔ:'fɔlədʒi] n. 形态学 10T
morphometric [,mɔ:fə'metrik] a. 地形测量的 17RB
mosaic [məu'zeiik] n. 镶嵌 3T
mudflow ['mʌdfləu] n. 泥石流 18RA
multiple ['mʌltipl] a. 多次的；多重的
～ reflections 多次反射 21T
multiplicity [mʌlti'plisiti] n. 多倍；复合度；多重 21RB
multitude ['mʌltitju:d] n. 众多；大量 6P
municipal [mju (:) 'nisipəl] a. 城市的；市政的 13R
muscovite ['mʌskəvait] n. 白云母 2T
myriad ['miriəd] a., n. 无数的；无数；极大数量 3R

N

naked eye 肉眼 16RB
namely ['neimli] ad. 即；也就是；那就是 13R
native ['neitiv] a. 本地的；天然（纯净）的 17RA
naval ['neivəl] a. 海军的；军舰的 6R
neap [ni:p] n. 最低潮 7T
Nevada [ne'vɑ:də] n. 内华达（美国州名） 15RB
New Madrid n. 新马德里（地名） 18RA
New Mexico [nju (:) 'meksikəu] n. 新墨西哥（美国州名） 17T
New Zealand [nju:'ziland] n. 新西兰 15RB
nitre ['naitə] n. 硝石 16
Noah ['nouə] n. 挪亚 6R
nomenclature [nou'menklətʃə] n. 名称；术语 6T
non-cored ['nɔn'kɔ:d] a. 无岩心的 11T
nonflowing ['nɔn'fləuiŋ] a. 非流动的；非自流的 15RB
normative ['nɔ:mətiv] a. 标准的；规范的 10RB
noxious ['nɔkʃəs] a. 有毒的；有害的 12RA
nuclear ['nju:kliə] a. 核子的；原子能的 17RB
nuclei ['nju:klai]（单数 nucleus）n. 核 13R

O

oak [əuk] n. 橡树，栎树 3T
oblique [ə'bli:k] a. 斜的；倾斜的
～ slip faults 倾斜滑动断层 6T
obscue [əbs'kjuə] v. t. 使模糊；使不分明；遮掩 24T
occupant ['ɔkjupənt] n. 居住者 4R
occurrence [ə'kʌrəns] n. 发生；出现；产状 13R
oceanographie [ouʃjənou'græfik] a. 海洋学的 6R
odorous ['əudərəs] a. 有气味 16RB
odour ['əudə] n. 气味；臭气 15RB
offset ['ɔ (:) fset] n. 水平断错 6T
old Faithful 老忠诚泉 15RB
olivine [ɔli'vi:n] n. 橄榄石 2T
omnidirectionally [ɔmnidi'rekʃənəli] ad. 全向地 21T
onwards ['ɔnwədz] ad. 向前；在前面 21T
ooze [u:z] n., v. 淤泥；渗出；冒出 18RA
opacity [ou'pæsiti] n. 不透光；不透明 9RB
open-cut mining 露天开采 11T
optical ['ɔptikəl] a. 光学的；光的 9RB
optimum ['ɔptiməm] n. 最适条件；最佳条件 23RA

orient ['ɔ:riənt] vt. 定向；定（方）位；标定 17RB

orogenic [ɔrə'dʒenik] a. 造山的

~ belts 造山带 1R

orogeny [ɔ'rɔdʒini] n. 造山运动；造山作用 1R

orthoclase ['ɔ:θəukleis] n. 正长石 2T

oscillate ['ɔsileit] vi. 振荡；振动；摆动 20R

outburst ['autbə:st] n. 突出 12RA

outflow ['autfləu] n. 流出（量）；溢出（量） 16T

outlet ['autlet] n. 排水口，出口 16RA

outline ['aut-lain] n. 轮廓 5T

overburden [əuvə'bə.dn] n. 风化层；表土；浮土 11RB

overhang ['ouvə'hæŋ] n. 悬垂物；伸出；外伸长度 12RA

oversimplify ['əuvəsimplifai] vt. 过于简化 15RA

oversteepen ['əuvə'sti:pen] v. （使）变得更陡峭，变得过陡

oversteepening n. 削峭作用；过陡作用 18RA

overstressing ['ouvə'stresiŋ] n. 逾限应力；超负载 12RB

overthrust ['əuvəθrʌst] n. 逆掩断层；掩冲断层 17RB

overturning [əuvə'tə:niŋ] n. 倒转 17RB

oxidation [ɔksi'deiʃən] n. 氧化（作用） 16RB

oxyfusinite [ɔksi'fju:znait] n. 氧化丝质体 10T

ozone ['ouzoun] n. 臭氧 1T

P

pack [pæk] v. 填塞；挤满 11R

package ['pækidʒ] n. 组；单元 5R

palaeochannel [pæliəu'tʃænl] n. 古河道 12T

paleobiology 古生物学 1T

paleobotanist [pæliəu'bɔtənist] n. 古植物学家 10T

paleobotany [pæliəu'bɔtəni] n. 古植物学 1T

paleocurrent ['pæliəu'kʌrənt] n. 古流向 8R

paleoecological [pæliəu'kɔlədʒikəl] a. 古生态学的 7T

paleoenvironmental [pæliəu'invaiərən mentl] a. 古环境的 9RA

paleotopographic [pæliəutɔpə'græfik] a. 古地形的 8T

Paleozoic [pæliəu'zəuik] n.，a. 古生代（的）；古生界（的） 7T

palynologic [pælinə'lɔdʒik] a. 孢粉学的 10RA

palynology [pæli'nɔlədʒi] n. 孢粉学 1T

pane [pein] n. 窗格玻璃 2T

panel ['pænl] n. 盘区；采区；板面 12RA

Pangaea n. 泛大陆；联合古陆 6A

Panthalassa 泛古洋 6R

paralic [pə'rælik] a. 近海的；海陆交互的 7T

parameter [pə'ræmitə] n. 参数 17RB

parasequence ['pærə'si:kwəns] n. 副层序；似层序

~ sets 副层序组 5R

parenchyma [pə'reŋkimə] n. 薄壁组织 10T

parenchymotelinite [pərenkimə'telinait] n. 薄壁结构镜质体 10T

parent material 母岩物质 18T

parting ['pa:tiŋ] n. 夹层；夹矸层；裂理 11RB

pass into 变成；成为；进入 13R

pass through 穿过；经过；通过 11R

passageway ['pæsidʒ'wei] n. 通道 17RB

patch [pætʃ] n. 补片；补块 1T

path [pɑ:θ] n. 途经；路线；轨迹 18T

pathogenic [pæθədʒi:nik] n. 病原的；致病的 16RB

peat [pi:t] n. 泥炭 7T

peatswamp ['pi:t'swɔmp] n. 泥炭沼泽 7T

peculiarity [pikju:li'æriti] n. 独特性；特色；特质 19T

pedalfer [pi'dælfə] n. 铁铝土 18T

pedology [pi:'dɔlədʒi] n. 土壤学 17RB

pedon ['pedɔn] n. （希腊语）土壤 18T

pedocal ['pedəkæl] n. 钙层土 8T

peg [peg] vt. 定界 21RA

pelitic [pi'litik] a. 泥质的 2T

pellet ['pelit] n. 球粒；团粒 10RB

pellicular [pe'likjulə] a. 薄膜的

~ water 薄膜水 11T

penetrate ['penitreit] v. 渗入（透） 17RB

perceive [pə'si:v] vt. 察觉；看出 4R

perceptible [pə'septəbl] a. 看得出的；察觉到的 10T
perception [pə'sepʃən] n. 感觉；理解 6R
perched aquifer 滞水层；(滞留含水层) 14T
perched water table 上层滞水位 7T
percolate ['pə:kəleit] v. (使) 渗透 14T
percolating water 渗透水；渗滤水 18T
percolation [ˌpə:kə'leiʃən] n. 渗透；渗漏 14T
percussion [pə:'kʌʃən] n. 冲击；撞击
percussion drilling 冲击钻进 11T
perforate ['pə:fəreit] vt. 穿孔；打眼 22T
peridot ['peridɔt] n. 贵橄榄石 2T
peridotite [ˌperi'doutait] n. 橄榄岩 3R
perish ['periʃ] vi. 灭亡；腐烂 4T
permafrost ['pə:məˌfrɔ (:) st] n. 永久冻土 20R
permeability [ˌpə:mjə'biliti] n. 渗透；渗透度 22T
permeable ['pə:mjəbl] a. 可渗透的；具渗透性的 6T
Permian ['pə:miən] n., a. 二叠纪 (的)；二叠系 (的) 5T
permittivity [pə:mi'tiviti] n. 介电常数；电容率 20T
pervasive ['pə (:) veisiv] a. 反常的；歪曲性的 1T
pervious layers 透水层 18RB
petroleum [pi'trəuljəm] n. 石油 4T
phaneritic ['fænəritik] a. 显晶质的 3R
phase [feiz] n. 阶段；状态 13R
phenocryst ['fi:nəkrist] n. 斑晶 3R
phosphorous [ˌ'fɔsfərəs] a. 含磷的 3T
photogrammetric [ˌfəutəgrə'metrik] a. 摄影测量的 1RA
photomultiplier [ˌfoutou'mʌltiplaiə] n. 光电信增管 22RB
phreatic [fri'ætik] a. 潜水的
～ water 潜水 14T
phreatic aquifer 潜水含水层 15T
physiographic [ˌfiziəg'ræfik] a. 自然地理的 6T
piece together 拼合；综合 5T
piezometer [paiə'zɔmitə] n. 水压计 18RB
piezometric [ˌpaiəzə'metrik] a. 测压 (水位) 的
～ (piestic) surface 测压面 15T
piezometric level 测压水位；承压水位 16RA
pit [pit] n. (水) 坑 17RA
plagioclase ['pleidʒiəukleis] n. 斜长石 2T
planet ['plænit] n. 行星 1T
plastically [ˌ'plæstikəli] ad. 可塑地；塑性地 1R
plate [pleit] n. 板；块
～ tectonics 板块构造 1R
plateau ['plætəu] n. 高原 5T
plies [plais] n. 多层薄层 (煤) 10RB
pluck [plʌk] v. 拔；弹 2T
pluton ['plu:tɔun] n. 深成岩体；深成火成岩 3R
plutonic [plu:'tɔnik] a. 深成岩体的 3R
point-load 集中载荷 11RB
polarization [ˌpoulərai'zeiʃən] n. 极化 23T
polarize ['pouləraiz] v. (使) 极化 20T
pollen ['pɔlin] n. 花粉 4T
pollutant [pə'lju:tənt] n. 污染物 (质) 16RB
polymictic ['pɔlimiktik] a. 多级的；复成分的；复碎屑的；复矿的 22RA
ponderous ['pɔndərəs] a. 沉重的 14R
pore space 孔隙 16T
porosity [pɔ:'rɔsiti] n. 孔隙度；孔隙率 14R
porous ['pɔ:rəs] a. 多孔的 16T
porphyritic [ˌpɔ:fi'ritik] a. 斑岩的；斑状的 3R
potassium [pə'tæsjəm] n. 钾 2T
potentiometric [pətenʃia'metrik] a. 电位 (势) 的
～ surface maps 地面等势图；地面等测压线图 17RB
pound [paund] v. 捣碎；猛击；冲击 18RA
pounding wave 击浪 4R
Precambrian ['pri:'kæmbriən] n., a. 前寒武纪的，前寒武系 (的) 18RA
precipitate [pri'sipiteit] v. 沉淀 2R
precipitation [prisipi'teiʃən] n. 沉淀 3T
predict [pri'dikt] v. 预示；预测 14R
predictability [pridiktə'biliti] n. 可预测性 5R
prediction [pri'dikʃən] n. 预测；预示；预报 14R
predominantly [pri'dɔminəntli] ad. 占优势地；突出地；最显著地 22RA

preliminary [pri'liminəri] a. 初步的；预先的 17RB
prerequisite [pri'rekwizit] n. 先决条件；前提 22T
pressure head 压头；压差；承压水位；承压水头 15T
presumed [pri'zju:md] a. 假定的 19R
prevail [pri'veil] vi. 胜（过）；占优势；普遍；盛行 17T
prevailing [pri'veiliŋ] a. 占优势的；主要的；普遍的 18T
prevalent ['prevələnt] a. 普遍的；盛行的 18RA
primary ore 原生矿石 6RA
prevent…from 阻止…；防止…以免… 15RB
primitive ['primitiv] a. 原始的
probe [proub] n. 探针；探头 22RB
prodigious [prə'didʒəs] a. 巨大的；庞大的 3R
profiling ['proufailiŋ] n. 剖面
electromagnetic ~ 电磁剖面法 20T
prograde ['prəugreid] v. 推进；延伸 8T
progressively [prə'gresivli] ad. 渐进地；逐渐地 20R
prone [proun] a. 易于…的；有…倾向的 1R
prop [prɔp] n.，v. 支架；支柱；加固 12RA
propensity [prə'pensiti] n. 倾向 18RB
proportional to 与…成比例的
inversely ~ 与…成反比 16T
proportionality [prəpɔ:ʃə'næliti] n. 比例；比值 16T
prospect [prɔspekt] n. 展望；前景；可能性；勘探 17RB
prospecting [prɔspektiŋ] n. 探矿；勘探 19T
protistid ['prəutistid] n. 始生类 4R
proton ['prəutɔn] n. 质子 23RB
protozoan [ˌprəutə'zəuən] n. 原生动物门 4T
provenance ['prɔvinəns] n. 起源；物源区 8R
proximal ['prɔksiməl] a. 最近的；近似的 8T
proximity [prɔk'simiti] n. 接近；邻近
~ log 邻近侧向测井 22RA
psilophyte ['psailəufait] n. 裸蕨植物 9RA
pulse [pʌls] n. 脉冲
intensive current ~ 强电流脉冲 20T
pulverize ['pʌlvəraiz] vt. 研磨；使成粉末 6T
pyrite ['pairait] n. 黄铁矿 7T
pyritic [pai'raitik] a. 黄铁矿的 7T
pyrofusinite [paiərəu'fju:znait] n. 火焚丝质体 10T
pyroxene [pai'rɔksi:n] n. 辉石 2T
pyroxenite [pai'rɔksənait] n. 辉岩 3R
pyrrhotite ['pirətait] n. 磁黄铁矿 9RA

Q

qualitative ['kwɔlitətiv] a. 定性的
~ interpretation 定性解释 23RA
quantify ['kwɔntifai] vt. 确定（表示）…的数量；定量表示 5R
quantitative ['kwɔntitətiv] a. 定量的
~ interpretation 定量解释 23RA
quarry ['kwɔri] n. 采石场 2T
quiescent [kwai'esnt] a. 不动的；静止的 8T
quotient [kwouʃənt] n. 商 20T

R

radiation [reidi'eiʃən] n. 放射；辐射 22RB
radioactive ['reidiouæktiv] a. 放射性的；放射引起的 19R
radioactivity [reidiouæk'tiviti] n. 放射性；放射现象 19T
radiography [reidi'ɔgrəfi] n. 射线照相 11T
radiolocation [reidioulou'keiʃən] n. 无线电定位 23RB
radiometric [reidiɔ'metrik] a. 辐射仪的 6R
raft [rɑ:ft] n. 木筏；木排 6R
rainstorm ['reinstɔ:m] n. 暴风雨 14R
random ['rændəm] a. 随便的 4R
range [reindʒ] n. 放牧区；山脉；区域 18RA
raw [rɔ:] a. 生的；未加工的；处于自然状态的 19T
react to 对…起反应；对…起反应（作用） 18RA
realm [relm] n. 领域；范围 13R
rearrangement ['ri:ə'reindʒmənt] n. 重新排列 3T
rebound ['ribəund] n. 回跳 11RB

recede [ri'si:d] vi. 降低 16RA
receptacle [ri'septəkl] n. 容器；贮藏器 11RB
recession [ri'seʃən] n. 下降 16RA
recharge ['ri:tʃɑ:dʒ] v. 补给；回灌 14T
recognition [rekəg'niʃən] n. 识别 22T
recrystallization ['ri:kristəlai'zeiʃən] n. 再结晶；重结晶 2R
rectangular [rek'tæŋgjulə] a. 矩形的；长方形的；成直角的 3R
red brown color 褐红色 18T
redistribution ['ri:distri'bju:ʃən] n. 再分布 12T
reduction [ri'dʌkʃən] n. 校正 24T
reed [ri:d] n. 芦苇 7T
reentrant [ri:'entrənt] a. 凹入的 6R
refer to 参考；涉及；关于；参见 5T
refine [ri'fain] vt. 精练；提纯 22RB
reflectance [ri'flektəns] n. 反射率 10T
refract [ri'frækt] v. 使折射 2R
refraction [rif'rækʃən] n. 折射 21RB
refractory [ri'fræktəri] a. 耐火的；耐熔的 9T
regolith ['regəliθ] n. 风化层，表土，浮土 18T
regressive [ri'gresiv] a. 海退的；后退的 8T
rejuvenate [ri'dʒu:vineit] v. 复活；回春 8R
relaxation [rilæk'seiʃən] n. 张弛；弛豫 19R
relentlessly [ri'lentlisli] ad. 无情地 1T
relief [rilif] n. 地势的起伏 23RA
relocation ['ri:lou'keiʃən] n. 重新安置；位置的改变 12RA
remain [ri'mein] n. 遗体 4T
remnant ['remnənt] n.，a. 侵蚀残余；残余（的） 17T
remote sensing 遥感；遥测 17RB
remuneration [rimju:nə'reiʃən] n. 报酬；酬劳 11RB
render ['rendə] vt. 提出；作出；放弃；提供 19T
renovate ['renəuveit] vt. 改善（进）；恢复；更新 17RA
repetition [ˌrepi'tiʃən] n. 重复
~ of beds 地层重复 17RB
replenish [ri'pleniʃ] vt. （再）注满；（再）添满；补充（给） 13RA
replenishment [ri'pleniʃmənt] n. 补给；充满；容量 17RA
reptile ['reptail] n.，a. 爬行动物（的） 5T
reserve [ri'zə:v] n. 储量 11T
reservoir ['rezəvwɑ:] n. 储集层；油储 5R
resinous ['rezinəs] a. 树脂的；象树脂的 2R
resistance [ri'zistəns] n. 阻力；抵抗 16T
resistive [ri'zistiv] a. 抵抗的；有抵抗力的；电阻的 20R
resistivity [rizis'tiviti] n. 电阻率 19T
resort [ri'zɔ:t] vi.，n. 求助；依靠
~ to 借助于；凭借；利用 17RA
rest water level 静止水位 13T
restoration [ˌrestə'reiʃən] n. 恢复 16RA
restore [ris'tɔ:] vt. 恢复；提高；增加 17RA
retard [ritɑ:d] vt. 延迟；使停滞；阻止；防碍 14T
retention [ri'tenʃən] n. 保留；保持；滞留 14T
retreat mining 后退式开采 12RA
revert to 回复 14T
rhomb [rɔm] n. 菱形 2R
rhombic ['rɔmbik] a. 菱形的 2T
rhombohedron-shaped [rɔmbə'hedrən-ʃeipt] a. 具有菱形六面体形状的 2R
rhyolite ['raiəlait] n. 流纹岩 3R
rift [rift] n. 裂缝；空隙；断裂；裂谷 3R
rig [rig] n. 钻塔；钻机 11T
right-hand side 右侧 16T
rill [ril] n. 小河；溪流 1T
rim [rim] n. 边缘 18RB
roar [rɔ:] n. 吼；咆哮；轰鸣声 15RB
rockburst ['rɔk'bə:st] n. 岩石突出 12RB
rockslide ['rɔk'slaid] n. 岩滑 8RA
rocky ['rɔki] a. 岩石的；稳固的 1T
rod [rɔd] n. 钻杆 11T
roll [roul] n.，v. 凸出 12RA
roof ~ 顶板凸出
floor ~ 底板凸出
rootlet ['ru:tlit] n. 小根；枝根 9T
rotary ['rəutəri] a. 旋转的；转动的 11T
~ drilling 回转钻进
Rotten Egg Spring 臭蛋泉 15RB
roundness ['raundnis] n. 圆度 3T
rumble ['rʌmbl] v. （使）降隆响 18RA

runoff ['rʌnɔ:f] n. 迳流 13R

S

sake [seik] n. 缘故
for the ~ of 为…起见 20T
salinity [sə'liniti] n. 盐度；含盐量 7T
San Andreas [sæn'ændrəs] n. 圣安德列斯 6T
sapropelic [sæprə'pelik] a. 腐泥的 10RA
satinspar ['sætin'spɑ:] n. 纤维石膏 2R
saturation [ˌsætʃə'reiʃən] n. 饱和 14T
scanty ['skænti] a. 不够大的；很小的；缺乏的 18T
scarcity ['skɛəsiti] n. 缺乏；不足；稀少；罕见 19T
scavenger ['skævindʒə] n. 食腐动物 4T
schematic [ski (:) 'mætik] n. 简（略）图 17RB
scissor ['sizə] n. 剪刀 6T
~ like 剪刀状的 6T
sclerotinite [skliə'rɔtinait] n. 菌类体 10RA
sclerotioid [skliə'rɔtioid] n. 似菌类体 10RA
sculpture [skʌlptʃə] vt. 刻蚀 1T
scour ['skauə] vt. 冲洗；冲刷成；侵蚀 1T
seal [si:l] n. 隔离层 5R
secrete [si'kri:t] vt. 藏匿 1R
section ['sekʃən] n. 断面；剖面 16T
sediment ['sedimənt] n. 沉积物 3T
sedimentary [sedi'mentəri] a. 沉积的；由沉积物形成的 2T
seek [si:k] v.（寻）找；调查；勘查 17RB
seep into 渗流（出）到… 13T
seepage ['si:pidʒ] n. 渗出；渗漏 12T
seismicity [saiz'misiti] n. 地震活动 17RA
seismic ['saizmik] a. 地震的 1R
3-D ~ surveys 三维地震勘查 5R
seismological [saizmə'lɔdʒikəl] a. 地震的 21T
seismology [saiz'mɔlədʒi] n. 地震学 19T
seismometer [saiz'mɔmitə] n. 测震表 6R
selenite ['selinait] n. 透明石膏；亚硒酸盐 2R
self-polarization [self pouləri'zeiʃən] n. 自激极化；自激极化强度
induced-polarization 激发极化 20T
semiaquatic [s'emiə'kwætik] a. 半水生的；近水生的；半水栖的 7T
semiconfined aquifer 半承压含水层 15T
semifusinitic ['semi'fju:zinaitik] a. 半丝质体的 10RA
semipermeable ['semi'pə:mjəbl] a. 半渗透的；半透水的 15T
sensitive ['sensitiv] a. 敏感的 4T
sensitivity [sensi'tiviti] n. 灵敏度 23RB
sensor ['sensə] n. 传感器；探头 23RB
septic ['septik] a. 引起腐烂的
~ tank 化粪池 11R
Sequence Stratigraphy 层序地层学 3R
set-up ['setʌp] n. 计划；方案 14R
severity [si'veriti] n. 严重；严厉 12RB
sewage ['sjuidʒ] n. 污水 11R
shaft [ʃɑ:ft] n. 竖井；矿井 17RA
sheetwash ['ʃi:twɔʃ] n. 片流；层状冲刷 1T
shield [ʃi:ld] n. 地盾 2T
shrub [ʃrʌb] n. 灌木；灌丛 7T
shock [ʃɔk] n. 震动 21RA
siderite ['sidərait] n. 菱铁矿 10RB
silica ['silikə] n. 硅石；二氧化硅 2T
silicate ['silikit] n. 硅酸盐 2T
sill [sil] n. 岩床；海底山脊 3R
silt [silt] n. 粉砂 1
siltstone ['siltstoun] n. 粉砂岩 22T
silty ['silti] a. 粉砂质的；淤泥的 3T
Sinking branch 地下支流（河） 17T
sinkhole ['siŋkhəul] n. 岩溶坑 17T
Sinking Greek 伏河；隐没河
Little ~ 小伏河
skeletal ['skelitl] a. 骨架的；骸骨的 5T
slab [slæb] n. 平板；厚板 5R
slake [sleik] v. n. 潮解；水解；熄灭 12T
sleet [sli:t] n. 霰；雨（夹）雪 13R
slickenside [slikənsaid] n. 擦痕面；断层擦面 6T
slippage ['slipidʒ] n. 滑动 6T
slump [slʌmp] n. 滑塌；滑移；滑动沉陷 18RA
smart [smɑ:t] a. 灵巧的 5T
snap [snæp] v. 突然折断 2T

snap back 恢复 2T
snowfield ['snəu'fi:ld] n. 雪原 13T
soas in 浸出；渗入 13T
soas into 渗透到… 13T
sodalite ['səudəlait] n. 方钠石 16
sodic ['səudik] a. 含钠的 3R
soft bodied animals 软体动物 4T
solifluction [,soli'flʌkʃən] n. 泥流（作用） 18RA
solum ['səuləm] n. 土层 18T
somber ['sɔmbə] a. 暗淡的；浅黑的 3R
sonar ['souna:] n. 声纳 21RB
sooty ['suti] a. 烟灰的；乌黑的 9T
sorb [sɔ:b] v. 吸附；吸收 12RB
sort [sɔ:t] v. n. 分选；把…分类；种类；分类 14R
sorting ['sɔ:tiŋ] n. 分选性；分选作用 8R
sounding ['saundiŋ] n. 测深
electromagnetic ～ 电磁测深 20T
south Dakota [də'kəutə] n. （美国）南达科他州 15RB
span [spæn] n. 跨（度）；一段时间 5T
sparker ['spa:kə] n. 火花发生器；电火花震源 21RA
spatial ['speiʃəl] a. 空间的 8R
spectacular [spek'tækjulə] a. 壮观的，惊人的，引人注意的 18RA
sphalerite ['sfæləreit] n. 闪锌矿 10RB
spherical ['sferikəl] a. 球的；球形的 1T
spil. [spil] v. （使）溢出；溅出；倾倒出 14R
splendid ['splendid] a. 有光彩的，灿烂的；壮丽的，辉煌的 1T
split [split] n. 分叉 11RB
spontaneous ['spɔnteinjəs] a. 自发的；自然的 22RA
spontaneous combustion 自燃 12RA
spontaneously [spɔn'teinjesli] ad. 自发地；自然发生地 20T
spore [spɔ:] n. 孢子 4T
sporinite [spɔ:rinait] n. 孢子体 10RA
spouter ['spautə] n. 喷井；喷口；喷流 15RB
spread [spred] v. 扩展；蔓延 5T
stability [stə'biliti] n. 稳定性 18RB
stacking ['stækiŋ] n. 叠加
～ pattern 叠加型式 5R
stagnant ['stægnənt] a. 停滞的；不流动的 7T
stalactite ['stæləktait] n. 钟乳石 17T
stalagmite ['stæləgmait] n. 石笋 17T
static ['stætik] a. 静态的；静的
～ corrections 静校止 21RA
stationing ['steiʃəniŋ] n. 测站 24RA
steadily ['stedili] ad. 稳定地 22RB
stick [stik] v. 粘住 18RA
stockpile ['stɔkpail] n. 矿堆；煤堆 10RB
storage ['stɔ:ridʒ] n. 贮藏，储集 13R
strata ['strɑ:tə] n. （复）地层 19R
strategy ['strætidʒi] n. 对策 4R
stratiform ['strætifɔ:m] n. 层状 15T
streak [stri:k] n. 条痕 2R
stringent ['strindʒənt] a. 严格的 23RB
strip away 剥离；剥去 18T
stumpy ['stʌmpi] a. 短柱状的 2T
stunt [stʌnt] v. 使发育不良 7T
subcrop [sʌbkrɔp] n. 隐伏露头 20R
subduction [səb'dʌkʃən] n. 俯冲 3R
subdued [səb'dju:d] a. 平缓的；削低的 14T
submarine ['sʌbməri:n] a. 水下的；水底的；海下的 19T
submerge [səb'mə:dʒ] vt. 浸没；淹没 6R
subsidence [səb'saidəns] n. 下沉；沉降 17RA
subsoil ['sʌbsɔil] n. 底土；心土 18T
substrate ['sʌbstreit] n. 基质；基层 7T
subsurface [,sʌb'sə:fis] a., n. 地下的；地表下的岩石 11T
subterranean ['sʌbtə'reinjən] a. 地下的 17T
succeed [sək'si:d] vt. 接替 4R
suction ['sʌkʃən] n. 负压；吸力 12RB
suitability [sju:tə'biliti] n. 适用性 11T
sulfate ['sʌlfeit] n. 硫酸盐 2R
sulphide ['sʌlfaid] n. 硫化物 2R
sump [sʌmp] n. 水池；水仓 11T
supercontinent [sju:pə'kɔntinənt] n. 超大陆 6R
superposition ['sju:pəpə'ziʃən] n. 叠加 17RB
suppression [sə'preʃən] n. 抑制；禁止 12T
surface subsidence 地表塌陷 12RA
surficial [sə:'fiʃəl] a. 表面的；地表的 9RB
surging wave 涌浪 4R

survive [sə'vaiv] v. 幸免于；幸存 5T
susceptibility [səseptə'biliti] n. 磁化率；磁化系数 19T
sustained yields 持续涌水量 17RB
swarm [swɔ:m] n.、v. 群；群集 12T
swell（过去式 swelled，过去分词 swollen）v t. 增长；膨胀 22T
Switzerland ['switsələnd] n. 瑞士 18RA
sy.vite ['silvait] n. 钾石盐 16
symmetrically [si'metrikəli] ad. 对称地；匀称地 22RA
synchronize ['siŋkrənaiz] vt. 同时发生；同步 21RB
synclinal [siŋ'klainl] a. 向斜的 8T
syncline ['siŋklain] n. 向斜 8R
synthesise ['sinθisaiz] vt. 综合（处理） 17RB
systems tracts 系统域 5R

T

tachymetry [tæ'kimitri] n. 视距测量法 11RA
tackle ['tækl] v. 解决；处理 13R
talus ['teiləs] n. 山麓堆积；碎屑堆 12T
tamper ['tæmpə] n. 夯；夯具 21RA
tan [tæn] n. 棕褐色；棕黄色 1T
tank [tæŋk] n. 贮水池 13R
tap [tæp] n. vt. 龙头；排水孔；（开孔）使流出，接通（自来水等） 15T
tar [tɑ:] n. 焦油（沥青） 4T
tardy ['tɑ:di] a. 慢的，行动缓慢的；迟的；迟到的 6R
target ['tɑ:gɪt] n. 目标；对象 17RB
tectonic fracture zones 构造断裂带 15T
tectonism [tek'tənizm] n. 构造作用 9RB
tectonophysics [tekˌtɔnə'fiziks] [复] n. [用作单] 构造物理学 19T
tedious ['ti:djəs] a. 冗长乏味的；使人厌烦的 23RB
teem with 充满；大量地出现 5T
telocollinite [telə'kɔlinait] n. 均质镜质体
telinite ['telinait] n. 结构镜质体 10T
temporal ['tempərəl] a. 暂时的；短暂的 5R
tenuidurain [tenju:i'djuərein] n. 薄壁孢子暗煤 10RA
terifying ['terifaiiŋ] a. 极大的；可怕的 18RA
terrain ['terein] n. 岩体；地体 2R
terrigenous [te'ridʒinəs] a. 陆源的；陆生的 8T
tetrahedra ['tetrə'hedrə] n. [复] 四面体 2T
the Andes Mountains 安第斯山脉（南美州） 18RA
the bulk of 大多数；大部分 5T
The Geologic Time Scale 地质年代表 5T
The Great Barrier Reef 大堡礁 4T
thermogravimetric [θə:məu'grævimetrik] a. 热解重量（分析）的 10RB
threat [θret] n. 威胁 18RA
throw up 推出；产生 17RA
thundering ['θʌndəriŋ] a. 雷鸣似的；极大的 15RB
tidal loading 潮压；潮汐载荷 16RA
tied up （停）滞留；束缚 13T
tint [tint] n. 色彩；色泽 3R
tonnage ['tʌnidʒ] n. 吨位；排水量 23RB
topography [tə'pɔgrəfi] n. 地形；地势；地形学 7R
topographic [təpə'græfik] a. 地形的；地形测量的 11RA
torbanite [tɔbænait] n. 托斑藻煤 10RA
tract [trækt] n. 土地，地域 16RA
transformed waves 转换波 20R
transient ['trænziant] a. 瞬变的 21T
transgression [træns'greʃən] n. 海侵；海进 7R
transverse waves 横波 21T
transpiration [ˌtranspi'reiʃən] n. 蒸腾（作用） 13R
transitional [træn'siʒənl] a. 过渡的
~ area 过渡区 15T
travertine ['trævəti:n] n. 石灰华；钙华 15RB
tremendous [tri'mendəs] a. 极大的 4T
trend [trend] n. 趋势；倾向 5T
trench [trentʃ] n. 深沟；地沟 1T
trigger ['trigə] v. 触发；激发起 18RA
tropics ['trɔpiks] n. 热带 18T
trough [trɔf] n. 槽；波谷；地堑 15T
troughlike ['trɔ (:) flaik] a. 槽形的

tubing ['tju:biŋ] n. 装管；敷设备管道
tuff [tʌf] n. 凝灰岩 3R
tunnel ['tʌnl] n. 巷道；通道
turbidity [tə:'biditi] n. 混浊度 16
twisting ['twistiŋ] a. 旋转的 18R

U

ultra-high-resolution 超高分辨（率） 5R
ultramafic ['ʌltrə'mæfik] a. 超基性岩的 3R
ultraviolet [ʌltrə'vaiəlit] a. 紫外的；紫外线的 1T
unblemished [ʌn'blemiʃt] a. 无疵的；清白无瑕的 2T
uncollide ['ʌnkə'laid] v t. 不接触；不冲突；不抵触
unconfined aquifer 非承压含水层 15T
unconformity ['ʌnkən'fɔ:miti] n. 不整合 5R
unconsolidated ['ʌnkən'sɔlideitid] a. 未固结的 3T
uncontaminated [ʌnkən'tæmineitid] a. 没有污染的；未沾染的 22T
underclay ['ʌndəkle1] n. 底粘土层（煤层下） 7T
undertake [ʌndə'teik] vt. 着手；从事；开始；进行 17RB
undercut ['ʌndə'kʌt] v. 掏蚀；底切；暗掘；底部掏槽 18RA
undoutedly [ʌn'dautidli] ad. 无容置疑的；肯定的 15RB
undulate ['ʌndjuleit] v. 波动；起伏 19R
undulation [ʌndju'leiʃən] n. 起伏；波浪 19R
unduly ['ʌn'dju:li] ad. 过分地；不适当地 11RB
uneven [ʌ'ni:vən] a. 不平坦的；崎岖的 24T
uneveness [ʌn'i:vənis] n. 不平坦；崎岖 24T
unending [ʌn'endiŋ] a. 无尽的，不停的，不断的 13T
unfavourable ['ʌn'feivərəbl] a. 不适宜的；不顺利的；不利的 20T
unify ['ju:nifai] vt. 统一；一致；使成一体 1R
unique [ju (:) 'nik] a. 唯一的
unmined ['ʌn maind] a. 未开采的 12RB
unpalatable [ʌn'pælətəbl] a. 难吃的；令人讨厌的 16RB
unproductive ['ʌnprə'dʌktiv] a. 非生产性的；没有收益的 17RB
unravel [ʌn'rævəl] vt. 阐明 4R
updip ['ʌpdip] a. 上倾的 8T
upland ['ʌpland] n. 高地；山地 6T
uplift [ʌp'lift] n. 上升；隆起 18RB

V

vadose ['veidəus] n. 渗流
～ water 渗流水 14T
valid ['vælid] a. 有效的；有根据的 15RA
variability [veəriə'biliti] n. 变化性；变异性 23RA
vast [vɑ:st] a. 巨大的；无边无际的 13T
velocity [vi'lɔsiti] n. 速度 16T
vein [vein] n. 脉；岩脉 10RB
venus ['vi:nəs] n. 金星 1T
vermicular [və:'mikjulə] a. 蠕虫状的 10RB
vertebrate paleontology 古脊椎动物学 4T
vessel ['vesl] n. 船 23RB
viability [vaiə'biliti] n. 可行性 11RB
viable ['vaiəbl] a. 可行的；能生存的 11T
vicinity [vi'siniti] n. 近处；附近（地区） 17RA
vital ['vaitl] a. 有生命力的；充满活力的；生气勃勃的；生命的；生机的 1T
vitrain ['vitrein] n. 镜煤 9T
vitreous ['vitriəs] a. 玻璃状的 2T
vitrinite ['vitrinait] n. 镜质组；镜质体 7T
vitrinization [vitrinai'zeiʃən] n. 镜煤化 9RB
void [vɔid] n. 空隙；孔隙 14T
volatile ['vɔlətail] a., n. 挥发的；挥发物 9RB

W

warm-blooded 热血的 16RB
warp [wɔ:p] v. 弯曲；翘曲 8T
washery ['wɔʃəri] n. 洗煤厂 10RB
washout [wɔʃaut] n. 冲蚀地段 21RA
washout ['wɔʃaut] n. 冲刷；冲蚀；冲刷沟 7R

watertight ['wɔ:tətait] a. 不透水的；隔水的 18RB
water-transmissive 导水的；传送水的 16T
water-yielding 给水的；涌水的 14T
weight dropping ['weit-dʒɔpiŋ] n. 落锤法 21RA
well log 测井曲线，钻井（剖面）记录 5R
whispy ['hwispɪ] a 充满沙沙声的 1T
whitish ['waitiʃ] a. 带白色的 18T
winning ['winiŋ] n.，a. 开采；准备采煤区 12RA
wireline drilling 钢绳钻进 11T
Wisconsin [wis'kɔnsin] n. （美国）威斯康星（州） 15RB
withdrawal [wið'drɔ:əl] n. 排出，抽水（量）；排水（量） 14T
withstand [wið'stænd] vt. 抵挡；经受住 4R
witness ['witnis] n. 证据；证言；证人；目击者 6RA
workings ['wə:kiŋs] n. 工作面；巷道；矿房；采场 12T
worm [wə:m] n. 蠕虫；蚯蚓 1T

X

xylotelinite [zailə'telinait] n. 木质结构镜质体 10T

Y

yearly pumpage 每年抽水量 13RA
Yugoslavia ['ju:gəu'slɑ:vjə] n. 南斯拉夫 17T

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地质专业英语

English for Geology

苏朴 胡斌 武永强 编

S9/6/29







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前　言

本书系根据煤炭系统“八五”教材规划精神编写，可衔接大学本科各类基础英语教材。

全书共“基础地质”、“煤田地质”、“水文地质”、“应用地球物理”四部分，共二十四课。大约包含1500个专业词汇。每课内容有：课文、词汇、习题、阅读材料等。重点课文对英语难句翻译、构词法、英文摘要写作等进行了讲解，书后附总词汇表。全书按110学时编写。课文及阅读材料全部选自美、澳、英等国有关专业的简明教程原著，除个别段落外，一般未作文字改动。为了帮助读者理解课文内容，每课都编入了习题，内容有中、英文互译、课文问答及选择填空等。

本书前六课为基础地质部分，可供地质各专业使用。有关地质类专业选用时，除选用基础地质部分及本专业内容外，可根据学时数酌情选用其它专业内容，一般可按70学时组织教学。

参加本书编写工作的有：山西矿业学院苏朴（第一、六、十九、二十、二十一、二十二、二十三、二十四课）、武永强（第二、三、七、八、九、十、十一、十二课）。焦作矿业学院胡斌（第四、五、十三、十四、十五、十六、十七、十八课）。全书最后由苏朴汇总、审定。

中国矿业大学任文忠老师、淮南矿业学院陈萍老师对本书的编写提供了很好的意见，在此谨致谢意。

编　者

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内 容 提 要

本书根据煤炭系统"八五"教材规划对地质类专业英语的要求编写。全书分"基础地质"、"煤田地质"、"水文地质"、"应用地球物理"四个部分，共计二十四课。每课包括课文、词汇、习题、阅读材料、重点课文对照词法、翻译的标准和常见的错误、英语难句翻译、英文摘要写作等内容进行了讲解。

本书内容以地质、水文、应用地球物理等专业基础知识读物为主，可衔接大学基础英语各类教材。本书除了作为地质类有关专业的大学本科专业英语教材外，也可供地质、应用地球物理、水文地质专业的科研、工程技术人员自学专业英语使用。



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