Two types of petroleum traps are structural and stratigraphic. Structural traps are formed by deformation of reservoir rock, such as by folding or faulting. Stratigraphic traps are formed by deposition of reservoir rock, such as a river channel or reef, or by erosion of the reservoir rock, such as an angular unconformity.

**Structural Traps—Anticlines and Domes**

Anticlines and domes were the first type of petroleum traps recognized. If the earth’s crust has several potential reservoir rocks, the folding can form multiple producing zones (Figure 15-1). The Santa Fe Springs field near Los Angeles, California, has 25 producing zones. Folding of the brittle basement rock often fractures the surface of the basement rock along the axis of the fold. In many fields, these basement fractures also hold petroleum.

Most anticlines and domes are asymmetrical; they have a steep and a gentle side. The crest of the folded structure often migrates with depth (Figure 15-2). A well drilled on structure at the surface crest of the fold could be too far off structure at reservoir rock depth to encounter petroleum.
The Salt Creek field in the Powder River basin of Wyoming is an example of the large, anticlinal traps found in the intermontane basins of the Rocky Mountains. The elliptical anticline (Figure 15-3) is steepest on the west. The structure has five producing zones, all sandstones, of which the Second Wall Creek Sandstone (Cretaceous) is the most prolific. A large oil seep was located over the trap, leading to its discovery. This field has produced over 500 million barrels of oil.

As the reservoir rocks are deformed into an anticlinal or domal structure, they are often cut by faults. The faults can be barriers to fluid flow (Figures 8-6 and 8-7), dividing the folded structure into individual producing compartments. Petroleum production from one side of the faulted structure will not affect production on the other side. Two observations can determine if a fault has divided the structure into separate producing compartments (Figure 15-4). Oil-water contacts in reservoirs are usually on different sides of the fault, the fault is acting as a fluid barrier. As water, gas, and oil are removed from the reservoir during production, the reservoir pressure decreases. If the reservoir pressure decrease is different on opposite sides of the fault, the fault has cut the reservoir into separate compartments.

The Wilmington field (Long Beach, California) has been cut by faults into separate compartments. The Wilmington field is formed by a large anticline 11 miles long and 3 miles wide. Flat sediments cover an angular unconformity at a depth of 2000 feet (Figure 13-9). There are seven sandstone-producing zones along with the fractured basement that also produces. The anticline is cut by five major faults that form six separate producing compartments (Figure 15-5). The seaward (western) compart-
ments were never developed until the completion, in 1965, of four artificial islands off Long Beach that were used for drilling by a consortium of oil companies (THUMS). The Wilmington field will ultimately produce 2.5 billion barrels of oil and a trillion cubic feet of gas.
Figure 15-5  A cross section of the Wilmington field, Long Beach, California, showing the separate producing compartments formed by faulting on the anticline. (Adapted from Mayuga, M. N. 1970, Geology and development of California’s giant—Wilmington oil field: in Halbouty, M. T. editor, Geology of Giant Oil Fields, Am. Assoc. Petrol. Geol. Mem. 14, pp. 158–184.)

As an anticline or dome is formed by folding (Figure 15-6a), the top of the structure is eroded flat, often removing the reservoir rocks from the crest of the structure (Figure 15-6b). Later sediments bury the eroded structure in the subsurface. When the petroleum migrates up the reservoir rocks, it is trapped below the angular unconformity (Figure 15-6c), and the crest of the structure is barren. This is called a bald-headed structure, as drilling on structure will result in a wet hole.

Figure 15-6  A bald-headed anticline formed by (a) uplift of sediments into an anticline, (b) erosion of the anticline, removing the potential reservoir rock from the crest and (c) covering the angular unconformity by sediments and migration of oil up along the flanks of the structure.
The Oklahoma City field, just south of Oklahoma City is a bald-headed structure. A large fault was involved in folding the sediments up to the west of the fault (Figure 15-7). Many of the potential reservoir rocks were eroded off the top of the structure, leaving an angular unconformity and only the Arbuckle Limestone as a reservoir rock over the basement. The unconformity and structure were then uplifted again, forming a broad anticline on the surface of the ground. In 1928, Indian Territory Illuminating Oil Company drilled the first well on the surface anticline, just 5 miles southeast of downtown Oklahoma City. The well came in as a gusher, flowing 6500 barrels of oil per day from the Ordovician Arbuckle dolomite at 6600 feet. The field has 30 pay zones, but only the Arbuckle dolomite was located on structure. Although highest on the structure, the Arbuckle dolomite was least productive (about 18 million barrels of oil) and the first to go to water. Drilling out from the center of the structure located the more prolific pay zones. In 1930, Indian Territory Illuminating Oil Company drilled the No. 1 Mary Sudik to the south of the Arbuckle dolomite discovery well. It was the first well into the Wilcox Sandstone. The well blew out at the rate of 200 million cubic feet of gas and 20,000 barrels of oil per day. Because the Wilcox Sandstone was loosely cemented, large quantities of sand blew up the well with the gas and oil, preventing the well from being controlled. Norman, Oklahoma,
Figure 15-8 Cross section of a trap showing the spill point and closure.

Figure 15-9 Structure contour map of one of the sandstone reservoir rocks of the Tom O’Conner field, south Texas, showing the roll-over anticline trap. (Adapted from Mills, H. G. 1970, Geology of Tom O’Conner field, Refugio County, Texas: in Halbouty, M. T. editor, Geology of Giant Oil Fields, Am. Assoc. Petrol. Geol. Mem. 14, pp. 292–300.)

to the south, and then Oklahoma City to the north, were covered with oil for 11 days. The Wilcox Sandstone, with porosity of 30%, is the most prolific reservoir rock on the structure. Over 500 million barrels of oil have been produced from the Wilcox Sandstone in the Oklahoma City field.

Petroleum, being light, fills the trap from the top downward. As gas and oil enter an anticlinal trap, it is filled from the top down to a level at which it cannot hold another drop of petroleum (Figure 15-8). This is the highest point on the rim of the anticline or dome and is the spill point. The vertical distance from the crest of the reservoir rock down to the spill point is the closure of the trap. It is the maximum pay zone that the trap can theoretically hold. The closure of any trap is an important factor because it is a measure of the potential size of the field. The concept of trap closure can be applied to most types of traps.

A roll-over anticline is a trap that forms on the basin side of a growth fault (Figure 9-17c). The Vicksburg fault trend along the south Texas coastal plain is a series of roll-over anticline traps (Figure 9-18). One of the largest of these is the Tom O’Conner field, formed by a roll-over anticline 10 by 3 miles in area (Figure 15-9). The anticline is on the down-
thrown (Gulf of Mexico) side of the Vicksburg fault. The field has several Oligocene to Pliocene sandstone reservoirs. Because the coastal plain sands are loosely cemented, porosities average 31% and permeabilities range up to 6500 millidarcies. The Tom O’Conner field will ultimately produce over 500 million barrels of oil and 1 trillion cubic feet of gas.

**Faults**

Dip-slip faults form traps by displacing a dipping reservoir rock (Figure 15-10). These types of traps, however, tend to be relatively small, as the fault is a linear feature and has no sides. The petroleum can usually flow up dip along one side of the fault and out of the trap. Two intersecting faults, however, can form larger traps by creating sides to the fault trap.

Folds and reverse and thrust faults are formed by compression. Many of the southern California petroleum traps are still forming today as a result of the action of plate tectonics—the collision of the North American plate with the Pacific plate (Figure 11-14). A cross section of the Ventura basin, north of Los Angeles, shows the South Mountain oil field, an anticline between two high-angle reverse faults and the Timber Canyon oil field below a reverse fault (Figure 15-11).

Buried, tilted fault blocks form large petroleum traps. During the geologic past, the sedimentary rock layers of the earth’s crust (Figure 15-12a)

![Figure 15-10](image_url) Dip-slip fault traps with (a) a normal fault and (b) a reverse fault.
Figure 15-11 A cross section of the Ventura basin, California, showing an anticlinal (South Mountain) and fault (Timber Canyon) trap. (Adapted from: Bailey, T. L., 1947, Origin and migration of oil into Sespe redbeds, California: Am. Assoc. Petrol. Geol. Bull. V. 31, pp. 1913–1935.)

Figure 15-12 A tilted fault block trap formed by (a) deposition of sedimentary rock layers, including a potential reservoir rock, (b) faults cutting and tilting the sediments into large fault blocks, and (c) sediments covering the tilted fault blocks and oil migrating into the reservoir rock.

were broken into large fault blocks, miles across (Figure 15-12b). Some of the fault blocks contained potential reservoir rocks. Later, seas covered the tilted fault blocks and deposited impermeable rocks such as shales or salts on the tilted reservoir rocks. The oil and gas then migrated into the trap (Figure 15-12c).

The Statfjord oil field in the North Sea is formed by a tilted fault block (Figure 15-13). During the Mesozoic breakup of the supercontinent Pangaea, an aulacogen formed along the present North Sea. Large blocks of sediments were tilted by faulting. One of these blocks contains two Jurassic-age sandstones that form the reservoirs for the 3 billion barrel oil field.
Drag Folds

Drag folds are formed by friction generated with the movement of fault blocks along a fault plane (Figure 15-14). Friction causes the beds on either side of the fault to be dragged up on one side and down on the

Figure 15-13 A cross section of the Statfjord oil field, North Sea, showing the two sandstone reservoirs in the tilted fault block. (Adapted from: Kirk, R. H., 1980, Statfjord field—a North Sea giant: in Halbouty, M. T., editor, Giant Oil and Gas Fields of the Decade 1968–1978, Am. Assoc. Petrol. Geol. Mem. 30, pp. 95–116.)

Figure 15-14 A series of cross sections showing the formation of drag folds by fault movement. (a) A marker bed undisturbed by fault movement. (b) The movement of the hanging wall block upward generates friction, bending the marker bed down into a drag fold. (c) The movement of the footwall block downward generates friction, bending the marker bed up into a drag fold.
other side of the fault. The geometry of the drag fold indicates the direction of the fault movement. If the drag fold is down toward the fault plane, that block moved up. Large drag folds occur along thrust faults where the movement has been great.

Most mountain chains on land have been formed by compressional forces (folds and reverse and thrust faults). The thrust faults usually occur in a belt called the overthrust or disturbed belt. The Rocky (Figure 15-15), Ouachita, and Appalachian mountains have overthrust belts. A west to east cross section (Figure 15-16) across the Rocky Mountain (Western) overthrust belt shows the deformation of the earth’s crust.

Figure 15-15 Map of the Rocky Mountain or Western overthrust or disturbed belt.

Figure 15-16 A west to east cross section through the Rocky Mountain overthrust belt showing the thrust faults and drag folds.
Thrust faulting occurred during the Cretaceous through Eocene formation of the mountains. Several of the thrust faults moved tens of miles horizontally. In Wyoming and Utah, a 1000-foot-thick Jurassic dune sandstone, the Nugget Sandstone, has been deformed into large subsurface drag folds along the thrust faults. The anticlinal drag folds in the Nugget Sandstone are the targets for Rocky Mountain overthrust drilling.

The Painter Reservoir field, Wyoming, which was discovered in 1977, is typical of the overthrust petroleum fields. A large-scale west to east cross section (Figure 15-17), shows the numerous thrust faults and the drag fold trap in the Nugget Sandstone at 10,000 feet below the surface. A small-scale cross section of the field (Figure 15-18) shows more faulting.


and very complex deformation. The oil and gas pay zone is over 1000 feet.

Location of drag folds in the subsurface cannot be predicted from the rock outcrops on the surface (Figures 15-16 and 15-17). It was not until the 1970s that improvements in seismic techniques and processing opened exploration and drilling in complex areas such as the overthrust belt.

**Fractures and Joints**

Fine-grained rocks may be porous, but they will not be reservoir rocks because they lack permeability. Shales and chalks (fine-grained limestone composed of microfossils) are good examples of this. If the fine-grained rock is naturally fractured, however, it has permeability and can be a reservoir rock.

Fractures or joints are formed when the rock is stressed. This occurs when the rock is disturbed by deformation (folding or faulting). Fractures have the highest probability of occurring where the rock is bent the most (along the axial plane) on a fold. Fractures also possibly occur along a fault plane where the two blocks grind against each other during the fault movement.

Petroleum traps in the Austin Chalk occur near Giddings and La Grange in south central Texas. The Mount Calm oil field (Figure 15-19) is typical of this type of trap. Fault movement has fractured the Austin Chalk adjacent to the fault plane and the oil field occurs in the fractured chalk. It has no relationship to high areas in the reservoir rock. Other oil fields occur in the Austin Chalk where it is fractured either by fault or folding.

**Stratigraphic Traps—Angular Unconformities**

Angular unconformities form giant gas and oil traps (Figures 3-10 and 3-11) when a reservoir rock is truncated (terminated) under an angular
unconformity and overlain by a seal (Figure 3-9). Petroleum reservoirs, however, can also be located directly above an angular unconformity (Figure 15-20). These sandstone reservoirs are called buttress sands. They were formed when rising seas deposited beach sand on an ancient land surface (Figure 15-21). An angular unconformity surface is an ancient erosional surface of the land. Seas rising (transgressing) to cover the land deposit a series of beach sands along the unconformity surface. With time, the beach sands are deposited further and further inland in a pattern called onlap. The onlapping sands (buttress sands) are then buried by younger sediments in the subsurface.

The Bolivar Coastal fields of Venezuela, containing over 30 billion barrels of oil, are examples of buttress sands. A cross section from west (through Lake Maracaibo) to east (Figure 15-22) shows the Oligocene angular unconformity dipping down to the west. A series of extensive buttress sands directly overlaps the unconformity and forms the oil
fields. Some of the oil has leaked out of the buttress sands up dip along the unconformity to form a line of large oil seeps along the eastern shores of Lake Maracaibo.

Reefs

Limestone reefs form prolific gas and oil traps. Reef traps in the Permian basin of West Texas and New Mexico (Figures 7-6 and 7-7) and the Golden Lane of Mexico (Figures 8-15 and 8-16) are giant oil fields. The reef flat environment of a reef has considerable original porosity. Subsurface waters percolating through the original pores can enlarge the pores by solution and transform the limestone into dolomite.

The disturbed belt and some drag fold reservoirs, such as Turner Valley field, occur along the eastern edge of the Rocky Mountains in Alberta, Canada (Figure 15-23). A large portion of the oil production, however, comes from buried Devonian atolls and barrier reefs. The first of the Devonian reef oil fields was Leduc, discovered in 1947.

The Redwater oil field is typical of the Devonian reef fields of Alberta. A map view (Figure 15-24) shows the elliptical shape of the large subsurface reef, and a cross section (Figure 15-25) illustrates its atoll nature. The reef flat (organic reef and reef detritus) is located on the outside of the reef. Lagoonal limestones in the center of the reef are typically micrites (fine-grained) and are not reservoir rocks. The oil occurs in the highest areas of the reservoir rock of the tilted reef. This field will ultimately yield 850 million barrels of oil.

Smaller patch reefs can also form petroleum traps. Hundreds of Cretaceous reefs, no more than a mile or a fraction of a mile in diameter, are buried in northern Michigan (Figure 15-26). These reefs are directly

![Figure 15-23](image)


Figure 15-26  Map of the Silurian pinnacle reef trends in northern Michigan.
Figure 15-27 Cross section of a Silurian pinnacle reef, northern Michigan.

overlain by salt, which acts as a seal. Many have been changed into dolomite. The reefs have a conical shape in cross section (Figure 15-27), which is why they are called pinnacle reefs. A high percentage of these reefs contain petroleum.

Petroleum production can come not only from the reef but also from compaction anticlines that occur over the reef (Figure 15-28). Compaction anticlines form by the burial of a hard rock mound or ridge, such as a limestone reef or bedrock hill. As the reef is buried in the subsurface by deposition of loose sands and muds, a greater thickness of loose sediments is deposited on the sides of the reef than on the top. As the sediments are buried deeper and deeper, the weight of overlying sediments compact the loose sediments. The reef, composed of resistant limestone, compacts very little. Because more compaction occurs in the thicker sediments along the flanks of the reef, a broad anticline forms in the sedi-

Figure 15-28 Cross section showing the compaction anticline in sediments overlying a buried reef.
ments over the reefs. If there are any reservoir rocks in the sediments overlying the reefs, traps are formed.

Horseshoe atoll (Figure 15-29), a buried Pennsylvanian-Permian reef in west Texas, is located in the northeastern Midland basin, one of the Permian basins. The reef is 70 to 90 miles across. High points along its rim form oil fields. The largest of these is the Kelly-Snyder oil field, which will ultimately produce over 1 billion barrels of oil. A cross section through the field (Figure 15-30) shows that the major production comes from the reef itself. Some production, however, also comes from compaction anticlines on thin sandstone layers in the overlying shale (Wolfcamp).

**Shoestring Sandstones**

Shoestring sandstones are long, narrow lenses of sand usually encased in a shale layer (Figure 15-31). These are deposited as shorelines (beaches, barrier islands, and spits), rivers (point bars and abandoned river channels), and deltas (bar fingers). Because of the close source rock–reservoir rock (shale-sandstone) relationship, shoestring sandstones are often
filled with oil or gas (Figures 1-8, 6-8, and 6-12). The shoestring sandstone oil fields are saturated (oil and water sharing the pore space), but the entire sandstone is often pay zone without an oil-water contact. Only the largest of shoestring sandstone oil fields (for example, Burbank field) have oil-water contacts.

The Bush City oil field in Kansas (Figure 15-32) is a shallow shoestring sand field. The sandstone is 13 miles long, \( \frac{3}{4} \) mile wide, and up to 55 feet thick. It is completely encased in Cherokee Shale. A cross section of the field shows that it is a buried river channel.

**Pinch-Outs**

An up-dip pinch-out of a reservoir rock forms a petroleum trap. In a typical coastal plain (Figure 9-14), the sediments are deposited with a slight dip down into the basin (ocean). A sandstone pinch-out or wedge in a shale layer will trap any petroleum (Figure 15-33) rising up the dip of the sandstone in a landward direction. These types of petroleum traps tend to be small, but several hundred have been found in the Gulf of Mexico coastal plain.
Figure 15-32 Map view of the Bush City field, Kansas, showing the shoestring sandstone reservoir rock. Each square on the map is 1 mile on a side. A cross section of the field (A-A') shows the buried, sand-filled river channel. (Adapted from: Charles, H. H., 1941, Bush City Oil Field, Anderson County, Kansas: in Levorsen, A. I., editor: Stratigraphic Type Oil Fields: Am. Assoc. Petrol. Geol., Tulsa, OK, pp. 43-56.)

Figure 15-33 Sandstone pinch-out or wedge-out traps on a coastal plain.
Combination Traps

Combination traps are formed by elements of both structural and stratigraphic processes. The largest gas field on the North American continent, the Hugoton-Panhandle gas field of Texas, Oklahoma, and Kansas is an example. It covers an enormous area (Figure 15-34). It is 275 miles long and from 8 to 57 miles wide. In Texas there is also oil production along the eastern margin of the field. The reservoir rocks are primarily limestones and dolomites that are collectively known as the Chase Group (Figure 15-35a). The Wichita Formation, containing salt layers, lies directly over the reservoir rocks and forms the seal. The Chase Group of reservoir rocks was deposited wedging out into impermeable, red-colored shales and sands to the west. An uplift to the west completed the trap (Figure 15-35b). Enormous volumes of gas formed in the deep Anadarko basin to the east and were trapped by the up-dip change from permeable to impermeable rocks. The gas contains an average of 0.5% helium. Ultimate recovery is estimated to be 70 trillion cubic feet of gas.

The Scipio field in Michigan (Figure 15-36a) is located in dolomitized Trenton Limestone at a depth of about 2500 feet below sea level. Subsurface fractures had cut the originally impermeable Trenton Limestone.
Figure 15-35 Cross sections showing the formation of the Hugoton-Panhandle field. (A) The deposition of Chase Group reservoir rocks that are permeable to the east and impermeable to the west. Wichita Formation containing salt overlies the Chase Group. (B) Uplift along the Stratford arch to complete the trap. Gas generated in the Anadarko basin to the east migrated up dip along the Chase Group to be trapped by the facies change along the flanks of the Stratford Arch. (Adapted from: Pippin, L., 1970, Hugoton-Panhandle field, Texas-Oklahoma-Kansas—the first fifty years in Halbouty, M. T., Geology of Giant Petroleum Fields, Am. Assoc. Petrol. Geol. Mem. 14. pp. 204–222.)

Figure 15-36 (A) Map of the Scipio field, Michigan, showing the dolomite reservoir rock producing wells between the subsurface fractures (straight lines). (Courtesy of Dan A. Busch, petroleum consultant, Tulsa, Oklahoma). (B) cross section of the Scipio field. (Adapted from D. A. Busch, 1954, Structure map of the Scipio pool in Michigan: in A. I. Leviron, Geology of Petroleum, W. H. Freeman and Co., San Francisco, p. 124.)
These formed a route for magnesium-rich waters to flow into the limestone and transform it into dolomite. Only between the fractures was the limestone changed into permeable dolomite (Figure 15-36b). There is no high point in the trap. The dolomite between the fractures is the reservoir rock and forms the oil field. Because of the volume decrease as limestone was transformed into dolomite, the dolomite trap actually occupies a low structure in the Trenton Limestone. The Scipio field will ultimately produce over 100 million barrels of oil and 200 billion cubic feet of gas. After the Scipio field was discovered by “random drilling” in 1957, a series of northwest-to-southeast-trending oil fields were located by following the Scipio trend. All these fields are located in dolomitized Trenton Limestone between fractures.

**Salt Domes**

Salt domes are large masses (up to miles across) of salt rising from the subsurface through overlying sediments to form a plug-shaped structure. Salt is a type of solid that flows slowly as a viscous liquid under pressure. Many areas are underlain by thick salt deposits. When the salt is originally deposited, it has a density of 2.2 grams per cubic centimeter. It is then buried by loose sediments such as sands and muds (Figure 15-37) with original densities of 1.9 grams per cubic centimeter. As the sediments are buried deeper, the weight of the overlying sediments exerts more and more pressure. The sands and muds compact by squeezing water out of the pore spaces. The salt layer, however, does not compact, since it is a crystalline sediment without pore spaces. There is nothing to give in a salt layer. Eventually the overlying sediments are denser than the underlying salt layer (Figure 15-37). The salt flows and rises by buoyancy through the overlying sediments to form the salt dome.

As the salt dome rises, it uplifts and pierces overlying sediments (Fig-
ure 15-38). The salt is composed primarily of halite and is highly soluble. Large amounts of salt are dissolved as the rising salt dome comes in contact with ground water in the overlying sediments. One to 5% of the salt is insoluble (anhydrite, gypsum, limestone, and/or dolomite). As the salt dissolves, an insoluble layer called the cap rock builds up on the top of the dome. This cap rock ranges from 100 to 1000 feet thick; it is often highly fractured and has vug-sized pores. Many subsurface salt domes can be detected on the surface because the rising salt forms a mound 10 to 15 feet high (Figure 15-38).

There are two drilling targets for salt dome petroleum traps (Figure 15-39). The first is to drill shallow over the top of the salt dome. Shallow
reservoir rocks are domed by the rising salt form traps. Near the top of the salt dome, the overlying sediments are faulted (normal faults and grabens) just before they are pierced by the salt. These fault traps are located in reservoir rocks directly above the salt. Because the cap rock is usually fractured and porous, it is often productive. The second is to drill deep along the flanks of the salt dome, where reservoir rocks that were uplifted and pierced have formed traps (Figure 15-39). Because the sediments both above and along the flanks of salt domes are intensely deformed, individual salt domes often have numerous petroleum traps. Bay Marchand is a salt dome in the shallow waters of the Gulf of Mexico to the south of New Orleans. This salt dome has several hundred separate producing reservoirs. The salt dome will ultimately yield 600 million barrels of oil.

The Gulf of Mexico is underlain by the Jurassic Louann Salt, which ranges in thickness from 600 to 1300 feet. The Louann Salt also underlies extensive areas of the Texas, Louisiana, and Mississippi coastal plains that were part of the Gulf of Mexico when the salt was deposited. This salt has formed hundreds of salt domes throughout the Gulf coastal plain and on the bottom of the Gulf of Mexico.

The Spindletop salt dome (Figure 15-40) near Beaumont, Texas, was the first salt dome that was drilled for petroleum (1901). Up to that time, no large oil fields or highly productive wells had been discovered in the United States. No one had ever drilled a “gusher”; all the wells had to be pumped. A large mound with gas and oil seeps marked the surface expression of the Spindletop salt dome. A well on that mound drilled into the Spindletop cap rock at just below 1000 feet. The cap rock was highly cavernous dolomite with high-pressure oil in it. This well became the world’s first gusher at the rate of 75,000 barrels of oil per day to a height of 200 feet above the rig. Within 9 months, 64 more wells were completed into the Spindletop cap rock, each producing a gusher. The cap rock of Spindletop yielded 17.5 million barrels of oil in 1902. Cap-rock production from Spindletop rapidly declined. It was not until 1925 that the deeper, flank oil on Spindletop (Figure 15-40) was discovered.
Abundant Spindletop oil inspired the creation of over 100 companies, including Gulf, Mobil, Texaco, and Sun, to drill, produce, refine, and/or market the oil. Crude oil had become cheap, and gasoline for internal combustion engines had became popular.

Salt domes also occur in Kansas, Utah, and Michigan. These, however, are unproductive. A thick salt layer, the Permian Zechstein Salt, underlies the North Sea and forms salt domes. Up until the late 1960s, over 200 exploratory wells had been drilled in the North Sea. Some found gas in the southern, United Kingdom sector. Most, however, were dry holes. Many companies were abandoning the North Sea when a well was drilled in 1969 on the Ekofisk salt dome (Figure 15-41) in the Norwegian sector. The reservoir rock, Ekofisk Chalk, has permeability due to fractures. The cap rock is formed by shales. The ultimate oil production from the Ekofisk field will be 6 billion barrels. Since that time, numerous other salt-dome and tilted-fault-block (Figure 15-13) oil fields, including other giants, have been discovered.