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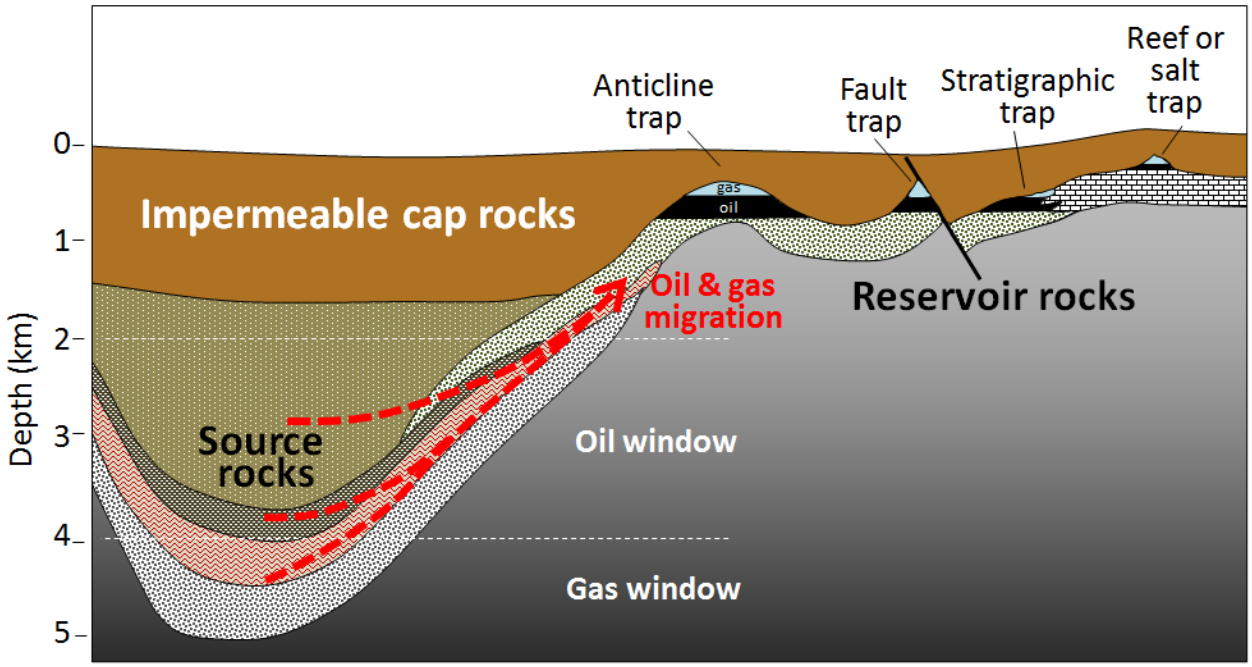
Petroleum Geology



Ижевск
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Кафедра иностранных языков в сфере права, экономики и управления
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Учебно-методическое пособие

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Рецензент: канд. филос. наук, доцент каф. иностр. яз. и речевой коммуникации Московского Международного университета Т.И. Галеева.

Составители: Роева К.М., Сушенцова Т.В.

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Данное методическое пособие предназначено для студентов Института нефти и газа, обучающихся по специальности «Геология нефти и газа». Пособие может быть использовано преподавателями для проведения практических занятий по иностранному языку, предполагает самостоятельную подготовку студентов к занятию и представляет интерес для желающих развить коммуникативные способности по специальности на иностранном языке.

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ОГЛАВЛЕНИЕ

ПРЕДИСЛОВИЕ

Учебно-методическое пособие представляет собой материал для углубленного изучения геологии нефти и газа на английском языке и может использоваться преподавателями вузов на практических занятиях по дисциплине «Иностранный язык в профессиональной и деловой коммуникации» или «Иностранный язык в академической и профессиональной коммуникации» (английский язык). Главная задача – предложить пути развития коммуникативных навыков у студентов неязыковых специальностей, которые необходимо сформировать для успешной реализации процесса изучения иностранного языка в рамках высшего учебного заведения. Развитие коммуникативных навыков включает в себя не только свободное владение языковыми единицами, но и правильное построение предложений в соответствии с грамматическими нормами изучаемого языка, распознавание грамматических формул и их использование при говорении.

Данное учебно-методическое пособие рассчитано на студентов, обладающих базовыми грамматическими и лексическими знаниями по тематике «Геология нефти и газа» и содержит более детальную информацию по профилю на иностранном языке. Пособие состоит из следующих разделов: The Earth crust – where we find it, Deformation of sedimentary rocks. Тексты заданной тематики сопровождаются упражнениями, направленными на закрепление лексического и грамматического материала, отраженного в текстах**.**

С помощью представленных в работе видов коммуникативной деятельности удается сформировать необходимые навыки языковой и грамматической компетенции, которыми должен обладать выпускник (УК-4 Способен осуществлять деловую коммуникацию в устной и письменной формах на государственном языке Российской Федерации и иностранном (-ых) языке (-ах)).

Данное методическое пособие основано на книге Hyne N. J. Nontechnical guide to petroleum geology, exploration, drilling and production (2nd Edition). Также использована информация со следующих сайтов:

http://www.mirnefti.ru/index.php?id=9
http://www.liberty-oil.ru
http://enc.guru.ua/index.php?title_id=100
http://ru.wikipedia.org/
http://www.planete-energies.com/en/energy-sources-/oil-and-gas/
http://geology.wikia.com/
http://www.glossary.oilfield.slb.com/

http://www.unctad.org/infocomm/anglais/gas/characteristics.htm
http://www.sjvgeology.org
https://www.geolsoc.org.uk/ks3/gsl/education/resources/rockcycle/page3572.html
https://studopedia.org/1-54961.html
https://studopedia.org/1-54961.html
http://www.thefullwiki.org/Unconformity

Данное пособие будет востребовано в учебном процессе, как преподавателями для проведения практических занятий по иностранному языку, а также для самостоятельной работы студентов. Может быть рекомендовано студентам Института Нефти и газа, получающим дополнительное высшее образование в сфере «Переводчик в сфере профессиональной коммуникации».

Part 1: The Earth crust – where we find it.

Mind the definitions

Aggregate	агрегат (скопление, срастание минералов, составляющих горную породу)	A rock is an aggregate of minerals and/or mineraloids and does not have a specific chemical composition.
Basement rock	подстилающая порода, фундамент	The term basement rock is used to define the rocks below a sedimentary platform or cover.
Brine	солёная вода; рассол, минерализованная вода,	Brine is commonly produced during well completion operations, particularly after the hydraulic fracturing of a well.
Calcite	кальцит, карбонат кальция, известковый шпат	Limestone is a sedimentary rock composed almost entirely of the mineral calcite.
Clastic sediments	обломочные отложения, терригенные	Clastic sediments are composed of fragments, or clasts, of pre-existing rock.
Clean sand	чистый песок	A “clean” sand consists of about 90 percent quartz.
Connate water	реликтовая вода; связанная вода	Connate water can be dense and saline compared with seawater.
Crystalline sediments	кристаллические осадочные породы	Chemical or crystalline sediments are formed from mineral solutions.
Dirty sand	заиленный песок	A “dirty” sand has more than 10 percent other material and/or silt mixed in.
Explore	вести разведку	The company explored for oil.
Fine-grained	мелкозернистый	Basalt is a dark-colored, fine-grained, igneous rock composed mainly of plagioclase and pyroxene minerals.
Ground water	грунтовая вода	Typically, groundwater is thought of as liquid water flowing through shallow aquifers.
Igneous	вулканического происхождения, магматический	In general, rocks are of three types, namely igneous, sedimentary, and metamorphic.
Interpret	объяснять, толковать,	The evidence is difficult to interpret.

Intrusion	внедрение, интрузия	They are also formed when rock is heated up by the intrusion of hot molten rock called magma from the Earth's interior.
Insulator	диэлектрик; изолятор; непроводник	It is not easy to choose the best insulator among the variety of those that are available at the market these days.
Lithology	литология	Lithology focuses on macroscopic hand-sample or outcrop-scale description of rocks.
Loose sediments	рыхлые отложения	The process of turning loose sediment into hard is called lithification.
Metamorphic	метаморфический, метаморфный	Metamorphic rocks arise from the transformation of existing rock types, in a process called metamorphism, which means “change in form”.
Mineral	минерал	Minerals range in composition from pure elements and simple salts to very complex silicates with thousands of known forms.
Overlie	перекрывать (залегать выше)	Soft clays overlie the basalt.
Plutonic	интрузивный	A pluton in geology is a body of intrusive igneous rock (called a plutonic rock) that crystallized from magma slowly cooling below the surface of the Earth.
Rock	порода	The scientific study of rocks is called petrology, and petrology is an essential component of geology.
Seashell	морская ракушка	Seashells have been admired, studied and used by humans for many different purposes throughout history and pre-history.
Stratification	напластование, наслоение	The upper units of stratification are younger and the lower are older.
Underlay	подстилать	The green fields are underlaid with limestone.
Volcanic	эффузивный	Volcanic rocks are among the most common rock types on Earth's surface, particularly in the oceans.
Water table	уровень грунтовых вод	In permeable or porous materials, such as sands and well fractured bedrock, the water table forms a relatively horizontal plane.

Rocks and Minerals

The earth is composed of rocks, which are aggregates of small grains or crystals called minerals (Fig. 1-1). Minerals are naturally occurring, relatively pure chemical compounds. Examples of minerals are quartz (SiO_2) and calcite ($CaCO_3$). Rocks can be composed of numerous grains or several different minerals. The rock **granite**, for example, is composed of the minerals quartz, **feldspar**, **hornblende**, and **biotite**. Rocks can also be composed of numerous grains of the same mineral. The rock limestone consists only of calcite mineral grains.

Granite – гранит
Feldspar – полевой шпат
Hornblende – роговая обманка, роговик
Biotite – биотит (чёрная слюда)

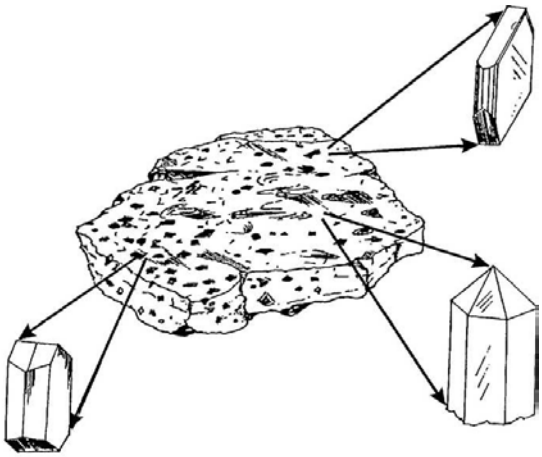


Fig. 1-1 Mineral grains in a rock

Rocks have been formed throughout the billions of years of earth's history. The same chemical and physical processes that form rocks today formed rocks throughout geological time. The **molten** lava flowing out a volcano in Hawaii or Italy today is forming lava rock similar to lava rock formed millions and billions of years ago. Ancient sandstone rock composed of sand grains was formed the same way sand is deposited today: along **beaches**, in river channels, and on desert **dunes**. There is nothing unusual about ancient rocks. They formed the same way rocks are forming today.

Molten – расплавленный
Beach – морской берег, взморье; отмель
Dune –дюна

Answer the questions:

1. What can rocks be composed of?
2. How are rocks formed?

Type of rocks

Three types of rocks make up the earth's crust: igneous, sedimentary, and metamorphic. Igneous rocks have been **crystallized** from a hot, molten liquid. Sedimentary rocks are composed of sediments that were deposited on the surface of the ground or bottom of the ocean or salts that **precipitated** out of water. Metamorphic rocks have been recrystallized from other rocks under high temperatures and pressures.

Crystallize – вызвать процесс кристаллизации, кристаллизовать
Precipitate – выпадать в осадок

Answer the questions:
1. What are the types of rocks?
2. How are they formed?

Igneous rocks

Igneous rocks are formed when a molten **melt** is cooled. Two types of igneous rocks are plutonic and volcanic, depending on where they formed.

Plutonic igneous rocks crystallized and solidified while still below the surface of the earth. Because the rocks that **surround** the cooling plutonic rocks are good insulators, plutonic rocks often take thousands of years to solidify. When a cooling melt is given a long time to crystallize, large mineral crystals are formed. Plutonic igneous rocks are easy to **identify** because the mineral crystals are all large enough to be seen by the naked eye. Plutonic rocks are formed as hot liquids that were injected into and **displaced preexisting** rocks in the subsurface. Because of this, plutonic rock bodies are called intrusions.

Volcanic igneous rocks crystallize on the surface of the earth as lava. As the lava flows out of a volcano, it immediately comes in contact with air or water and rapidly solidifies. The rapid crystallization forms very small crystals that are difficult to **distinguish** with the naked eye.

Melt – таять, расплавленное вещество
Surround – окружать; обступать
Identify – опознавать, распознавать;
Displace – вытеснять, заменять, замещать
Preexisting – существующие ранее
Distinguish – находить отличия; различать, распознавать

Answer the questions:
1. What are the types of igneous rocks?
2. How are plutonic igneous rocks formed?
3. How are volcanic igneous rocks formed?

Sedimentary rocks

Sedimentary rocks are composed of sediments of which there are three types. Clastic sediments are whole **particles** that were formed by the breakdown of rocks and were transported and deposited as whole particles. **Boulders**, sand grains, and mud particles are examples. Organic sediments are formed biologically such as seashells. Crystalline sediments are formed by the precipitation of salt out of water. As sediments are buried in the subsurface, they become solid, sedimentary rocks. Sedimentary rocks are the rocks that are drilled to find gas and oil. They are the source and reservoir rocks for gas and oil.

Particle – частица; крупица
Boulder – осадочный валун, диаметром не более 256 мм.

Loose sediments (unconsolidated sediments) become relatively hard sedimentary rocks (**consolidated sediments**) in the subsurface by the processes of **cementation** and **compaction**. No matter how some sediments such as sand grains are packed together, there will be pore spaces between the grains (Fig. 1-2). Once the grains have been buried in the subsurface, the pore spaces are **filled** with water that can be very salty. Under the higher temperatures and pressures of the subsurface, salts often precipitate out of the subsurface waters to **coat** the grains. These coatings grow together to **bridge** the loose grains. This process, called cementation, **bonds** the loose grains into a solid sedimentary rock. Two common cements are the minerals calcite ($CaCO_3$) and quartz ($Si0_2$). Also, as the sediments are buried deeper, the increasing weight of overlying rocks **exerts** more pressure on the grains. This compacts the sediments that also solidify the rock.

Consolidated sediments – уплотненные осадочные породы
Cementation – цементирование. скрепление, объединение
Compaction – уплотнение
Fill – наполнить
Coat – покрывать слоем чего-л
Bridge – соединять
Bond – связывать, соединять, скреплять
Exert – оказывать

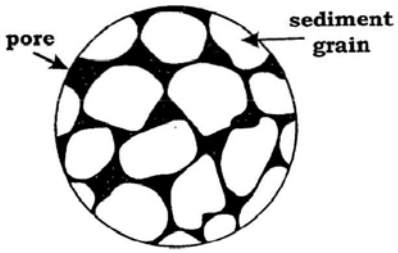


Fig. 1-2 Microscopic view of pores between sediment grains

Sedimentary rocks often consist of three parts when **examined** under a microscope (Fig. 1-3). First, there are sediment grains. These are composed of minerals such as quartz or feldspar or seashells. Second, there are natural cements coating and bonding the grains together. Third, there are pore spaces. The pores are filled with fluids (water, gas, or oil) in the subsurface.

Examine – исследовать; изучать

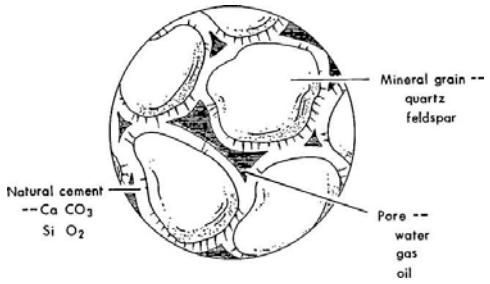


Fig. 1-3 Clastic sedimentary rock under a microscope

There is an enormous amount of water below the surface of the ground, called ground water, in the pores of the sedimentary rocks (Fig. 1-4). Ground water is described by salt content in parts per thousand (ppt). Fresh water contains so little salt (0-1 ppt) that it can be used for **drinking water**.

Drinking water – питьевая вода

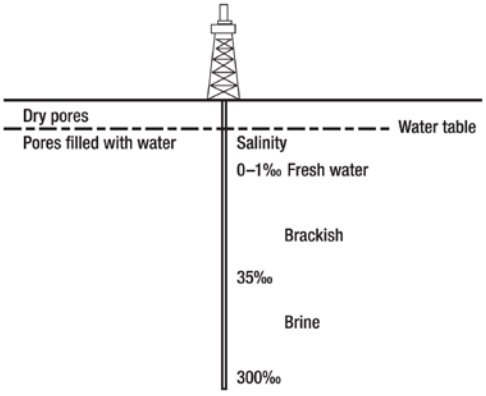


Fig. 1-4 Groundwater

Brines are subsurface waters that contain more salt than **seawater** (35-300 ppt). **Brackish waters** are mixtures of fresh waters and brines (1-35 ppt). Below the surface is a boundary called the water table between the dry pores above and pores that are filled with water below. The water table can be on the surface or very deep depending on how much rain falls in that area. Just below the water table, the ground water is usually **fresh** because

Seawater – морская вода

Brackish water – солоноватая вода

Fresh – пресный

Percolate – просачиваться,

of rain water that **percolates** down from the surface. Deep waters, however, are usually brines. When a well is drilled, completed, and producing, near-surface fresh waters must be protected. **Meteoric water** is fresh, subsurface water. Connate water is saline, subsurface water that has been out of contact with the atmosphere for a long time. Connate water is often water that was originally trapped in the sediments when they were deposited.

проникать сквозь
Meteoric water – подземные воды, образовавшиеся при просачивании атмосферных осадков

The sizes of the clastic grains that make up an ancient sedimentary rock are important. The rock is often classified according to the grain size. Sandstones are composed of sand-sized grains whereas shales are composed of fine-grained (clay-sized) particles. Also, the size of the grains controls the size of the pore spaces and the quality of the oil or gas reservoir. Larger grains have larger pores between them. It is easier for fluids, such as gas and oil, to flow through larger pores. Clastic grains in sedimentary rocks are classified by their diameters in millimetres (Fig. 1-5). They are called boulder, **cobble**, **pebble**, **granule**, sand, **silt**, and clay-sized particles. The finest grains (i.e., sand, silt, and clay-sized) are the most common.

Cobble –крупная галька (размером 64-256 мм)
Pebble –гравий
Granule – гранула; мелкая частица (2-4 мм)
Silt – мелкозем, частицы почвы 0,05-0,002 мм в диаметре)

Sorting is the range of particle sizes in the rock (Fig. 1-6). A well-sorted rock is composed of particles of approximately the same size (Fig. 1-6a). A poorly-sorted, rock is composed of particles with a wide range of sizes (Fig. 1-6b). Sorting is the most important factor in **determining** the amount of original pore space in a clastic sedimentary rock. Finer-sized particles in a poorly sorted rock occupy the spaces between the larger-sized particles and **reduce** the volume of the pores. Poorly sorted rocks can **hold** less fluids and are lower-quality reservoir rocks than well-sorted rocks. Well-sorted sandstones are called clean sands. Because sand grains are light in colour, clean sandstones are usually light in colour. Poorly sorted sandstones with significant amounts of silt- and clay-sized grains are called dirty sands. Because silt- and clay-sized particles are usually dark in colour, dirty sandstones are dark coloured.

Sorting – сортировка, классификация
Determine – определять устанавливать
Reduce – понижать сокращать, уменьшать
Hold – сохранять, удерживать
Layering – наслаивание

Sedimentary rocks are identified by their **layering**, called stratification or **bedding**. As the sediments are deposited, there are frequent variations in the amount and composition of sediment supply and the level of the ocean that **cause** the layering. Sediment layers are originally deposited horizontal in water. Geologists can interpret how sedimentary rocks were deposited. Lithology (rock composition) is an important clue as to how a sedimentary rock was formed. Sand grains, mud particles, and shell beds each form different sedimentary rocks. Each is originally deposited in a very different **environment**. Sedimentary structures such as **ripple marks**, **mud cracks**, and **flow marks** help to visualize the environment in which the rock was deposited. Another aid to interpretation is fossils, preserved remains of plants and animals.

Bedding – напластование; наслоение, слоистость; залегание

Cause – вызывать

Environment – окружение

Ripple marks – рябь

Mud crack – трещина усыхания

Flow mark – знак течения, след потока

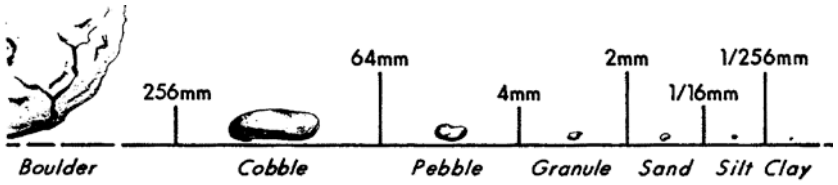


Fig. 1-5 Grain size in millimetres

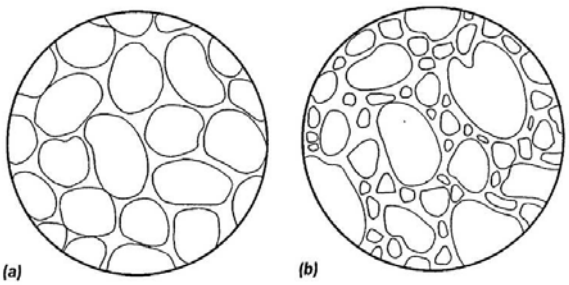


Fig. 1-6 Particle sorting (a) well sorted, (b) poorly sorted

Answer the questions:

1. What are three types of sedimentary rock?
2. How can loose sediments become hard?
3. What are three parts the sedimentary rocks often consist of?
4. What types of water are there?
5. What is rock classified according to?
6. What is the difference between well- and poorly-sorted rocks?
7. How are sediments deposited?

Metamorphic rocks

Metamorphic rocks are any rocks that have been **altered** by high heat and pressure. **Marble** ($CaCO_3$), a metamorphic rock, is metamorphosed limestone ($CaCO_3$), and quartzite (SiO_2) is metamorphosed quartz sandstone (SiO_2). Since temperatures and pressures become greater with depth, a rock often becomes metamorphosed when buried deep in the earth.

Alter – изменять, видоизменять
Marble – мрамор

Structure of the Earth's Crust

The earth is **estimated** to be about 4.5 billion years old. Even the sedimentary rocks that generated and hold the gas and oil are millions to hundreds of millions of years old. During that vast expanse of geological time, sea level has not been constant. Sea level has been rising and falling. During the rise and fall of sea level, sediments were deposited in layers. Sands were deposited along the ancient beaches. Mud was deposited in the shallow seas offshore. Seashells were deposited in shell beds. These ancient sediments form the sedimentary rocks that are drilled to find gas and oil. The rise and fall of sea level has occurred in numerous **cycles** (Fig. 1-7). The largest cycles occured every few hundreds of millions of years. There are shorter cycles on the large cycles and even shorter cycles on them. At least five **orders** of sea level cycles have occurred, with the shortest occurring every few tens of thousands of years. The shorter cycles are thought to be caused by the **freezing** and melting of **glaciers**.

Estimate – оценивать
Cycle – цикл, (хронологический) период
Order – порядок, последовательность
Freeze – замерзать, обледеневать
Glacier – ледник

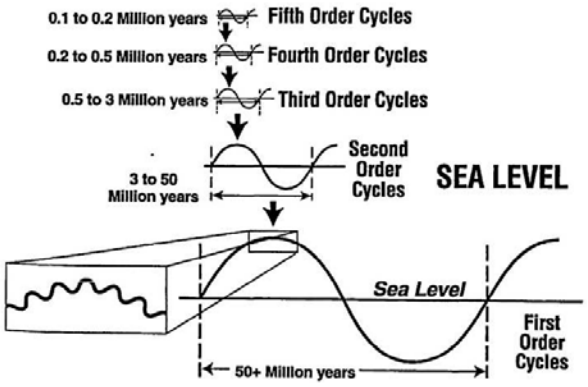


Fig. 1-7 Sea level cycles (Hyne, 1995)

In a typical section of the earth's crust such as Tulsa, Oklahoma, about 5000 ft (1500 m) of well-layered sedimentary rocks are underlain by very old metamorphic or igneous rocks (Fig.1-8).

There are about one hundred layers of sedimentary rocks. Sands form the rock sandstone. Mud forms the rock shale. Sea shells form the rock limestone. The **unproductive** rocks, usually igneous and metamorphic rocks underlying the sedimentary rocks, are called basement rocks. When drilling encounters basement rock, the drilling is usually stopped.

Unproductive – непродуктивный
Shield – щит
Ore – руда

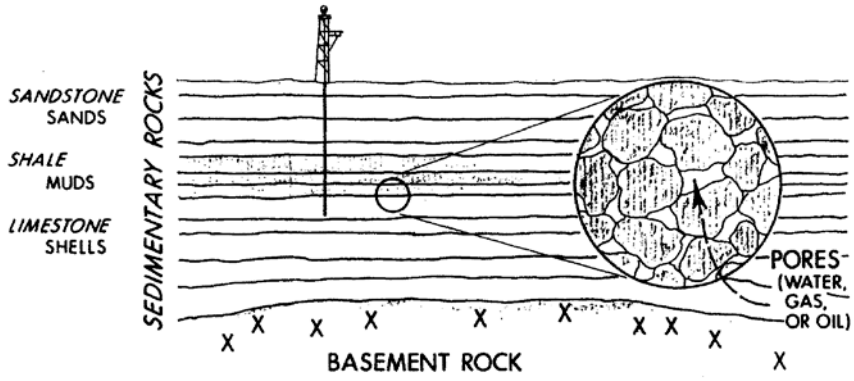


Fig. 1-8 Cross section of the earth's crust

In some areas of the earth, there are no sedimentary rocks, and the basement is on the surface. These areas are called **shields**, and there is no gas or oil. Every continent of the world has at least one shield area (Fig. 1-9). A shield, such as the Canadian shield in eastern Canada, tends to be a large, low-lying area. **Ore** minerals such as **iron**, **copper**, **lead**, **zinc**, **gold**, and **silver** are **mined** from the basement rock in shield areas. The southwest portion of Saudi Arabia is a shield. All the Saudi Arabian oil fields are located in sedimentary rocks to the northeast of the Arabian Shield.

Iron – железо
Copper – медь
Lead – свинец
Zinc – цинк
Gold – золото
Silver – серебро
Mine – разрабатывать рудник; добывать

Fig. 1-9 Map of the world showing the location of shields in black where unproductive rocks for gas and oil occur on or near the surface

In other areas called basins, the sedimentary rocks are very thick. The Caspian basin (Caspian Sea) has about 85,000 ft (26,000 m) of sedimentary **rock cover**. However, 20,000 to 40,000 ft (6,000 to 12,000 m) of sedimentary rocks is typical of many basins. Basins such as the Gulf of Mexico, the Anadarko basin of southwestern Oklahoma, and the Denver- Julesburg basin of Colorado are large areas that are often more than 100 miles (160 km) across.

Rock cover – осадочный чехол

It is in the sedimentary rock basins that the most gas and oil is found and produced. Because of the thick sedimentary rock, most basins have source rocks that have been buried deep enough in the geological past to generate gas and oil (Fig. 1-10). The deep part of the basin where the gas and oil forms is called the **kitchen** or oven. After the gas and oil is generated, it flows upward in the overlying rocks. If it intersects a layer of reservoir rock, the gas and oil then migrates through the **interconnected** pores of the reservoir rock layer up the **flanks** of the basin where it can be trapped and concentrated. The trap, such as an anticline, is a relatively small feature compared to the basin. Numerous traps can occur along the flanks of the basin.

Kitchen – зона образования УВ
Interconnected – связанный, взаимосвязанный; соединённый,
Flank – бок; край, сторона

There are about 600 sedimentary rock basins in the world. Of the basins that have been explored and drilled, about 40% are very productive. About 90% of the world's oil occurs in only 30 of those basins. The other

Barren – пустой, не содержащий полезного ископаемого, безрезультатный

60% of the explored basins are **barren**. The unproductive basins either have no source rocks, the source rocks have never been buried deep enough to generate gas and oil, or the basin was overheated, and the oil was destroyed.

(о скважине) нефтенепродуктивный.

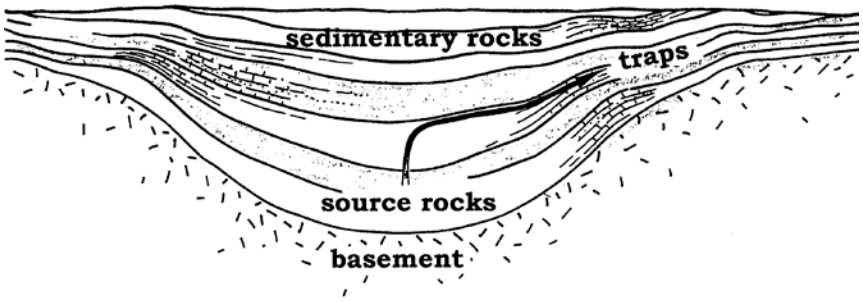


Fig. 1-10 Cross section of sedimentary rock basin

Answer the questions:

1. What are metamorphic rocks?
2. Where were different sedimentary rocks deposited?
3. How often did cycles occur?
4. What is a shield?
5. What can you tell about basins?

Exercises

Exercise № 1. **Match English words with their Russian equivalents.**

1. geological time	a) разлом породы
2. lava rock	b) быстрая кристаллизация
3. the same way	c) геологический период
4. rapid crystallization	d) рыхлые породы
5. preexisting rocks	e) возрастающий вес
6. whole particles	f) покрывать зерна
7. breakdown of rocks	g) вулканическая порода
8. loose sediments	h) породы, существовавшие ранее
9. to coat the grains	i) цельные частички
10. increasing weight	j) таким же образом

Exercise № 2. Make up word combinations and translate them.

1. molten	a) sediments
2. earth’s	b) crust
3. metamorphic	c) rocks

4. physical	d) hard
5. plutonic	e) process
6. clastic	f) lava
7. organic	g) sediments
8. crystalline s	h) rocks
9. relatively	i) grains

Exercise № 3. Match English words with their Russian equivalents.

1. exert more pressure	a) подземные воды
2. water table	b) мелко-зернистые частички
3. dry pores	c) оказывать больше давления
4. meteoric water	d) непродуктивная порода
5. fine-grained particles	e) чистый песчаник
6. clean sandstone	f) уровень грунтовых вод
7. interconnected pores	g) подниматься и опускаться
8. ripple marks	h) взаимосвязанные поры
9. rise and fall	i) пустые поры
10. unproductive rock	j) рябь

Exercise № 4. Make up word combinations and translate them.

1. salt	a) trapped
2. drinking	b) rock
3. connate	c) color
4. originally	d) basins
5. well-sorted	e) water
6. light in	f) water
7. dirty	g) rocks
8. mud	h) environment
9. basement	i) cracks
10. different	j) content
11. barren	k) water
12. ground	l) sands

Exercise № 5. Match words with their definitions.

igneous rock mineral precipitate intrusion cementation bridge brackish waters bedding percolate sorting shields kitchen

1. Rock that is formed through the cooling and solidification of magma or lava.

2. Forms and spatial position of rocks in the earth’s crust.

3. A naturally occurring solid chemical substance formed through biogeochemical processes, having characteristic chemical composition, highly ordered atomic structure, and specific physical properties.

4. The range of sedimentary grain sizes that occurs in sediment or sedimentary rock.

5. Water that has more salinity than fresh water, but not as much as seawater.

6. Part of the continental crust in which these usually Precambrian basement rocks crop out extensively at the surface.

7. Cause (drops of moisture or particles of dust) to be deposited from the atmosphere or from a vapour or suspension.

8. Liquid rock that forms under Earth's surface.

9. The binding together of particles or other things by cement.

10. To connect pore spaces or fluid paths in a rock formation.

11. (Of a liquid or gas) filter gradually through a porous surface or substance.

12. An area of the subsurface where source rock has reached appropriate conditions of pressure and temperature to generate hydrocarbons.

Exercise № 6. Complete the definitions given.

1. A material or structure formed from a loosely compacted mass of fragments or particles.

2. Form or cause to form crystals again.

3. A rock formed from magma erupted from a volcano.

4. The depth at which soil pore spaces or fractures and voids in rock become completely saturated with water.

5. Water trapped in the pores of a rock during formation of the rock.

6. A description of its physical characteristics visible at outcrop, in hand or core samples or with low magnification microscopy, such as colour, texture, grain size, or composition.

7. Rocks that result when magma cools and crystallizes slowly within the Earth's crust (example granite).

8. Change (something) to a liquid condition by heating it.

9. A solution of salt (usually sodium chloride) in water.

10. A process that returns to its beginning and repeats itself in the same sequence.

11. A large-scale structural formation of rock strata.

12. Be situated under (something).

Exercise № 7. Fill the gaps using the words given.

examples precipitation minerals drinking water metamorphic rocks aggregates grains igneous rocks plutonic rocks the unproductive basins a poorly-sorted water table volcanic Loose sediments brackish waters ground water connate water clean sands the grain size cementation fossils shields stratification to coat basins the oven

1. … have been recrystallized from other rocks under high temperatures and pressures.
2. Boulders, sand grains, and mud particles are … .
3. Because the rocks that surround the cooling plutonic rocks are good insulators, … often take thousands of years to solidify.
4. The earth is composed of rocks, which are … of small grains or crystals called minerals.
5. Rocks can be composed of numerous … or several different … .
6. Crystalline sediments are formed by the … of salt out of water.
7. Fresh water contains so little salt (0-1 ppt) that it can be used for … .
8. … have crystallized from a hot, molten liquid.
9. …become relatively hard sedimentary rocks in the subsurface by the processes of cementation and compaction.
10. The … can be on the surface or very deep depending on how much rain falls in that area.
11. …igneous rocks crystallize on the surface of the earth as lava.
12. Salts often precipitate out of the subsurface waters … the grains.
13. This process, called …, bonds the loose grains into a solid sedimentary rock.
14. There is an enormous amount of water below the surface of the ground, called …, in the pores of the sedimentary rocks.
15. The rock is often classified according to … .
16. … either have no source rocks, the source rocks have never been buried deep enough to generate gas and oil, or the basin was overheated, and the oil was destroyed.
17. … is often water that was originally trapped in the sediments when they were deposited.
18. Well-sorted sandstones are called … .
19. In some areas of the earth, called …, there are no sedimentary rocks, and the basement is on the surface.
20. Another aid to interpretation is …, preserved remains of plants and animals.
21. …are mixtures of fresh waters and brines.
22. In other areas called …, the sedimentary rocks are very thick.
23. Sedimentary rocks are identified by their layering, called … .

24. The deep part of the basin where the gas and oil forms is called … .

25. …rock is composed of particles with a wide range of sizes.

Exercise № 8. Insert the verbs from brackets into correct form in Conditional sentences.

1. If the cooling (to be) so rapid as to prevent the formation of even small crystals after extrusion, the resulting rock may be mostly glass.

2. If the cooling of the lava happened slowly, the rocks (to be) coarse-grained.

3. The minute structures, however, disappear, often completely, if the thermal alteration (to be) very profound; thus small grains of quartz in a shale are lost or blend with the surrounding particles of clay, and the fine ground-mass of lavas is entirely reconstructed.

4. If the anticlines are relatively young, they (not to erode) and appear as topographic ridges on the surface.

5. If an area of the earth's crust is compressed, the rocks (to fold) into anticlines and synclines.

6. If folds (to be) present in the rocks of the earth's crust, that area probably has been compressed some time in the past.

7. If the ancient reef is covered with a shale or salt caprock, it (to form) a gas and oil trap.

8. If the contour line elevations (to increase) in a direction, the slope is rising.

9. If the contours (to be spaced) relatively close together, the elevation is changing rapidly, and the slope is steep.

10. If the source rock is buried deeper, where temperatures are above 300°F (150°C), thermogenic gas (to generate) from organic matter left in the source rock.

11. Oil can be generated at lower temperatures if the source rock (to expose) to those temperatures for a longer time.

12. If there is no trap on the migration route, the gas and oil (to flow) out onto the surface as a gas or oil seep.

13. If there (to be) a trap along migration route, the gas and oil will accumulate in the trap.

14. If the trap (to form) after the migration, no gas and oil will occur in the trap

15. If the trap has been filled with oil and gas down to the spill point and more migrates into the trap, some of the oil (to spill) out the side of the trap.

16. If a large mass of magnetite-bearing rock (to occur) near the surface, it is detected by a larger magnetic force than the normal, regional value

17. If the seismic velocities through the rocks (to know), the structure-contour and isotime maps can be converted into structural and isopach maps.

18. If the reflections from two intersecting seismic records (not to correlate), it is called a mis-tie**.**

19. If no well is available, a stratigraphic test well (to drill) on the seismic line.

Exercise № 9. Translate sentences into English.

1. Магматические горные породы – это породы, образовавшиеся непосредственно из магмы (расплавленной массы преимущественно силикатного состава, образованной в глубинных зонах Земли), в результате её поступления в верхние горизонты Земли, охлаждения и застывания.

2. Магматические горные породы (интрузивные и эффузивные) классифицируются в зависимости от размера кристаллов, текстуры, химического состава или происхождения.

3. Горные породы вулканического происхождения, которые образовались на глубине, называются плутоническими или интрузивными.

4. Те породы, которые образовались в результате излияния на поверхность, называются эффузивными (излившимися) или вулканическими.

5. Благодаря быстрому остыванию, кристаллы в них мелкие, практически не различимы невооружённым глазом (базальт, риолит и др).

6. Интрузивные породы образуются за счёт полной раскристаллизации магматического расплава. Образуются глубоко в недрах Земли (от 5 до 40 км) в течение большого времени, при относительно постоянных температуре и давлении.

7. Грунто́вые воды образуют водоносный горизонт на первом от поверхности водоупорном слое. В связи с неглубоким залеганием от поверхности уровень грунтовых вод испытывает значительные колебания по сезонам года: он то повышается после выпадения осадков или таяния снега, то понижается в засушливое время. В суровые зимы грунтовые воды могут промерзать. Эти воды в большей мере подвержены загрязнению.

8. Солоноватая вода – вода, содержащая больше солей, чем пресная вода, но не больше чем морская вода.

9. Технически солоноватая вода содержит от 0,5 до 30 граммов соли на литр.

10. Пре́сная вода́ – противоположность морской воды, охватывает ту часть доступной воды Земли, в которой соли содержатся в минимальных количествах.

11. Вода, солёность которой не превышает 0,1 %, даже в форме пара или льда называется пресной.

12. Ледяные массивы в полярных регионах и ледники содержат в себе наибольшую часть пресной воды земли. Помимо этого, пресная вода существует в реках, ручьях, пресных озёрах, а также в облаках.

13. По разным подсчётам доля пресной воды в общем количестве воды на Земле составляет 2,5-3 %.

14. Около 85-90 % запасов пресной воды содержится в виде льда.

15. Литоло́гия (от *лито* – камень… и …*логия* – слово) – наука об осадочных породах и современных геологических осадках, их вещественном составе, строении, закономерностях и условиях образования и изменении.

16. Более строго литологию можно определить как отрасль объективного знания о составе, отношениях и связях между геологическими телами и слагающими их породами, образованными при процессах, происходящих в гидросфере, атмосфере и биосфере.

17. Классификация обломочных пород основана на величине обломков. Выделяют следующие виды обломочных пород:1. крупнообломочные породы или псефиты – размер обломков более 1 мм. Это валуны, галька, гравий и другие.2. среднеобломочные породы или псаммиты – размер зерен от 0,1 до 1,0 мм. Это пески и песчаники.

18. Песчаники представляют собой сцементированные пески.

19. Минералом принято называть природное химическое соединение, являющееся составной частью земной коры.

20. Каждый минерал обладает своей химической формулой, однако состав минерала довольно изменчив.

21. Минерал представляет собой решетку, в которой атомы одних элементов занимают строго определенное положение относительно других. Любому кристаллу и минералу свойственна своя кристаллическая решетка.

22. Каждый минерал имеет определенные физические свойства, такие как твердость, блеск, удельный вес, цвет и т. д. Минералы образуются везде: в недрах земли, в болотах, в пустынях, в озерах. Большинство минералов образуется из магмы.

23. Горные породы – это составляющая земной поверхности. Образовались горные породы около 4600 миллионов лет назад из природных кристаллических веществ – минералов.

24. Породы обладают разнообразными цветами и строением, но все они делятся на три типа: осадочные, магматические и метаморфические. Причем земные породы медленно выветриваются и постоянно превращаются друг в друга.

25. Канадский щит – выступ докембрийского складчатого фундамента, занимающий северную половину Северо-Американской (Канадской) платформы, включая Гренландию. Состоит из ограниченных разломами плит, образованных метаморфированными и гранитизированными складчастыми участками архейской и протерозойской эпохи, с которыми связаны расположения здесь руд железа, золота, меди, никеля, кобальта, урана, свинца, цинка и др.

Exercise № 10. Render the text.

Го́рные поро́ды – природная совокупность минералов более или менее постоянного минералогического состава, образующая самостоятельное тело в земной коре. Планеты и другие твёрдые космические объекты состоят из горных пород.

По происхождению горные породы делятся на три группы: магматические (эффузивные и интрузивные), осадочные и метаморфические. Магматические и метаморфические горные породы слагают около 90 % объёма земной коры, однако, на современной поверхности материков области их распространения сравнительно невелики. Остальные 10 % приходятся на долю осадочных пород, занимающие 75 % площади земной поверхности.

Магматические горные породы по своему происхождению делятся на эффузивные и интрузивные. Эффузивные (вулканические) горные породы образуются при изливании магмы на поверхность земли. Интрузивные горные породы, напротив, возникают при изливании магмы в толще земной коры.

Разделение пород на магматические, метаморфические и осадочные не всегда очевидно. В осадочных горных породах, в процессе диагенеза, уже при очень низких (в геологическом смысле) температурах, начинаются минеральные превращения, однако породы считаются метаморфическими при появлении в них новообразованного гранита. При умеренных давлениях начало метаморфизма соответствует температуре 300 °C.

При высоких степенях метаморфизма стирается грань между метаморфическими и магматическими горными породами. Начинается плавление пород, смешение новообразованных расплавов с явно внешними. Часто наблюдаются постепенные переходы от явно метаморфических, полосчатых пород, к типичным гранитам.

Магматические горные породы

По глубине формирования породы делятся на три группы: породы кристаллизующиеся на глубине – интрузивные горные породы, например, гранит. Они образуются при медленном остывании магмы и обычно хорошо раскристаллизованны; гипабиссальные горные породы образуются при застывании магмы на небольших глубинах, и часто имеют неравномерно зернистые структуры (долерит). Эффузивные горные породы формируются на земной поверхности или на дне океана (базальт, риолит, андезит).

Важнейшей характеристикой магматической породы является состав. Существует несколько классификаций магматических горных пород по составу (номенклатура горных пород). Наибольшее значение имеет классификация по содержанию в породах кремнезёма SiO_2, и щелочей ($Na_2O + K_2O$).

Образование магматических пород непрерывно происходит и сейчас, в зонах активного вулканизма и горообразования.

Метаморфические горные породы образуются в толще земной коры в результате изменения (метаморфизма) осадочных или магматических горных пород. Факторами, вызывающими эти изменения, могут быть: близость застывающего магматического тела и связанное с этим прогревание метаморфизуемой породы; воздействие отходящих от этого тела активных химических соединений, в первую очередь различных водных растворов (контактовый метаморфизм), или погружение породы в толщу земной коры, где на неё действуют факторы регионального метаморфизма – высокие температуры и давления.

Типичными метаморфическими Г. п. являются гнейсы, разные по составу кристаллические сланцы, контактовые роговики, скарны, амфиболиты, мигматиты и др. Различие в происхождении и, как следствие этого, в минеральном составе Г. п. резко сказывается на их химическом составе и физических свойствах.

Осадочные горные породы образуются на земной поверхности и вблизи неё в условиях относительно низких температур и давлений в результате преобразования морских и континентальных осадков. Осадочные горные породы (ОГП) – горные породы, существующие в термодинамических условиях, характерных для поверхностной части земной коры, и образующиеся в результате переотложения продуктов выветривания и разрушения различных горных пород, химического и механического выпадения осадка из воды, жизнедеятельности организмов или всех трёх процессов одновременно.

Более трёх четвертей площади материков покрыто ОГП, поэтому с ними наиболее часто приходится иметь дело при геологических работах. Кроме того, с ОГП генетически или пространственно связана подавляющая часть месторождений полезных ископаемых. В ОГП хорошо сохранились остатки вымерших организмов, по которым можно проследить историю развития различных уголков Земли. Исходным материалом при формировании ОГП являются минеральные вещества, образовавшиеся за счёт разрушения существовавших ранее минералов и горных пород магматического, метаморфического или осадочного происхождения и перенесённые в виде твёрдых частиц или растворенного вещества.

Изучением осадочных горных пород занимается наука Литология.

Exercise № 11. Watch the video “Three main rock types” and do Tests 1, 2, 3. https://distedu.udsu.ru/course/view.php?id=3296 The Earth crust

Part 2. Deformation of Sedimentary Rocks

Mind the definitions

Deformation	искривление нарушение, деформация	Rocks become deformed when the Earth’s crust is compressed or stretched. The forces needed to do this act over millions of years – deformation is a very slow process.
Structural trap	структурная ловушка	A structural trap is a type of geological trap that forms as a result of changes in the structure of the subsurface, due to tectonic, diapiric, gravitational and compactional processes.
Weathering	выветривание разрушение	The process of rock disintegration by the direct influence of local atmospheric conditions on the Earth's surface is called weathering.
Erosion	эрозия	Erosion is the removal of rock and soil material by natural processes, principally running water, glaciers, waves, and wind. Erosion transports rocky material after the process of weathering has broken bedrock down into smaller, moveable pieces.
Unconformity	стратиграфическое несогласие	An unconformity is a buried erosion surface separating two rock masses or strata of different ages, indicating that sediment deposition was not continuous.
Disconformity	параллельное несогласие	Disconformity is an unconformity between parallel layers of sedimentary rocks, which represents a period of erosion or non-deposition.
Angular unconformity	угловое несогласие	Angular unconformity is an unconformity where horizontally parallel strata of sedimentary rock are deposited on tilted and eroded layers, producing an angular discordance with the overlying horizontal layers.

Erode	выветривать разрушать	Many human activities remove vegetation from an area, making the soil easily eroded.
Uplift	поднятие взброс	Understanding the idea of uplift is the key to making sense of the rock cycle, as it allows us to see rocks that were once deeply buried beneath the surface.
Arch	перекрывать сводом, арка	If the rocks are folded into an arch shape, the resulting structure is called an anticline.
Blow	фонтанировать	An oil well blew out in the North Sea, causing a very big floating mass of oil.
Anticline	антиклиналь	In structural geology, an anticline is a type of fold that is an arch-like shape and has its oldest beds at its core.
Syncline	синклиналь	In structural geology, a syncline is a fold with younger layers closer to the center of the structure.
Fold	складка	A geological fold occurs when one or a stack of originally flat and planar surfaces, such as sedimentary strata, are bent or curved as a result of permanent deformation.
Ridge	вершина	A ridge or mountain ridge is a geological feature consisting of a chain of mountains or hills that form a continuous elevated crest for some distance.
Dome	купол	Domes are distinct, rounded, spherical-to-ellipsoidal-shaped protrusions on the Earth's surface.
Homocline	моноклиналь	In structural geology, a homocline or homoclinal structure, (from old Greek: homo = same, cline = inclination) is a geological structure in which the layers of a sequence of rock strata, either sedimentary or igneous, dips uniformly in a single direction having the same general inclination in terms of direction and angle.

Fracture	разрыв	A fracture is any separation in a geologic formation, such as a joint or a fault that divides the rock into two or more pieces. A fracture will sometimes form a deep fissure or crevice in the rock.
Joint	разлом без сдвига	A joint is a break (fracture) of natural origin in the continuity of either a layer or body of rock that lacks any visible or measurable movement parallel to the surface (plane) of the fracture.
Fault	дизъюнктив	In geology, a fault is a planar fracture or discontinuity in a volume of rock, across which there has been significant displacement as a result of rock-mass movement.
Dip-slip fault	сброс со смещением по падению	Dip-slip faults can be either “normal” (“extensional”) or “reverse”.
Strike-slip fault	сброс со смещением по простиранию	In a strike-slip fault (also known as a wrench fault, tear fault or transcurrent fault), the fault surface (plane) is usually near vertical and the footwall moves laterally either left or right with very little vertical motion.
Oblique-slip fault	дизъюнктивное нарушение со смещением и по горизонтали, и по вертикали	A fault, which has a component of dip-slip and a component of strike-slip, is termed an oblique-slip fault.
Horst	горст	A horst represents a block pushed upward relative to the blocks on either side by the faulting
Graben	грабен	A graben is a block generally long compared to its width that has been lowered relative to the blocks on either side due to the faulting. Graben is usually represented by low-lying areas such as rifts and river valleys whereas horsts represent the ridges between or on either side of these valleys.

Thrust fault	надвиг	A thrust fault is a break in the Earth's crust, across which younger rocks are pushed above older rocks.
Overthrust belt	надвиговая зона	An elongate area in which thick rock layers have been pushed over one another by compressional forces within the earth's crust.

Sedimentary rocks are originally deposited in horizontal layers. One type of oil and gas trap, a structural trap, is formed by the deformation of these rock layers.

Weathering, Erosion, and Unconformities

Weathering is the breakdown of solid rock. Once a rock is **exposed** on the surface of the earth, either to the atmosphere or ocean bottom, it will eventually be mechanically broken into particles or chemically **dissolved** by the forces of weathering. Some sedimentary rocks, such as sandstones, are more resistant to weathering, and others, such as shales, readily break down. Erosional processes are those that transport and deposit sediments. These processes include rivers, wind, waves, gravity (landslides), and glaciers.

Expose – обнажаться; подвергаться
Dissolve – растворять

Sea level has been rising and falling throughout geological time. Whenever sea level was lower, the land was exposed to erosion, and some of the sedimentary rocks were **stripped off** the surface of the land. Buried, ancient erosional surfaces that were formed during these times are called unconformities. Two types are disconformities and angular unconformities.

Strip off – откалываться

A disconformity is an erosional channel in which the sedimentary rock layers above and below the erosional surface are parallel (fig. 2–1). It is an ancient river channel usually filled with sand that has become sandstone.

Fig. 2-1 Disconformity

An angular unconformity is an ancient erosional surface in which the sedimentary rock layers below the unconformity are **tilted** at an **angle** to the layers above the unconformity (plate 2–1). An angular unconformity represents a time of **mountain building** followed by erosion. It often covers a large, subsurface area. The formation of an angular unconformity started with the deposition of horizontal sediment layers **as** ancient seas covered the earth. After the seas **retreated**, exposing the earth, the sedimentary rocks were tilted to form hills and mountains. The hills and mountains were then eroded down, leaving an erosional surface. The seas again covered the land, depositing horizontal sedimentary rock layers on the erosional surface, burying it in the subsurface.

Tilt – наклонять
Angle – угол
Mountain building – горообразование
As – по мере того, как
Retreat – отступать

Plate 2–1. Angular unconformity in a sea cliff in England showing flat sedimentary rocks above and sedimentary rocks tilted at an angle below.

Angular unconformities can form gas and oil traps (fig. 2–2). One of the sedimentary rock layers tilted at an angle below it must be a reservoir rock that can **store** gas and oil, usually a sandstone or limestone. The sedimentary rock layer above it must be a caprock that acts as a **seal**, usually a **shale** or salt layer. The gas and oil are formed below the unconformity in a source rock such as **black shale**. They migrate up into and then through the pore spaces of the reservoir rock until they reach the angular unconformity surface where they are trapped below the caprock. Because angular unconformities can cover large subsurface areas, they can form giant gas and oil fields. The two largest oil fields in the United States, the East Texas field and the Prudhoe Bay field in Alaska, are both in angular unconformity traps. In both fields, the horizontal rock layers on the surface of the ground do not give any **indication** of the subsurface angular unconformities and their giant oil accumulations.

Store – сохранять
Seal – изолирующий слой
Shale – глина
Black shale – углистый сланец
Indication – признак

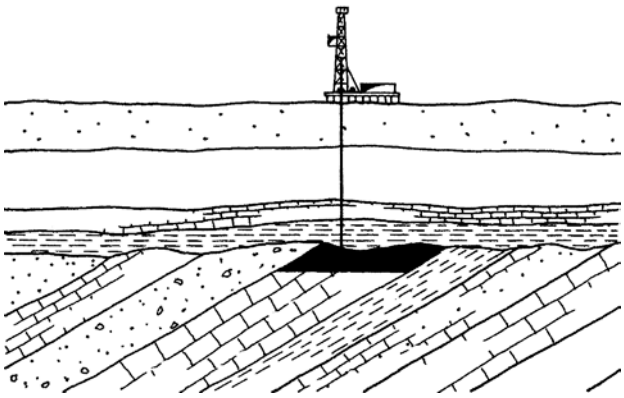


Fig. 2–2. Angular unconformity trap

The East Texas field originally contained more than 7 billion bbl (1.1 billion m3) of oil. The oil **is located** in the Woodbine Sandstone below an angular unconformity (fig. 2–3). The Austin **Chalk**, a very finegrained limestone that forms the caprock, directly overlies the angular unconformity. The Woodbine Sandstone was originally deposited as a horizontal

Be located – располагаться
Chalk – мел

layer of sand when shallow seas covered East Texas about 100 million years ago (fig. 2–4a). The sandstone was then buried in the subsurface as it was covered with other sediments (fig. 2–4b). Later, the Sabine uplift, along the Texas-Louisiana border, **arched up** and exposed the Woodbine Sandstone (fig. 2–4c). Erosion **removed** the Woodbine Sandstone from the top of the arch (fig. 2–4d). After that, the seas **invaded** the area, depositing the Austin Chalk and other sediments, covering the angular unconformity (fig. 2–4e). The oil formed in the Eagle Ford Shale source rock below and migrated up into the Woodbine Sandstone. It then flowed along the porous sandstone toward the east until it was trapped under the angular unconformity, unable to flow into the Austin Chalk.

Arch up – выгибаться
Remove – срезать
Invade - занимать

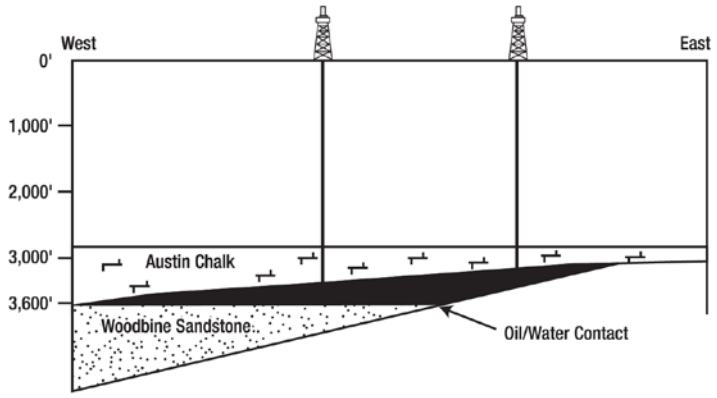


Fig. 2–3. Cross section of East Texas oil field

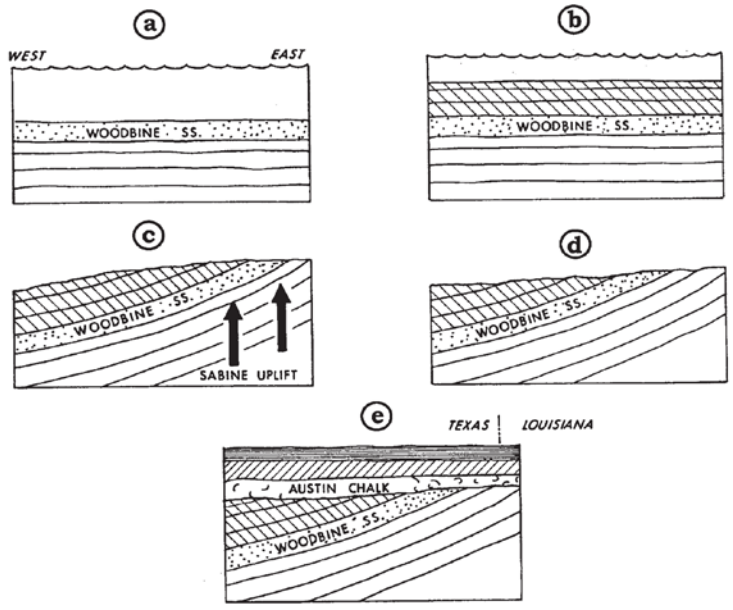


Fig. 2–4. Formation of East Texas oil field trap

The discovery of the East Texas oil field in 1930 is a classic example of petroleum history. Oil companies explored this area in the early 1900s. There were no oil seeps in the area, and the companies became discouraged after drilling some dry holes. The companies **abandoned** this area by the mid-1920s and instead drilled in the newly discovered West Texas oil fields. Because of this, Columbus Marion “Dad” Joiner, a driller and promoter, was able to obtain leases for drilling in a large area of eastern Texas by promising the cotton farmers who owned the land a share of any oil revenue if he found oil. He started to drill in the area in the late 1920s using a method best described as “random drilling.” His only geological help was from a veterinarian named Dr. A. D. Lloyd. The local farmers would often volunteer to help drill the well. Because Dad Joiner had little money, he traded shares in the well for room and board, equipment repair, supplies, and hired help.

Abandon – оставлять

After two wells had caved in, the No. 3 Daisy Bradford well finally reached below the angular unconformity at 3,725 ft (1,135 m) after 16 months of drilling and blew in the East Texas oil field on October 5, 1930. The well initially tested 6,800 bbl/day (1,080 m3/day) and was completed to produce 300 b/d (48 m3/day). Unfortunately, Dad Joiner, in his financial need during drilling, had sold 300% of the Daisy Bradford well and was in legal trouble. The investors had **filed a lawsuit** to take all the leases away from him. Dad had no money to hire lawyers and defend himself. H. L. Hunt negotiated a deal with Dad to settle his legal problems and pay him $1,335,000, mostly in future oil production for 5,000 acres of prime leases in the field.

File a lawsuit – подать в суд

The East Texas oil field is 45 miles (72 km) long and 5 miles (8 km) wide (fig. 2–5). More than 30,000 wells were drilled in the field that has now produced more than 5 billion bbl (800 million m^3) of light, sweet crude oil. Hundreds of poor farming families that had land in the field became Texas millionaires, and H. L. Hunt became a billionaire. Dad Joiner went to another area to drill a series of dry holes and died penniless.

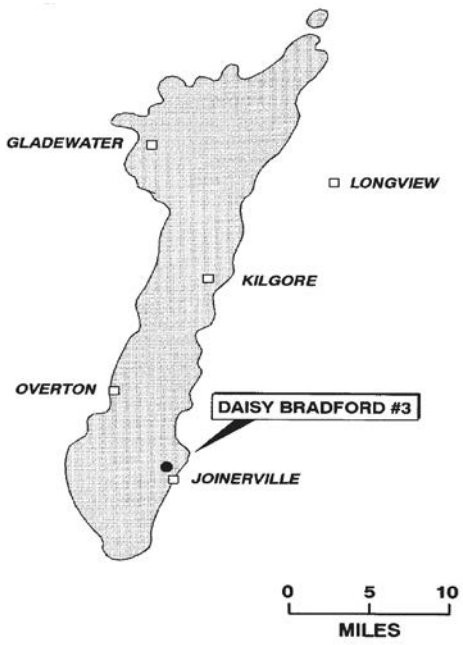


Fig. 2–5. Map of East Texas oil field.
(Modified from Halbouty, 1991.)

Answer the questions:

1. What is weathering?
2. What rocks are more resistant to weathering?
3. What is an erosional process?
4. What happened with the sea level throughout geological time?
5. What are two types of unconformity?
6. What is an indication of disconformity?
7. What is an angular unconformity?
8. Describe the process of angular unconformity forming.
9. What do angular unconformities form?
10. What sedimentary rocks can store oil and gas?
11. What are the characteristics of Austin chalk?
12. When were East Texas oil fields discovered?
13. What method did Dad Joiner use to drill wells?
14. Why did Joiner die penniless?

Anticlines and Synclines

An anticline is a large, upward arch of sedimentary rocks (fig. 2–6), whereas a syncline is a large, downward arch of rocks. Anticlines, but not synclines, form high areas in reservoir rocks and can be gas and oil traps. Folds such as anticlines expose the rocks to erosion. If the anticlines are relatively young, they have not been very eroded and appear as topographic ridges on the surface. A series of young, rising anticlines that are also prolific petroleum producers occur as a line of hills that cross the Los Angeles basin (fig. 2–7). These trend from Beverly Hills in the north, through the Inglewood (Baldwin Hills) and Dominguez fields, southward to Long Beach and the Wilmington field, and offshore into the Huntington Beach field.

Plunging anticline – погружающаяся антиклиналь
Lobate – лопастной
Pattern – контур

Most anticlines and synclines are not level and are tilted with respect to the surface of the earth. These are called **plunging anticlines** (fig. 2–8) and plunging synclines. When a plunging anticline or syncline is eroded down, it leaves a characteristic **lobate**-shaped **pattern** on the surface (fig. 2–9).

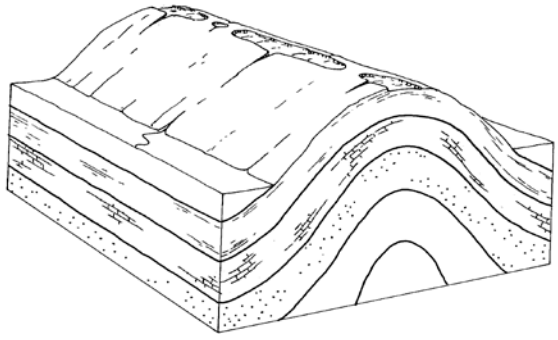


Fig. 2–6. Anticline

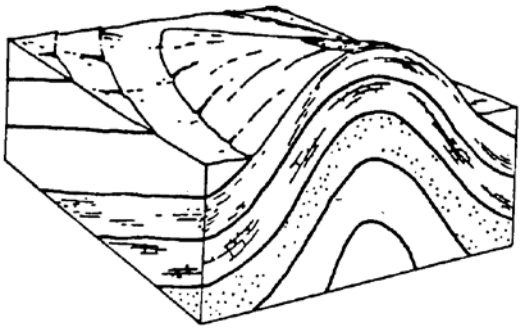


Fig. 2–8. Plunging anticline

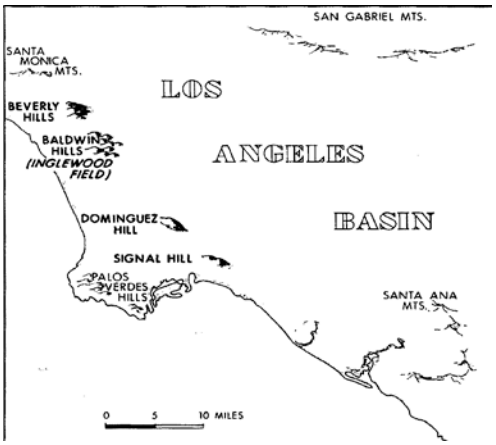


Fig. 2–7. Los Angeles basin showing trend of anticline oil fields

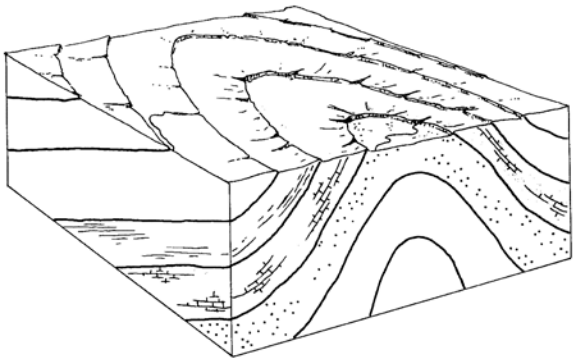


Fig. 2–9. Surface pattern of eroded, plunging anticline

The formation of anticlines and synclines **results in** shortening of the earth's crust (fig. 2–10). Forces that **shorten** the earth's crust are compressional. If an area of the earth's crust is compressed, the rocks will be folded into anticlines and synclines. If **folds** are present in the rocks of the earth's crust, that area probably has been compressed some time in the past.

Result in – приводить
Shorten – сокращать, укорачивать
Fold – складка

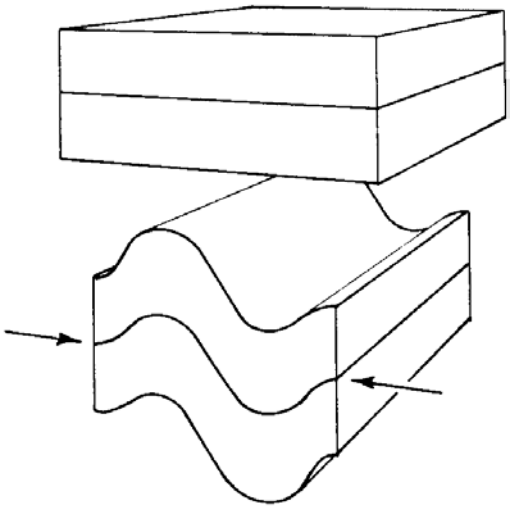


Fig. 2–10. Formation of anticlines and synclines by compression

Answer the questions:

1. What is the difference between anticline and syncline?
2. Why are most anticlines and synclines plunging?
3. What does the formation of anticline and syncline result in?
4. What do anticlines form?
5. What are anticlines and synclines?
6. What are the forces that shorten the Earth's crust?

Domes

A dome is a circular or elliptical uplift. Domes also form gas and oil traps. Before a dome is eroded down, it forms a hill. Oil was first discovered in the Middle East in Bahrain, an island in the Persian Gulf, in 1932. The traps in Bahrain were domes with a low hill on the surface above each of them. A similar low hill above a dome in Saudi Arabia was drilled to find the first oil field there in 1937. If the dome is eroded, it leaves a characteristic **bull's eye pattern** (fig. 2–11) on the surface.

Bull's eye pattern – в форме бычьего глаза

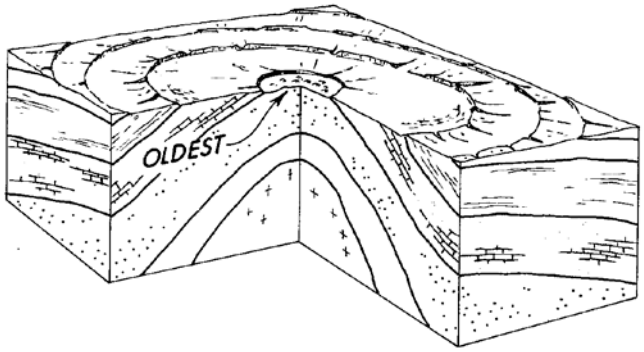


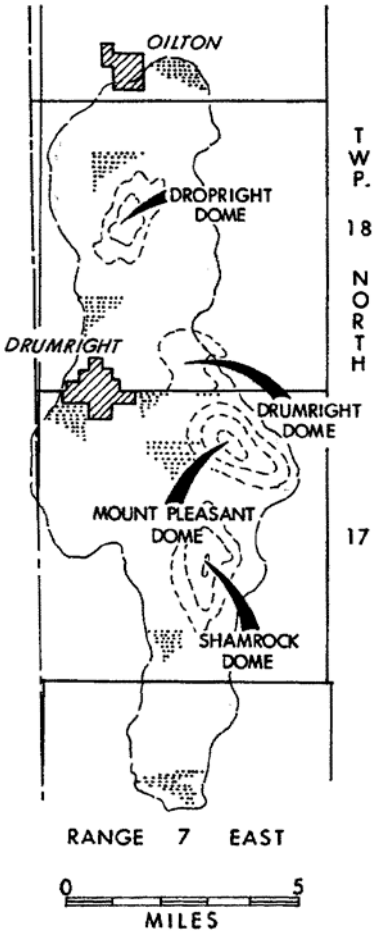
Fig. 2–11. Surface pattern of eroded dome

Anticlines and domes were the first type of petroleum trap recognized. They form many of the giant oil and gas fields of the world. Most of the Middle East oil fields are in anticline and dome traps. The Cushing oil field of Oklahoma, **discovered** in 1912, is located southwest of Tulsa. The trap is an anticline with three domes **superimposed** on it (fig. 2–12). The major reservoir rock is the Bartlesville sandstone. The best producing wells are on domes. The Cushing oil field will produce 450 million bbl (72 million m^3) of oil. It was the largest oil field in the world during World War I.

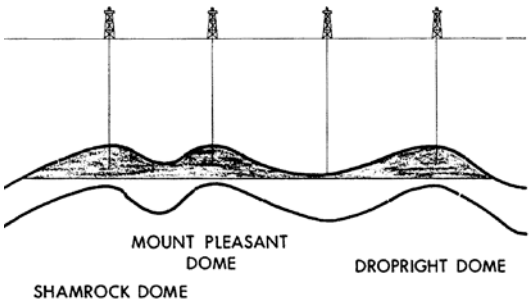
Discover – открывать, обнаруживать
Superimpose – напластовать

Answer the questions:

1. What is a dome?
2. What do domes form?
3. Where was oil first discovered?
4. What is the Bartlesville sandstone?
5. What are traps in the Middle East?
6. Which field was the largest in the world during World War I?



a



b

Fig. 2-12 Cushing field, Oklahoma: (a) map, (b) cross section

Homoclines

Sedimentary rocks **dipping** uniformly in one direction are known as a homocline (fig. 2–13). Although homoclines are common, they do not form gas and oil traps.

Dip – наклоняться, залегать

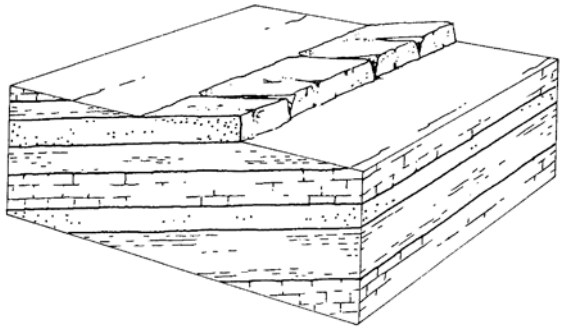


Fig. 2–13. Homocline

Fractures

Two types of natural fractures in rocks are joints and faults.

Joints

A joint is a fracture in the rocks with no movement of one side relative to the other (plate 2–2). Joints are common in sedimentary rocks and are oriented perpendicular (90˚) to the **bedding planes**. There are usually two **sets** of joints oriented at right angles (90˚) to each other. They were formed when erosion removed sedimentary rocks that were located above and **stress** on the rock was **relieved**. Joints in sedimentary rocks **improve** the reservoir quality of the rock. They slightly increase the **fluid storage capacity** of the rock (porosity) and greatly increase the ability of the fluid to flow through the rock (permeability). Any naturally fractured rock is a potential reservoir rock.

Bedding plane – плоскость напластования
Set – строение, конфигурация
Stress – давление
Relieve – облегчать
Improve – улучшать
Fluid storage capacity – емкостные свойства резервуара

Plate 2–2. Joints in a sandstone (Winding Stair Mountains, Oklahoma)

Faults

Faults are breaks in the rocks along which one side has moved relative to the other (plate 2-3). The relative movement of each side is used to classify faults (fig. 2–14). Dip-slip faults move primarily up and down, whereas strike-slip faults move primarily horizontally. Oblique-slip faults have roughly equal dip-slip and strike-slip **displacements**. The side of a fault that **extends** under the **fault plane** is called the **footwall** (fig. 2–15), and the side that **protrudes** above the fault plane is the **hanging wall**. Throw (fig. 2–16) is the vertical displacement on a dip-slip fault. The side of the dip-slip fault that goes down is called the downthrown side, and the side that goes up is called the upthrown side.

Displacement – смещение
Extend - простираться
Fault plane – плоскость сместителя
Footwall – лежачее крыло
Protrude – выступать
Hanging wall – висячее крыло

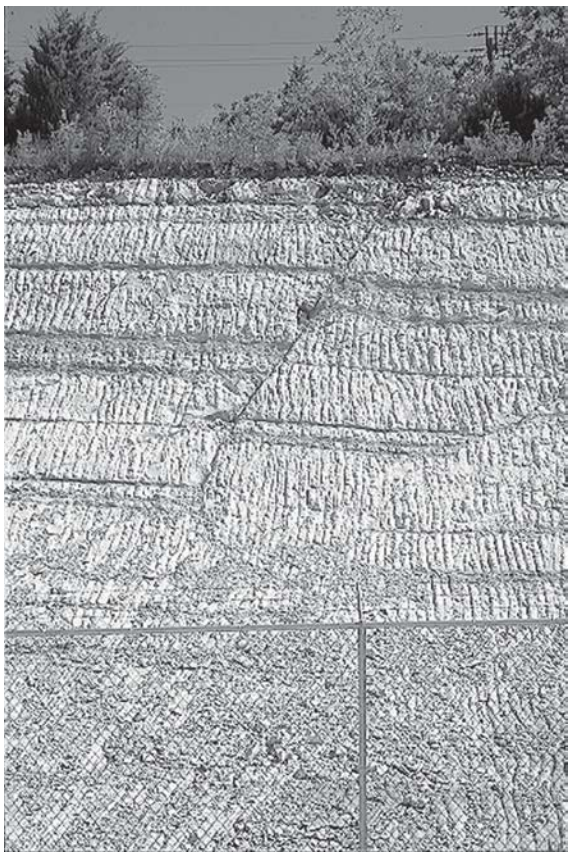


Plate 2–3. Fault showing displacement of sedimentary rock layers (Austin Chalk, Texas)

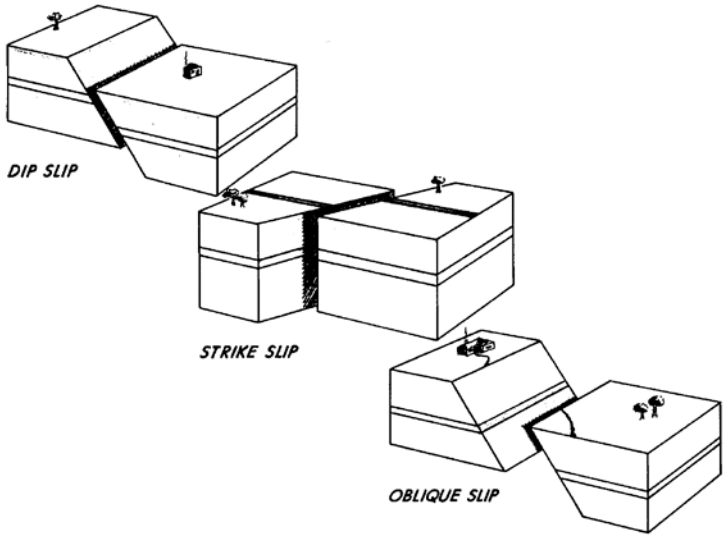


Fig. 2–14. Types of faults

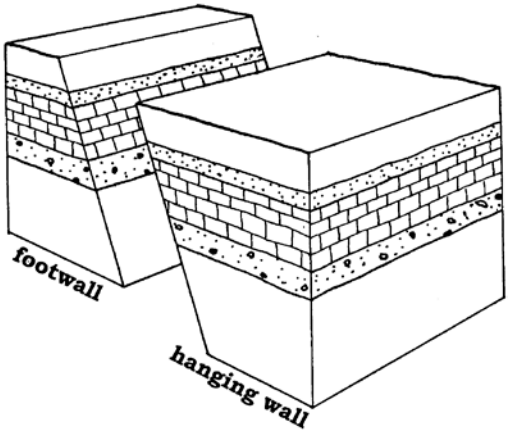


Fig. 2–15. The sides of a fault

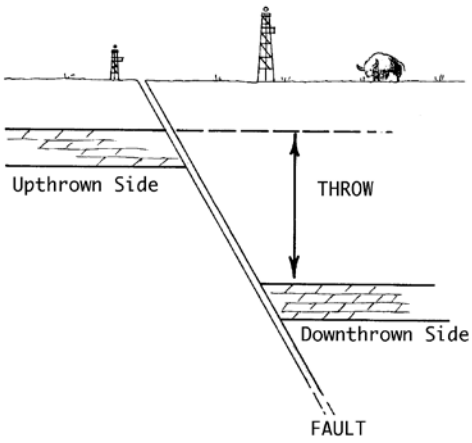


Fig. 2–16. Dip-slip fault terminology (upthrown and downthrown)

Two types of dip-slip faults are normal and **reverse**. If the hanging wall has moved down relative to the footwall, it is a normal dip-slip fault (fig. 2–17). In a normal dip-slip fault, the beds are separated and **pulled apart**. A normal dip-slip fault is identified in the subsurface by a lost section, a **missing** layer or layers of rocks when a well is drilled through the fault (fig. 2–18).

Reverse – взброс, обратный
Pull apart – раздвигаться, сдвигаться
Missing - отсутствующий

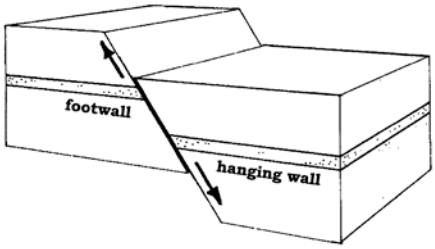


Fig. 2–17. Normal dip-slip fault

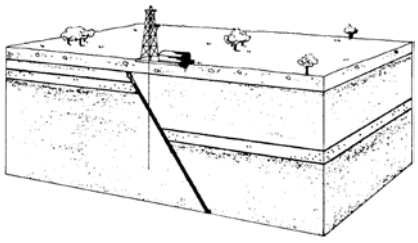


Fig. 2–18. Lost section on a normal dip-slip fault

A **series** of parallel, normal dip-slip faults forms a structure called horst and graben (fig. 2–19). A graben is the **down-dropped** block between two normal faults. A horst is the ridge left standing between two grabens. These can range in size from inches to tens of miles across.

Series – система
Down-dropped – погруженный
Overlap – перекрывать

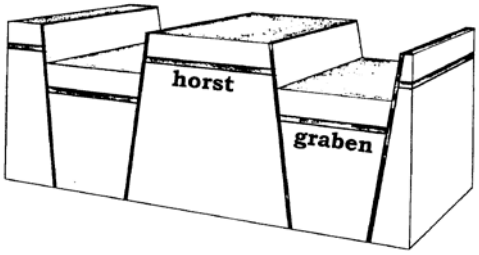


Fig. 2–19. Horst and graben

If the hanging wall has moved up relative to the footwall, it is a reverse dip-slip fault. In a reverse dip-slip fault, some subsurface beds **overlap**. It is possible to drill through this fault and encounter the same rock layers twice in a double section (fig. 2–20). A thrust fault is a reverse fault with a fault plane less than 45° from horizontal (fig. 2–21). On a thrust fault, the upper hanging wall has been thrust up and over the lower footwall. There are some thrust faults in the earth's crust where the hanging wall has been thrust horizontally tens of miles over the footwall. Several large thrust faults, called the Rocky Mountain overthrust belt, occur in a band along the Rocky Mountains. A series of large gas and oil traps are located in the overthrust belt.

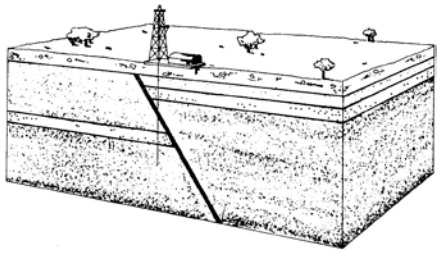


Fig. 2–20. Double section on a reverse dip-slip fault

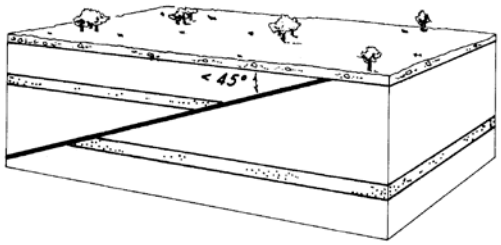


Fig. 2–21. Thrust fault

A normal dip-slip fault is formed when the rocks are pulled apart by **tensional forces**. A reverse dip-slip fault is formed by shortening the rocks with compressional forces (fig. 2–22). When the earth's crust is pulled apart, normal

Tensional force – сила растяжения

Squeeze – сжимать

dip-slip faults with horsts and grabens are formed. When the earth's crust is **squeezed**, reverse dip-slip and thrust faults and folds, such as anticlines and synclines, are formed.

Recoverable oil – извлекаемая нефть

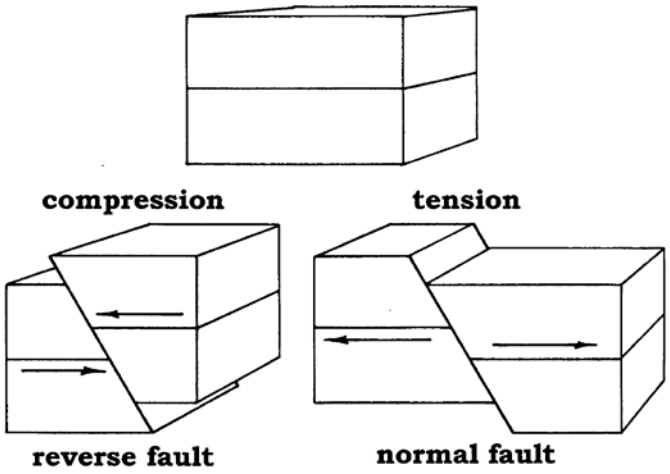


Fig. 2–22. Forces that form a normal dip-slip fault and a reverse dip-slip fault

Faults can be both active and inactive. When a fault moves, it can produce shock waves called an earthquake. Many faults, however, moved a long time ago and are inactive today. Two very large faults occur in Oklahoma, the Seneca and Nemaha faults. Both were active hundreds of millions of years ago but are inactive today.

Dip-slip faults form traps by displacing the reservoir rock (fig. 2–23). The fault must be a sealing fault, which means it prevents fluid flow across or along the fault. Any gas and oil migrating up a reservoir rock will be trapped under the sealing fault. The largest oil field on land in England is the Wytch Farm field, located southwest of London on the South Dorset coast. There are natural oil seeps along the coast, and the field was discovered in 1973. The trap was formed by a fault cutting the Sherwood Sandstone reservoir rock (fig. 2–24). It contains 286 million bbl (45 million m^3) of **recoverable oil**.

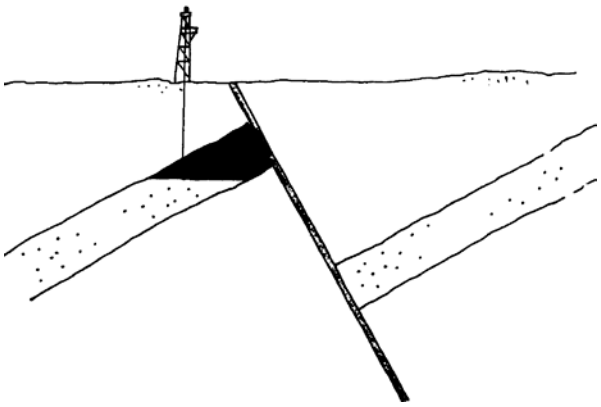


Fig. 2–23. Fault trap

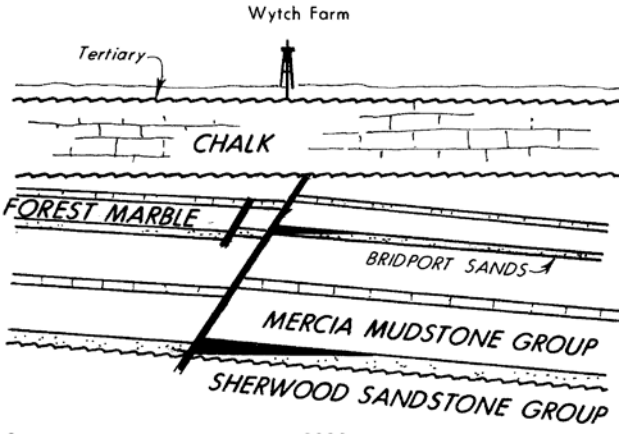


Fig. 2–24. Cross section of Wytch Farm oil field, England. (Modified from Colter and Harvard, 1981.)

A strike-slip fault is described by the horizontal movement of one side relative to the other (fig. 2–25). If the opposite side of the fault as you face it moves to the right, it is a right-lateral strike-slip fault. If it moves to the left, it is a left-lateral strike-slip fault. The San Andreas fault of California is an active right-lateral strike-slip fault. It is hundreds of miles long and has moved many tens of miles over a long time. The Potrero oil field in California (fig. 2–26) is formed by an anticline on sandstone reservoir rocks. The **crest** of the anticline is displaced 1,200 ft (365 m) by the Potrero fault, a right-lateral strike-slip fault.

Crest – сводовая часть складки

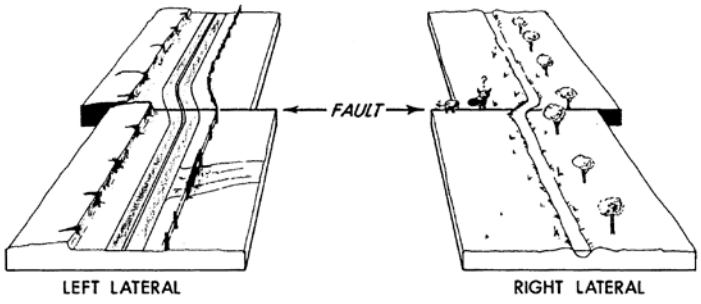


Fig. 2-25. Strike-slip faults

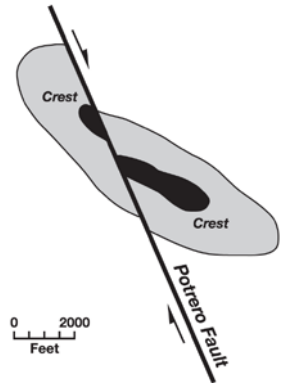


Fig. 2–26. Map of Potrero oil field, California

Answer the questions:

1. How many types of fractures are there?
2. What is a joint?
3. What is the difference between horst and graben?

4. What is a fault?
5. What are the types of dip-slip faults?
6. What faults move horizontally?
7. What is the difference between dip-slip and strike-slip faults?
8. How does right-lateral strike-slip fault differ from left-lateral one?
9. How is dip-slip fault formed?
10. How can you understand what wall is a footwall.
11. How is normal dip-slip fault identified?
12. What properties of rock are connected with fractures?
13. How are the sides of joints oriented?

Exercises

Exercise № 1. Match English words with their Russian equivalents.

1. Weathering	a) эрозия
2. Particles	b) антиклиналь
3. Erosion	c) частицы
4. Unconformity	d) разлом без сдвига
5. Tilt	e) плоскость
6. Deposition	f) дизъюнктив
7. Anticline	g) выветривание
8. Folds	h) сводовая часть складки
9. Joint	i) наклоняться
10. Plane	j) отложение
11. Footwall	k) богатый
12. Fault	l) вершина
13. Crest	m) лежачее крыло
14. Ridge	n) складки
15. Prolific	o) несогласие

Exercise № 2. Make up word combinations and translate them.

1. Angular	a) processes
2. Erosional	b) side
3. finegrained	c) anticlines
4. upward	d) wall
5. plunging	e) limestone
6. Dip-slip	f) faults
7. hanging	g) trap
8. downthrown	h) unconformity

9. thrust	i) apart
10. right	j) plane
11. tensional	k) belt
12. overthrust	l) building
13. lost	m) forces
14. pulled	n) fault
15. fault	o) section
16. structural	p) lateral
17. mountain	q) fractures
18. topographic	r) ridges
19. elliptical	s) arch
20. natural	t) uplift

Exercise № 3. Match English words with their Russian equivalents.

1. erosional surface	a) сброс со скольжением по падению
2. fault plane	b) смещение по простиранию
3. plunging synclines	c) взброс
4. shortening of the earth's crust	d) канал древней реки
5. ancient river channel	e) сокращение земной коры
6. downward arch	f) эрозионная поверхность
7. fluid storage capacity	g) ёмкостные свойства коллектора
8. Dip-slip fault	h) плоскость сместителя
9. strike-slip displacement	i) погружающаяся антиклиналь
10. reverse fault	j) нисходящая арка

Exercise № 4. Match the following words with their definitions.

Syncline	Graben	Horst	Joint	Crest
Angular unconformity	Fold	Dome	Deposit	Deformation
Dissolve	Dip	Earthquake	A structural trap	Weathering
Anticline	Thrust fault	Reverse fault	Fracture	Erode

1. It is a type of geological trap that forms as a result of changes in the structure of the subsurface, due to tectonic, diapiric, gravitational and compactional processes.
2. It involves changes in the shape and/or volume of these substances.
3. To mix a solid substance into a liquid so that it becomes included in it.
4. Sediments that have accumulated, usually after being moved by wind, water or ice.
5. The highest point of a wave, mountain or geologic structure.
6. The sudden release of accumulated stress in the Earth by movement or shaking.

7. A relatively low-standing fault block bounded by opposing normal faults. It can form in areas of rifting or extension, where normal faults are the most common type of fault.
8. A type of fault formed when the hanging wall fault block moves up along a fault surface relative to the footwall. Such movement can occur in areas where the Earth's crust is compressed.
9. The youngest rock layers of this trap form the core of the fold and outward from the core progressively older rocks occur. It typically does not trap hydrocarbons because fluids tend to leak up the limbs of the fold.
10. A surface of breakage, cracking or separation within a rock along which there has been no movement parallel to the defining plane.
11. The angle between a planar feature, such as a sedimentary bed or a fault, and a horizontal plane.
12. A type of anticline that is circular or elliptical rather than elongate.
13. A wave-like geologic structure that forms when rocks deform by bending instead of breaking under compressional stress. Anticlines are examples.
14. A surface that separates younger strata from eroded, dipping, older strata and represents a gap in the geologic record.
15. A type of reverse fault in which the fault plane has a very shallow dip, typically much less than 45°. The hanging wall fault block moves up the fault surface relative to the footwall.
16. A relatively high-standing area formed by the movement of normal faults that dip away from each other. They can form in areas of rifting or extension, where normal faults are the most abundant variety of fault.
17. A crack or surface of breakage within rock not related to foliation or cleavage in metamorphic rock along which there has been no movement.
18. An arch-shaped fold in rock in which rock layers are upwardly convex. The oldest rock layers form the core of the fold, and outward from the core progressively younger rocks occur. They form many excellent hydrocarbon traps, particularly in folds with reservoir-quality rocks in their core and impermeable seals in the outer layers of the fold.
19. To cause or undergo erosion, the process of denudation of rocks, including physical, chemical and biological breakdown and transportation. The material from the rocks can be transported by wind, water, ice, or abrasive solid particles, or by mass-wasting, as in rock falls and landslides.
20. The physical, chemical and biological processes that decompose rock at and below the surface of the Earth through low pressures and temperatures and the presence of air and water. Weathering includes processes such as dissolution, chemical weathering, disintegration and hydration.

Exercise № 5. Give the definitions.

1. It is a type of geological trap that forms as a result of changes in the structure of the subsurface, due to tectonic, diapiric, gravitational and compactional processes.
2. It involves changes in the shape and/or volume of these substances.
3. To mix a solid substance into a liquid so that it becomes included in it.
4. Sediments that have accumulated, usually after being move by wind, water or ice.
5. The highest point of a wave, mountain or geologic structure.
6. The sudden release of accumulated stress in the Earth by movement or shaking.
7. A relatively low-standing fault block bounded by opposing normal faults. It can form in areas of rifting or extension, where normal faults are the most common type of fault.
8. A type of fault formed when the hanging wall fault block moves up along a fault surface relative to the footwall. Such movement can occur in areas where the Earth's crust is compressed.
9. If the displacement is particularly great, it is a reverse fault in which the fault plane has a shallow dip, typically much less than 45º.
10. A surface of breakage, cracking or separation within a rock along which there has been no movement parallel to the defining plane.
11. The angle between a planar feature, such as a sedimentary bed or a fault, and a horizontal plane.
12. A type of anticline that is circular or elliptical rather than elongate.
13. A wave-like geologic structure that forms when rocks deform by bending instead of breaking under compressional stress. Anticlines are examples.
14. A surface that separates younger strata from eroded, dipping, older strata and represents a gap in the geologic record.
15. A type of reverse fault in which the fault plane has a very shallow dip, typically much less than 45º. The hanging wall fault block moves up the fault surface relative to the footwall.
16. A relatively high-standing area formed by the movement of normal faults that dip away from each other. They can form in areas of rifting or extension, where normal faults are the most abundant variety of fault.
17. A crack or surface of breakage within rock not related to foliation or cleavage in metamorphic rock along which there has been no movement.
18. An arch-shaped fold in rock in which rock layers are upwardly convex. The oldest rock layers form the core of the fold, and outward from the core progressively younger rocks occur. They form many excellent hydrocarbon traps, particularly in

folds with reservoir-quality rocks in their core and impermeable seals in the outer layers of the fold.

19. To cause or undergo erosion, the process of denudation of rocks, including physical, chemical and biological breakdown and transportation. The material from the rocks can be transported by wind, water, ice, or abrasive solid particles, or by mass-wasting, as in rock falls and landslides.

20. The physical, chemical and biological processes that decompose rock at and below the surface of the Earth through low pressures and temperatures and the presence of air and water. Weathering includes processes such as dissolution, chemical weathering, disintegration and hydration.

Exercise № 6. Fill the gaps using the words given.

flow	breakdown	downthrown	down-dropped
deformation	overthrust belt	folds	domes
angular	anticline	fractured	earthquake
unconformities	surface	fault	

1. When a fault moves, it can produce shock waves called an … .
2. A graben is the … block between two normal faults.
3. It prevents fluid … across or along the fault.
4. An … is a large, upward arch of sedimentary rocks.
5. … unconformities can form gas and oil traps.
6. If … are present in the rocks of the earth's crust, that area probably has been compressed some time in the past.
7. The hills and mountains were then eroded down, leaving an erosional … .
8. In a reverse dip-slip … , some subsurface beds overlap.
9. A structural trap is formed by the … of these rock layers.
10. … were one of the petroleum traps recognized.
11. Weathering is the … of solid rock
12. Any naturally … rock is a potential reservoir rock.
13. The side of the dip-slip fault that goes down is called the … side.
14. Buried, ancient erosional surfaces are called … .
15. A series of large gas and oil traps are located in the … .

Exercise № 7. Put the verbs in brackets into Active or Passive Voice.

1. Oil and gas traps, sometimes referred to as petroleum traps are below ground traps where a permeable reservoir rock (to cover) by some low permeability cap rock.

2. These traps are types that (to form) as a result of some structural deformation – a bend or dip – of rock.

3. Anticline traps (to form) by a folding of rock.

4. A sandstone bed covered with low permeability shale (to fold) into a trap that contains petroleum products.

5. Hydrocarbons (to trap) in the peak of this fold.

6. Most anticline traps (to create) as a result of sideways pressure, folding the layers of rock, but can also occur from sediments being compacted.

7. The process of this salt deforming rock (to know) as salt tectonics, and take place over hundreds of millions of years.

8. When the sediment that creates the reservoir rock (to deposit) in a discontinuous layer, the seals are created beside and on top of the reservoir.

9. There are two main types of stratigraphic traps that (to classify) by when changes (to occur) relative to the sedimentation process.

10. Secondary stratigraphic traps (to result) from changes that develop after sedimentation has occurred.

11. Petroleum geologists broadly (to classify) traps into three categories that (to base) on their geological characteristics: the structural trap, the stratigraphic trap and the far less common hydrodynamic trap.

12. Traps (to describe) as structural traps (in deformed strata such as folds and faults) or stratigraphic traps (in areas where rock types change, such as unconformities, pinch-outs and reefs).

13. If there is a layer of impermeable rock (to present) in this dome shape, then hydrocarbons can accumulate at the crest until the anticline (to fill) to the spill point

14. These traps (to hold) oil and gas because the earth has been bent and deformed in some way.

15. The stratigraphic trap (to form) when rock layers at the bottom were tilted, then eroded flat.

16. An unconformity (to represent) time during which no sediments were preserved in a region.

17. Disconformities (to mark) by features of subaerial erosion.

18. A nonconformity (to exist) between sedimentary rocks and metamorphic or igneous rocks when the sedimentary rock (to lie) above and was deposited on the pre-existing and eroded metamorphic or igneous rock.

19. Anticlines usually (to develop) above thrust faults.

20. On a geologic map, synclines (to recognize) as a sequence of rock layers, with the youngest at the fold's center or hinge and with a reverse sequence of the same rock layers on the opposite side of the hinge.

21. The domed strata generally (to break) by faults that radiate out from the salt on circular domes but that may be more linear on elongate domes or anticlines with one fault or set of faults predominant.

22. Thrust faults with a very low angle of dip and a very large total displacement (to call) overthrusts or detachments; these often (to find) in intensely deformed mountain belts.

23. Reverse fault displacements (to combine) vertical and compressional displacements.

24. Together, normal and reverse faults (to call) dip-slip faults, because the movement on them (to occur) along the dip direction -- either down or up, respectively.

25. A plunging anticline (to make) a U-shaped or V-shaped pattern that points, or closes, in the direction of plunge.

Exercise № 8. Translate these sentences into English.

1. Структурная ловушка - подземная ловушка для нефти или газа, возникшая при деформации породы-коллектора, такая как сброс или складка.

2. Поскольку нефть и газ легче воды, а коллекторы обычно имеют региональный уклон, хотя часто и слабый, нефть и газ движутся в воде, как в вертикальном, так и в горизонтальном направлении, пока не встретят на своем пути непроницаемые или слабопроницаемые породы. Непроницаемый слой, перекрывающий коллектор, называется покрышкой.

3. Структурная ловушка представляет собой результат преобразования формы коллектора; стратиграфическая же ловушка возникает благодаря изменениям свойств самой породы.

4. Наиболее распространенный случай возникновения ловушки для нефти и газа в погребенной проницаемой толще связан с образованием антиклинальной складки.

5. Существует множество классификаций ловушек для нефти и газа. Классификация Клаппа включает следующие основные их разновидности: 1) антиклинальные структуры, 2) синклинальные структуры, 3) гомоклинальные структуры, 4) куполовидные структуры, или «купола», 5) несогласия, 7) трещины и 8) дизъюнктивы.

6. Образование почти всех ловушек нефти и газа происходит вследствие деформаций коллекторских пластов.

7. Согласное залегание характеризуется отсутствием перерывов в осадконакоплении.

8. При согласном залегании границы слоев параллельны между собой, а изменение состава указывает на постепенное закономерное изменение условий осадконакопления.

9. Несогласное залегание или несогласие выражает перерыв в осадко-накоплении, который выражается отсутствием определенных

стратиграфических горизонтов и обусловлен различными причинами. Такое несогласие называется стратиграфическим.

10. Поверхность, разделяющая несогласно залегающие толщи, называется поверхностью несогласия.

11. Угловое несогласие проявлено в перерыве осадконакопления между двумя толщами слоев, имеющими различный угол наклона.

12. В этом случае поверхность несогласия под углом пересекает нижние слои (более древние) и располагается параллельно наслоению верхней, более молодой толщи.

13. Сбросами называются нарушения, в которых поверхность разрыва наклонена в сторону расположения опущенных пород.

14. Взбросами называются нарушения, в которых поверхность разрыва наклонена в сторону расположения приподнятых пород.

15. Горстами называются структуры, образованные сбросами или взбросами, центральные части которых приподняты и на поверхности сложены более древними породами, чем породы, обнаженные в их краевых частях

16. Разрывы взбросового характера, возникающие одновременно со складчатостью, называются надвигами.

17. Грабенами называются структуры, образованные сбросами или взбросами, центральные части которых опущены и сложены на поверхности породами, более молодыми, чем породы, обнажающиеся в приподнятых краевых частях.

18. В настоящее время разрывные нарушения без смещения называют просто трещинами.

19. Надвиг – один из видов разрывных смещений слоёв горных пород.

20. Надвиг представляет собой надвигание одной массы пород на другую по наклонённому разлому.

21. Таким образом, пласты, лежащие с верхней стороны разлома, сдвинуты вверх, а с нижней — вниз.

22. Первый блок называется висячим, второй – лежачим.

23. При этом разлом наклонён к горизонту под небольшим углом — иначе объект называют не надвигом, а взбросом.

24. Границу между ними обычно проводят по величине угла 45°.

25. Надвиги образуются при сжатии земной коры.

Exercise № 9. Render the text using words from the unit.

Первичное и нарушенное залегание слоёв

Большая часть осадков образуется в морских или континентальных водоёмах или на прибрежных равнинах. Залегание осадков при этом практически горизонтальное (угол наклона не более 1). Такое залегание называют первичным. Первичное залегание с более крутым залеганием пород, достигающем 3-4°, а иногда 10° может возникнуть на склонах наземных и подводных возвышенностей, каньонов, уступов. Первичное залегание осадочных пород сохраняется сравнительно редко и нарушается последующими тектоническими движениями, что приводит к их наклонному залеганию, образованию складчатых и разрывных нарушений.

Пласты осадочных пород могут иметь согласное и несогласное залегание по отношению друг к другу. В случае согласного залегания каждый вышележащий слой, без каких-либо следов перерыва в накоплении осадков налегает на нижележащие породы. Несогласное залегание образуется тогда, когда между вышележащим и подстилающим слоями отмечается перерыв в осадконакоплении и стратиграфическая последовательность нарушена. Несогласное залегание может быть параллельным, когда пласты, несмотря на перерыв в отложении осадка, сохраняют параллельное залегание и угловым, когда одна толща лежит с перерывом по отношению к другой под определённым углом. Например, когда на смятом в складки пласте известняка горизонтально залегает слой песчаника. Выявление стратиграфических несогласий является одной из наиболее важных задач геологического картирования и проводится с использованием следующих признаков:

1. характерное строение поверхности несогласия, имеющей неровности, уступы;
2. угловое несогласие между слоями разного возраста;
3. резкий возрастной разрыв между фауной в выше- и нижележащих слоёв;
4. резкое различие в степени метаморфизма двух соприкасающихся слоёв;
5. резкий переход от морских к континентальным отложениям и наоборот;
6. следы выветривания на поверхности несогласия.

Пликативные дислокации слоёв горных пород

В результате действия пластических деформаций горных пород возникает нарушенное залегание слоёв земной коры без видимого разрыва их сплошности. Такие формы нарушений называют пликативными дислокациями. К ним относится образование моноклиналей, складок и флексур.

Моноклинальное залегание образуется тогда, когда горизонтально залегающие породы в результате тектонических движений приобрели наклон

под одним углом на значительном пространстве. Моноклиналь – это наиболее простая форма пликативных дислокаций, широко проявлена в чехлах молодых и древних платформ. Существуют слабонаклонные (до 15°), пологие (16-30°), крутые (30-75°), поставленные на голову (80-90°) моноклинали.

Складчатые деформации или складки – это волнообразные изгибы пластов без разрыва сплошности пород. Этот тип дислокаций проявлен наиболее широко. Во всех типах складок различают несколько основных элементов. Часть складки в месте перегиба слоёв называется замком, сводом или ядром. Крылья - боковые части складок, примыкающие к своду. Размеры складок характеризуются длиной, шириной, высотой.

Складки, пласты которых выгнуты кверху, называются антиклиналями. У этих складок в ядре на дневной поверхности обнажаются более древние породы, а на крыльях - более молодые и они наклонены от ядра. Складки, пласты которых прогнуты книзу, называются синклиналями. У них в ядре обнажаются более молодые породы, и крылья наклонены к ядру. Это две основные формы складок.

Тектонические движения иногда приводят к разрыву сплошности пластов горных пород и образованию разрывных нарушений или дизъюнктивных дислокаций. Различают нарушения без существенного смещения по ним и нарушения со смещениями. Нарушения без смещения – это трещины. Они различаются по ширине (от миллиметров до нескольких метров), по протяжённости (от первых сантиметров до десятков километров), по глубине, форме (прямолинейные, дугообразные и др.) и т. д. Кроме трещин тектонического происхождения существуют трещины экзогенного (нетектонического) происхождения – трещины усыхания, оползней, обвалов, расширения пород, отслаивания и др.

К нарушениям со смещением относятся сбросы, взбросы, сдвиги и надвиги. Элементами тектонических нарушений являются: сместитель, крылья, угол наклона сместителя амплитуды смещения. Сместитель – это плоскость, по которой происходит смещение. Угол наклона сместителя может варьировать от нескольких градусов до 80-90°. Крылья – толщи пород, расположенные по обе стороны сместителя. При наклонном положении сместителя крыло, которое располагается над ним, называется висячим крылом, а расположенное под ним – лежачим.

Одной из наиболее характерных форм разрывных нарушений является сброс. Это нарушение, у которого сместитель наклонён в сторону опущенного крыла (независимо от того, является оно висячим или лежачим). Если же сместитель наклонен в сторону приподнятых пород и уходит под них, то такое нарушение называется взброс. В отличие от описанных типов

нарушений сдвигом называется разрывное нарушение, у которого перемещение происходит преимущественно в горизонтальном направлении, а сместитель расположен вертикально. Часто (или почти всегда) сбросы и сдвиги проявляются совместно и называются сбросо-сдвигами и сдвиго-сбросами.

Надвигом называется дислокация с разрывом пластов и надвиганием одного крыла на другое по относительно пологой или горизонтальной плоскости. Это нарушение взбросового типа, возникающее обычно вместе со складчатостью. Выделяют крутые (более 45^{o}), пологие (менее 45^{o}) и горизонтальные надвиги. Эти структуры широко проявлены в складчатых областях. Надвиг с большим горизонтальным перемещением называется шарьяжем, у которого висячее крыло может перемещаться на многие километры и даже на десятки километров.

Сбросовые нарушения часто проявляются в виде систем сбросов и взбросов. При этом образуются своеобразные структуры. Грабен – опущенный участок земной коры, ограниченный параллельными сбросами значительной протяжённости. Горст – приподнятый участок земной коры, заключенный между параллельными разломами. Несколько параллельных ступенчато расположенных грабенов образуют сложный грабен. Это относится к структурам Великих африканских озёр (Танганьика, Альберта, Рудольфа), рифту Красного моря, рифту озера Байкал, Рейнскому грабену и др.

Exercise № 10. Watch the film

https://distedu.udsu.ru/course/view.php?id=3296 **файл Joint and faults, Deformation of sedimentary rocks. Give the main peculiarities of different types of joints and faults according to the information in the video.**

Exercise № 11. Do you know that?

Ghawar is an oil field located in Eastern Province, Saudi Arabia. Measuring 280 by 30 km (174 by 19 mi), it is by far the largest conventional oil field in the world, and accounts for roughly a third of the cumulative oil production of Saudi Arabia as of 2018.

Ghawar occupies an anticline above a basement fault block dating to Carboniferous time, about 320 million years ago; Cretaceous tectonic activity, as the northeast margin of Africa began to impinge on southwest Asia, enhanced the structure. Reservoir rocks are Jurassic Arab-D limestones with exceptional porosity (as much as 35% of the rock in places), which is about 280 feet thick and occurs 6,000-7,000 feet beneath the surface. Source rock is the Jurassic Hanifa formation, a marine shelf deposit of mud and lime with as much as 5% organic material (1%

to 7% is considered good oil source rock). The seal is an evaporitic package of rocks including impermeable anhydrite.

Notable examples of anticlines

Europe

The Weald – Artois Anticline is a major anticline which outcrops in southeast England and northern France. It was formed from the late Oligocene to middle Miocene, during the Alpine orogeny.

North America

Anticlines can have a major effect on the local geomorphology and economy of the regions in which they occur. One example of this is the El Dorado anticline in Kansas. The anticline was first tapped into for its petroleum in 1918. Soon after the site became a very prosperous area for entrepreneurs following World War I and the rapid popularization of motor vehicles. By 1995 the El Dorado oil fields had produced 300 million barrels of oil. The central Kansas uplift is an antiform composed of several small anticlines that have collectively produced more than 2.5 million barrels of oil.

Another notable anticline is the Tierra Amarilla anticline in San Ysidro, New Mexico. This is a popular hiking and biking site because of the great biodiversity, geologic beauty and paleontological resources. This plunging anticline is made up of Petrified Forest mudstones and sandstone and its caprock is made of Pleistocene and Holocene travertine. The anticline contains springs that deposit carbon dioxide travertine that help to contribute to the rich diversity of microorganisms. This area also contains remains of fossils and ancient plants from the Jurassic period that are sometimes exposed through geological erosion.

The Ventura Anticline is a geologic structure that is part of the Ventura oil fields, the seventh largest oil field in California that was discovered in the 1860s. The anticline runs east to west for 16 miles, dipping steeply 30–60 degrees at both ends. Ventura County has a high rate of compression and seismic activity due to the converging San Andreas Fault. As a result, the Ventura anticline rises at a rate of 5 mm/year with the adjacent Ventura Basin converging at a rate of about 7–10 mm/year. The anticline is composed of a series of sandstone rock beds and an impermeable rock cap under which vast reserves of oil and gas are trapped. Eight different oil bearing zones along the anticline vary greatly from 3,500 to 12,000 feet. The oil and gas formed these pools as they migrated upward during the Pliocene Era and became contained beneath the caprock. This oil field is still active and has a cumulative production of one billion barrels of oil making it one of the most vital historical and economic features of Ventura County.

Faults and ore deposits

Many ore deposits lie on faults. This is due to the fact that damaged fault zones allow for the circulation of mineral-bearing fluids. Intersections of near-vertical faults are often locations of significant ore deposits.

An example of a fault hosting valuable porphyry copper deposits is northern Chile's Domeyko Fault with deposits at Chuquicamata, Collahuasi, El Abra, El Salvador, La Escondida and Potrerillos.[Further south in Chile Los Bronces and El Teniente porphyry copper deposit lie each at the intersection of two fault systems.

Large overthrust faults occur in areas that have undergone great compressional forces. These conditions exist in the orogenic belts that result from either two continental tectonic collisions or from subduction zone accretion. The resultant compressional forces produce mountain ranges. The Himalayas, the Alps, and the Appalachians are prominent examples of compressional orogenies with numerous overthrust faults.

Thrust faults occur in the foreland basin which occur marginal to orogenic belts. Here, compression does not result in appreciable mountain building, which is mostly accommodated by folding and stacking of thrusts. Instead thrust faults generally cause a thickening of the stratigraphic section. When thrusts are developed in orogens formed in previously rifted margins, inversion of the buried paleo-rifts can induce the nucleation of thrust ramps.

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Составители:
Роева Кристина Михайловна
Сушенцова Татьяна Вячеславовна

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Издательский центр «Удмуртский университет»
426034, г. Ижевск, ул. Ломоносова, 4Б, каб. 021
Тел. : + 7 (3412) 916-364, E-mail: editorial@udsu.ru