高等学校教材

English for Oil and Gas Geology

油气地质专业英语

张焕香　黄文辉　高　平　主编

石油工业出版社
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内 容 提 要

本书共40课，每课由课文、词汇、难段翻译和习题四部分组成，内容上涵盖了油气地质基础、油气开发技术和非常规油气资源三大块。全书遵从专业英语课程教学的系统性及完整性，遵循由浅入深、循序渐进的教学规律，使专业英语教学与专业课教学相匹配，同时突出了石油地质的理论性、石油工程的应用性和新型能源的前瞻性。

本书可为高等院校能源地质和石油工程等专业的专业英语教材，也可供相关专业的师生以及从事常规、非常规油气勘探开发的生产和科研人员参考。

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前　　言

在全球能源消费不断增长的今天，世界经济和工业体系对传统的常规能源仍具有很强的依赖性，然而各种统计数据显示，常规能源产量已进入下降趋势。在这种情况下，全球能源消费结构必将发生转变，非常规油气的开发利用必然将作为重要的补充。目前，全球范围内已经掀起了非常规油气特别是页岩气开发的热潮。同时，随着我国技术和经验的积累，开采应用甚至输出非常规油气都成为可能，立足国内、开拓海外也已成为历史的必然。在石油工程专业人才的培养上，懂专业、精外语的复合型人才已成为高校适应能源国际化发展的重要标志；具备较强的专业英语听、说、写、译的能力已成为现代高校国际化人才的重要培养目标之一。

目前，国内适用于能源地质和石油工程专业的英语专著不多，更缺乏涵盖最新的常规及非常规油气地质、勘探开发的专业英语教材。本教材是在这方面进行的有益尝试。

考虑到能源地质和石油工程专业的特殊要求，本教材包括有较多油气开发方面的内容。在课文的选择上，涉及知识面较广，力求单词及词组覆盖面大，并反映国内外最新的新理论与新成果；在体系安排上，遵从专业英语教学的系统性和完整性，使专业英语的教学与专业课的教学相匹配。让学生在学习专业英语的同时，又学习了专业知识，达到专业英语与专业课相互促进提高的目的。

本教材共分40课，包括三大部分——油气地质基础、油气开发技术和非常规油气资源。其中，第一部分由张焕香、黄海平编写，第二部分由高平、李克文编写，第三部分由黄文辉、张元福、李胜利编写。全书由张焕香、黄文辉、高平统稿并担任主编。

本教材在编写过程中参考了大量国内外相关教材、专著和文献，在此，编者对这些作者表示衷心感谢，同时还要感谢中国地质大学（北京）研究生院为本教材的出版提供了经费资助。能源学院的研究生唐鑫萍、刘帅、刘芳、裴松伟在本教材的编写过程中付出了很多的努力，在此一并表示感谢！

由于水平有限，教材中难免会有不妥之处，敬请广大师生及读者批评指正。

编者

2013年1月

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Lesson 1　Classification of Sedimentary Rocks

For the identification of **sedimentary rock** types in the field, the two principal features to note are composition-**mineralogy** and grain-size. On the basis of origin, sedimentary rocks can be grouped broadly into four categories (Tab 1 – 1).

Tab 1 – 1　The four principal categories of sedimentary rock with the broad lithological groups

Terrigenous Clastics	Biochemical-biogenic-organic Deposits	Chemical Precipitates	Volcaniclastics
sandstones, mudstone **conglomerates + breccias**	limestones + dolomites, coal **phosphorites**, chert	ironstones, **evaporites**	tephra (pyroclastic deposits) **tuffs**

The most common lithologies are the sandstones, mudstone and **limestones** (which may be altered to **dolomites**). Other types—evaporites, ironstones, cherts and **phosphates**—are rare or only locally well developed, and volcaniclastics are important in some places.

In some cases, you may have to think twice as to whether the rock is even sedimentary in origin or not. Greywacke sandstones, for example, can look very much like dolerite or basalt, especially in hand-specimens away from the outcrop. Points generally indicating a sedimentary origin include the presence of: stratification; specific minerals of sedimentary origin (e. g., glauconite, chamosite); sedimentary structures on bedding surfaces and within beds; fossils; grains or pebbles which have been transported (that is, clasts).

Terrigenous clastic rocks

These are dominated by **detrital** grains (especially silicate minerals and rock fragments) and include the sandstones, conglomerates, breccias and mudstones.

Sandstones are composed of grains chiefly between 1/16 and 2 mm in diameter. Bedding is usually obvious and sedimentary structures are common within the beds and upon the bedding surfaces. They are composed of five principal ingredients: rock fragments (lithic grains), quartz grains, feldspar grains, matrix and cement. The matrix consists of clay minerals and silt-grade quartz, and in most cases this fine-grained material is deposited along with the sand grains. It can form from the diagenetic breakdown of labile (unstable) grains, however, and clay minerals can be precipitated in pores during diagenesis. Cement is precipitated around and between grains, also during diagenesis; common cementing agents are quartz and calcite.

Conglomerates and breccias, also referred to as rudites, consist of large clasts (pebbles, cobbles and boulders), more rounded in conglomerates, more angular in breccias, with or without a sandy or muddy matrix. The key features which are important in the description of conglomerates and breccias are the types of clast present and the texture of the rock. On the basis of clast origin, intraformational and extraformational conglomerates and breccias are distinguished. Intraformational clasts are pebbles derived from within the basin of deposition; many of these are fragments of mudstone or lime mudstone liberated by **penecontemporaneous** erosion on the seafloor, river channel, etc., or by desiccation along a shoreline, lake margin, tidal flat, etc., with subsequent reworking. Extraformational clasts are derived from outside the basin of deposition and are thus older than the enclosing sediment.

Mudstones are fine-grained with particles mostly less than 1/16 mm in diameter, and are dominated by clay minerals and silt-grade quartz. Many mudstones are poorly bedded and also poorly exposed. Colour is highly variable, as is fossil content. Mudstones are the most abundant of all lithologies but they are often difficult to describe in the field because of their fine grain-size. Mudstone is a general term for sediments composed chiefly of silt (4 to 62 μm) and clay (< 4μm) sized particles. Siltstone and claystone are sediments dominated by silt and clay-grade material respectively. Claystones can be recognized by their extremely fine grain-size and usually homogeneous appearance; mudstones containing silt or sand have a "gritty" feel when crunched between your teeth. Shales are characterized by the property of **fissility**, the ability to split into thin sheets generally parallel to the bedding; many shales are laminated. Mudstones are non-fissile and many have a blocky or massive texture. Argillite refers to a more **indurated** mudstone, whereas slate possesses a cleavage. A marl is a calcareous mudstone. Mudstones grade into sandstones.

With increasing grain-size muds/mudstones grade into sands/sandstones and the latter into gravels/conglomerates, and there are also mixtures of all three, of course. Sediments consisting of a rapid interbedding of sandstones and mudstones are often referred to as heterolithic facies.

Limestones and dolomites

Limestones are composed of more than 50% $CaCO_3$, so the standard test is to apply dilute hydrochloric acid (HCl); the rock will fizz. Many limestones are a shade of grey, but white, black, red, buff, cream and yellow are also common colours. Fossils are commonly present, in some cases in large numbers. Limestones, like sandstones, can be described in only a limited way in the field; the details are revealed through studies of thin-sections and peels. Three components make up the majority of limestones: carbonate grains; lime mud/**micrite** (micro-crystalline calcite) and cement (usually calcite spar, also fibrous calcite). The principal grains are bioclasts (skeletal grains/fossils), ooids, peloids and intraclasts. Many limestones are directly analogous to sandstones, consisting of sand-sized carbonate grains which were moved around on the seafloor, whereas others can be compared with mudstones, being finegrained and composed of lithified lime mud (i. e., micrite or lime mudstone). Some limestones are formed in situ by the growth of carbonate skeletons as in reef limestones, or through trapping and binding of sediment by microbial mats (formerly algal mats) as in stromatolites and microbial laminites.

Dolomites (also dolostones) are composed of more than 50% $CaMg(CO_3)_2$. They react little with dilute acid (although a better fizz will be obtained if the dolomite is powdered first), but more readily with warm or more concentrated acid. Alizarin red S (茜素硫磺钠) in hydrochloric acid stains limestone pink to mauve, whereas dolomite is unstained. Many dolomites are creamy yellow or brown in colour and they are commonly harder than limestones. Most dolomites have formed by replacement of limestone and as a result in many cases the original structures are poorly preserved. Poor preservation of fossils and the presence of vugs (irregular holes) are typical of dolomites. The majority of dolomites, especially those of the **Phanerozoic**, have formed by replacement of limestones. This dolomitisation can take place soon after deposition, i. e., penecontemporaneously and notably upon high intertidal-supratidal flats in semi-arid regions, or later during shallow-burial or deeperburial diagenesis. For facies analysis it is important to try to decide which type of dolomite is present.

Other lithologies

Gypsum is the only **evaporite mineral** occurring commonly at the Earth's surface, mostly as nodules of very small crystals in mudstone, although veins of fibrous gypsum (satin spar) are usually associated. Evaporites such as anhydrite and halite are encountered at the surface only in very arid areas. Most gypsum at outcrop is very finely crystalline and occurs as white to pink nodular masses within mudstones (which are commonly red) or as closely packed nodules with thin stringers of sediment between (chickenwire texture). Irregular and contorted layers of gypsum form the so-called enterolithic texture. Nodular and enterolithic textures are typical of gypsum-anhydrite precipitated in a marine sabkha (supratidal) environment, so that other peritidal sediments may be **interbedded** (e. g., microbial laminites/stromatolites, fenestral lime mudstones/dismicrites), or in a continental sabkha, where fluvial and aeolian sediments may be associated.

Ironstones include bedded, nodular, oolitic and replacement types. They commonly weather to a rusty yellow or brown colour at outcrop. Some ironstones feel heavy relative to other sediments.

Cherts are mostly cryptocrystalline to microcrystalline siliceous rocks, occurring as very hard bedded units or nodules in other lithologies (particularly limestones). Many cherts are dark grey to black, or red.

Sedimentary phosphate deposits or phosphorites consist mostly of concentrations of bone fragments and/or phosphate nodules. The phosphate itself is usually cryptocrystalline, dull on a fresh fracture surface with a brownish or black colour.

Organic sediments such as hard coal, brown coal (lignite) and peat should be familiar, and oil shale can be recognized by its smell and dark colour.

Volcaniclastic sediments, which include the tuffs, are composed of material of volcanic origin, chiefly lava fragments, volcanic glass and crystals. Volcaniclastics are variable in colour, although many are a shade of green through chlorite replacement. They are commonly badly weathered at outcrop. The term pyroclastic refers to material derived directly from volcanic activity, whereas the term epiclastic is used to refer to "secondary" sediments such as debris flow and fluvial deposits resulting from the reworking of **pyroclastic material**.

Reference

Maurice E. Tucker Sedimentary Rocks in the Field. West Sussex: John Wiley & Sons, 2003:29 - 51.

New Words and Phrases

1. sedimentary rock 沉积岩
2. mineralogy [ˌminəˈrɔlədʒiː,-ˈræl-] *n.* 矿物学
3. terrigenous clastics 陆源碎屑岩
4. volcaniclastics [vɔlˌkæniˈklæstiks] *n.* 火山碎屑岩
5. conglomerate [kənˈglɔməˌreit] *n.* 砾岩
6. breccia [ˈbretʃə] *n.* 角砾岩
7. phosphorite [ˈfɔsfərait] *n.* 磷灰岩
8. evaporite [iˈvæpərait] *n.* 蒸发岩
9. tephra [ˈtefrə] *n.* 火山灰
10. tuff [tʌf] *n.* 凝灰岩
11. limestone [ˈlaimˌstəun] *n.* 石灰岩
12. dolomite [ˈdɔləmait] *n.* 白云岩
13. phosphate [ˈfɔsˌfeit] *n.* 磷酸盐
14. detrital [diˈtraitəl] *adj.* 由岩屑形成的
15. penecontemporaneous [ˌpiːnikənˌtempəˈreinjəs] *adj.* 沉积后到固结前的,准同期的
16. fissility [fiˈsiləti] *n.* 易裂性,分裂性,可裂变性
17. indurate [ˈindjureit] *vt. & vi.* (使)坚硬,变得坚硬
18. micrite [ˈmikrait] *n.* 微晶灰岩,泥晶灰岩
19. Phanerozoic [ˌfænərəˈzəuik] *adj.* 显生宙的
20. evaporite mineral 蒸发矿物
21. interbedded [ˌintəˌbedid] *adj.* 层间的,夹层之间的
22. pyroclastic material 火山碎屑物

Translation of Difficult Paragraphs

(1) The most common lithologies are the sandstones, mudstones and limestones (which may be altered to dolomites). Other types—evaporites, ironstones, cherts and phosphates—are rare or only locally well developed, and volcaniclastics are important in some places.

最常见的岩石为砂岩、泥岩和石灰岩(可能变成白云岩),其他类型(蒸发岩、铁矿石、硅质岩和磷酸盐)很罕见或只在局部地区发育良好,火山碎屑岩是一些地方很重要的岩石。

(2) Sandstones are composed of grains chiefly between 1/16 and 2mm in diameter. Bedding is usually obvious and sedimentary structures are common within the beds and upon the bedding

surfaces. They are composed of five principal ingredients: rock fragments (lithic grains), quartz grains, feldspar grains, matrix and cement. The matrix consists of clay minerals and silt-grade quartz, and in most cases this fine-grained material is deposited along with the sand grains. It can form from the diagenetic breakdown of labile (unstable) grains, however, and clay minerals can be precipitated in pores during diagenesis. Cement is precipitated around and between grains, also during diagenesis; common cementing agents are quartz and calcite.

砂岩是由直径大部分在1/16～2mm之间的颗粒组成的。层理通常很明显,沉积结构常在层理之间和层理表面。它们包含五种主要成分:岩石碎片(岩屑颗粒)、石英颗粒、长石颗粒、杂基和胶结物。杂基包括黏土矿物和粉砂级石英,在大多数情况下,这种细粒物质随砂粒一起沉积,然而,它可以形成于不稳定的(不牢固的)颗粒在成岩作用过程中的破裂,黏土矿物在成岩作用过程中也可以沉淀在孔隙中。胶结物同样是在成岩作用过程中,在颗粒周围和颗粒之间沉淀;常见的胶结物有石英和方解石。

Exercises

Ⅰ. Translate the following terms from Chinese to English or English to Chinese.

沉积岩	tidal flat
陆源碎屑岩	intraformational clasts
长石颗粒	calcareous mudstone
层理面	heterolithic facies
黏土矿物	sand grain

Ⅱ. Decide whether the following statements are true or false.

1. Terrigenous clastic rocks are dominated by detrital grains, and include the sandstones, conglomerates, breccias and mudstones.

2. Sandstones are composed of five principal ingredients: rock fragments (lithic grains), quartz grains, feldspar grains, matrix and cement.

3. Intraformational clasts are derived from outside the basin of deposition and are thus older than the enclosing sediment.

4. Three components make up the majority of limestones: carbonate grains; lime mud/micrite (micro-crystalline calcite) and cement.

5. Pyroclastic is used to refer to "secondary" sediments such as debris flow and fluvial deposits resulting from the reworking of pyroclastic material.

Ⅲ. Answer the following questions.

1. How is sedimentary rock classified on the basis of origin?

2. Greywacke sandstones can look very much like dolerite or basalt. How can we know whether the rock is sedimentary in origin or not?

3. What are the most common three cementing agents for sandstones?

4. With grain-size increasing, how many grades can sedimentary rocks be divided into?

5. What are the main differences between limestones and dolomites?

Lesson 2 Clastic Rocks

Sedimentary rocks come from clastic sources, a variety of **precipitates**, and from organically related processes. The origin can be further classified by the rock type and the environment of deposition. In this manner, the rock is completely classified and identified by all significant parameters. An example of this classification is a quartzose **deltaic channel sandstone**. The sandstone was laid down as a clastic rock in a deltaic channel under marginal marine conditions and is composed of quartz grains. A complete description of the rock would include bedding characteristic, grain sizes, grain shapes, **trace minerals**, and modifiers where applicable to fully cover the background and present features of deposit.

Clastic rocks are composed of clasts, which are **fragments** or grains of pre-existing rocks. The fragments are derived from the pre-existing rock, transported, deposited, and hardened, or lithified, into a new rock. **Mechanical weathering** is usually the manner in which the clastic particles are derived from the **original rock**. However, chemical weathering of **susceptible** materials surrounding resistant grains in the original rock produce rock and mineral fragments as well.

The mechanical properties of clastic rocks are not only affected by the **external factors**, such as the state of stress and surrounding geological environment, but also strongly dependent on the depositional and sedimentary environments, including components, **textures**, and structures of the rocks. It is of importance to study the mechanical properties of clastic rocks for energy industry, because oil and gas, as well as coal, are situated in these rocks. Until now, most research on the microstructure of the rock and its **deformation** and strength behaviors mainly focuses on **granites** and other hard rocks. Therefore, relations between the sedimentary characteristics and mechanical properties of clastic rocks need to be addressed, particularly those of soft rocks such as mudstone and shale.

Clastic sedimentary rocks can consist of virtually any material as long as they are made of fragments of pre-existing rocks. It is on the basis of size of the fragments that make up clastic rocks by which they are classified (Tab 2 – 1).

Tab 2 – 1 Clastic Sedimentary Rocks

Sediment	Size, mm	Rock
Gravel	>2	Conglomerate
Sand	2 ~ 1/16	Sandstone
Silt	1/16 ~ 1/256	Siltstone
Clay	<1/256	Mudstone

Conglomerate is a clastic sedimentary rock composed of **gravel** of boulders, cobbles, and/or pebbles cemented together. Boulders are clastic fragments larger than 256 mm in diameter.

Cobbles range from 64 to 256 mm, and pebbles from 2 to 64 mm. Boulders, cobbles, and pebbles in conglomerates are usually rounded by abrasion and are laid down in stratified units. The large conglomerate constituents are surrounded by a matrix of much finer sand and mud and are cemented together to form the hard rock. Porosity and permeability in conglomerate are variable with grain shape and amount of matrix materials. Conglomerates are often good reservoirs for hydrocarbons.

Conglomerates and sandstones form 20% ~25% of the stratigraphic record but have received much more than 25% of the attention of sedimentary petrologists. This imbalance has occurred for several reasons. The grains in sandstones are coarse enough to be seen easily, and these rocks typically contain textures and structures that can be described and photographed, such as pebble shape, grain rounding, **cross-bedding**, **ripple marks**, and **graded bedding**. These can be diagnostic of transport mechanism or depositional environment. Also, sandstones supply about half of the world's production of petroleum and natural gas and most of the groundwater we drink.

Sandstone fragments vary in size from 1/16 to 2 mm. Sandstone is composed of these sand-size particles that have been compacted and cemented together. Sorting of sandstone particles ranges from good to poor in a rock that can be designated as coarse, medium, or fine within the size range for sandstone. Since sandstone fragments can be of virtually any composition, the sandstone rock itself can be designated according to its mineral constituents or its combinations of constituents. Examples are quartz sandstone, which consists of resistant quartz grains, feldspathic or arkosic sandstone with more than 20% feldspar grains, greywacke, which consists of poorly-sorted grains with abundant feldspar, and a clay matrix, some of which may be altered to chlorite (Tab 2-2).

Tab 2-2 Mineral Composition of Some Common Sandstones (Sandstone Classification 2 ~ 1/16 mm)

Particle Composition	<15% Clay Matrix	>15% Clay Matrix
Rock Fragments	Sandstone (Rock Fragment)	Argillaceous Sandstone (Rock Fragment)
Feldspar	Feldspathic: >30% Sandstone (Arkosic)	Argillaceous Feldspathic: Sandstone
Quartz	Quartz Sandstone	Argillaceous Quartz Sandstone

Clean, well-sorted sandstones can be tightly or loosely cemented and therefore can have a wide range of porosity and permeability. Many Gulf Coast sandstones are clean, well-rounded, and weakly cemented. They provide good hydrocarbon reservoirs. Certain **Ordovician** sandstones of mid-continent area are some of the best-sorted, best-rounded, clean sandstones developed anywhere in the world. They are loosely cemented and are excellent reservoirs in a number of mid-continent oil and gas fields. Sandstone bodies are formed in a large variety of environments and acquire a variety of shapes and characteristics. Because sandstone is deposited virtually everywhere, it is the rock type that occurs most often as a reservoir rock.

Sandstone reservoirs produce large volumes of petroleum in the North Sea, China, Soviet Union, and North and South America. The upper **Paleozoic Gardner barrier bar** is a productive sandstone in central Texas.

Sandstone can consist of grains of virtually any composition, and it follows that a sandstone of limestone grains is not only a possibility but a common reality. Fragments derived from pre-existing limestone deposit, transported and deposited, form a sandstone composed of limestone fragments. This particular rock is called a **calcarenite**, or calcareous sandstone.

Mud and fine-grained materials that are coarse enough to feel gritty on the teeth are components of siltstone. Siltstone grain sizes range from 1/16 to 1/256 mm. Rocks of this classification have limited porosity and permeability because of their potentially high clay content and small grain size. They have limited potential as reservoir beds.

Clay and mud with particles of less than 1/256 mm diameter combine to form shale that is smooth and not gritty on the teeth. Shale is usually finely **laminated** and fissile, which allows it to split easily along its bedding surfaces. Rocks of similar composition that are not fissile are called mudstone, which has a blocky character.

To say that shale is the product of mechanical accumulation of small clastic fragments in a manner similar to the formation of sandstone is not completely accurate. Shale materials are often stable end-stage weathering products derived from unstable clay-forming minerals. Because they are stable, they no longer respond to chemical breakdown. Clay minerals can be carried in chemically stable **suspensions** and **colloids** and will be deposited by chemical or electrolytic differences in the waters in the depositional areas. In this way, the mode of clay mineral transport is different from the simple mechanical process of moving chemically inert grains from origin to place of deposition.

Shale, with high-preserved organic content, is considered to represent the most favorable of potential source rocks. After their formation waters and fluids are expelled, shales provide sealers for porous reservoir rocks and are instrumental in forming **hydrocarbon traps**. They are not generally considered to be reservoirs, however, although fractured shales can act in that capacity.

Organic-rich shale provides the petroleum source and subsequent seal for the highly productive Tertiary Zelten reef limestone of the Zelten Field in east-central Libya. Upper Paleozoic shale provides source and seal to numerous fields in northeastern Oklahoma as well.

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New Words and Phrases

1. clastic rock 碎屑岩
2. precipitate [pri'sipiteit] *n.* 沉淀物
3. deltaic channel sandstone 三角洲河道砂岩
4. trace mineral 微量矿物

5. fragment [ˈfægmənt] *n.* 碎片
6. mechanical weathering 机械风化
7. original rock 原生岩石,基岩
8. susceptible [səˈseptəbl] *adj.* 易变质的,易受影响的
9. external factor 外界因素
10. texture [ˈtekstʃə] *n.* 结构,构造
11. deformation [ˌdiːfɔːˈmeiʃən, ˌdefə-] *n.* 变形
12. granite [ˈgrænit] *n.* 花岗岩
13. gravel [ˈgrævəl] *n.* 砾石
14. cross-bedding [ˌkrɔsˈbediŋ] *n.* 交错层理
15. ripple mark 波痕
16. graded bedding 粒级层
17. Ordovician [ˌɔːdəˈviʃən] *n.* & *adj.* 奥陶纪(的)
18. Paleozoic [pæliəˈzəuik] *n.* & *adj.* 古生代(的)
19. Gardner [ˈgaːdnə] [美国]加德纳
20. barrier bar 滨外沙坝;障壁坝
21. calcarenite [ˌkælkəˈriːnait] *n.* 灰屑岩
22. laminated [ˈlæməˌneitid] *adj.* 层压的,层积的
23. suspension [səˈspenʃən] *n.* 悬浮,悬浮液
24. colloid [ˈkɔlɔid] *n.* & *adj.* 胶体(的)
25. hydrocarbon trap 油气圈闭

Translation of Difficult Paragraphs

(1) The mechanical properties of clastic rocks are not only affected by the external factors, such as the state of stress and surrounding geological environment, but also strongly dependent on the depositional and sedimentary environments, including components, textures, and structures of the rocks. It is of importance to study the mechanical properties of clastic rocks for energy industry, because oil and gas, as well as coal, are situated in these rocks. Until now, most research on the microstructure of the rock and its deformation and strength behaviors mainly focuses on granites and other hard rocks. Therefore, relations between the sedimentary characteristics and mechanical properties of clastic rocks need to be addressed, particularly those of soft rocks such as mudstone and shale.

碎屑岩的力学性质不仅受到像应力状态、周围地质环境这样的外部因素的影响,而且也强烈地依赖于包括组分、纹理和岩石结构在内的沉积作用和沉积环境。对能源产业而言,研究碎屑岩的力学性质是十分重要的,因为石油和天然气以及煤炭都存在于这些岩石中。到目前为止,关于岩石的微观结构及其变形与强度特性的大多数研究主要集中在花岗岩和其他坚硬的岩石上。因此,碎屑岩,特别是像泥岩、页岩等软岩的沉积特征和力学性质之间的关系是需要解决的问题。

(2) To say that shale is the product of mechanical accumulation of small clastic fragments in a manner similar to the formation of sandstone is not completely accurate. Shale materials are often

stable end-stage weathering products derived from unstable clay-forming minerals. Because they are stable, they no longer respond to chemical breakdown. Clay minerals can be carried in chemically stable suspensions and colloids and will be deposited by chemical or electrolytic differences in the waters in the depositional areas. In this way, the mode of clay mineral transport is different from the simple mechanical process of moving chemically inert grains from origin to place of deposition.

页岩是小的碎屑碎片、以与形成砂岩类似的方式机械积累而成的产物,这种说法不完全准确。形成页岩的物质往往来自不稳定黏土矿物的稳定的终末期风化产物,因为它们是稳定的,因此不再对化学分解作出反应。黏土矿物可以携带在化学上稳定的悬浮物和胶体中,然后由于化学上或电解质的差异在沉积区水域中沉积下来。这样,黏土矿物运输的模式不同于化学惰性颗粒从物源区移动到沉积区的简单机械过程。

Exercises

Ⅰ. Translate the following terms from Chinese to English or English to Chinese.

碎屑岩	mineral constituents
边缘海	reservoir rock
机械风化	original rock
砾岩	chemical breakdown
地层记录	source rock

Ⅱ. Decide whether the following statements are true or false.

1. Clastic rocks are composed of clasts, which are fragments or grains of pre-existing rocks.

2. Chemical breakdown is usually the manner in which the clastic particles are derived from the original rock.

3. Conglomerates contain textures and structures that can be described and photographed, such as pebble shape, grain rounding, cross-bedding, ripple marks, and graded bedding.

4. Certain Ordovician sandstones of mid-continent area are some of the poorly sorted, poorly rounded, graywacke developed anywhere in the world.

5. To say that shale is the product of mechanical accumulation of small clastic fragments in a manner similar to the formation of sandstone is accurate enough.

Ⅲ. Answer the following questions.

1. How can we make a complete description of clastic rocks?

2. How are clastic rocks classified according to the size of the fragments?

3. Why do sedimentary petrologists pay more attention to conglomerates and sandstones?

4. What are the mineral constituents and combinations of quartz sandstone?

5. Why do sandstones often occur as reservoir rocks?

Lesson 3 Components of Carbonate

Carbonate rocks make up about one-fifth to one-quarter of all sedimentary rocks in the stratigraphic record. They occur in many **Precambrian assemblages** and in all geologic systems from **Cambrian** to **Quaternary**. Both limestone and dolomite are well represented in the stratigraphic record. Dolomite is the dominant carbonate rock in Precambrian and Paleozoic sequences, whereas limestone is dominant in carbonate units of **Mesozoic** and **Cenozoic** age.

Sandstones consist dominantly of various kinds of sand and silt-size **silicate** grains with various amounts of fine, siliciclastic mud matrix and secondary cements, including carbonate cements. The mineralogy of carbonate rocks is almost totally different from that of sandstones, but many limestones resemble sandstones texturally in that they consist of various kinds of sand- and silt-size carbonate grains and various amounts of fine lime mud matrix and carbonate cements.

Although limestones commonly contain only one or two dominant minerals, in contrast to sandstones, several distinct kinds of carbonate grains are recognized. Most of these grains are not single crystals but are composite grains made up of large numbers of small **calcite** or **aragonite** crystals. Folk (1962) proposed the term **allochem** to cover all of these organized carbonate **aggregates** that make up the bulk of many limestones. Carbonate grains include both nonskeletal grains (e. g. lithoclasts, ooids) and skeletal grains (fossil and fossil fragments).

Carbonate grains

Peloids are spherical, ovoid, or rod-shaped, mainly silt-sized carbonate grains that commonly lack definite internal structure. They are generally dark gray to black owing to contained organic material and may or may not have a thin, dark outer rim. The most common size of peloids ranges from about 0. 05 to 0. 20 mm, although some are much larger. Peloids are composed mainly of fine micrite 2 to 5 microns in size, but larger crystals may be present. They are commonly well sorted and they may occur in clusters.

Coated grain is a general term used for all carbonate grains composed of a **nucleus** surrounded by an enclosing layer or layers commonly called the cortex. Various kinds of coated grains are recognized, largely on the basis of the structure of the cortex. Coated grains are divided into four broad groups:

(1) Calcareous ooids are small, more or less spherical to oval carbonate particles, which are characterized by the presence of concentric laminae that coat a nucleus. The nucleus may be a skeletal fragment, peloid, smaller ooid, or even a siliciclastic grain such as a quartz grain. Most ooids are sand- to silt-size particles. They range in size from about 0. 1 to more than 2 mm, with 0. 5 to 1 mm being most common.

(2) Coated grains more irregular in shape than ooids, and with more irregular laminae, are