Chapter 5 - Searching for Oil and Gas

The Origin of Oil and Natural Gas

Travel back in time when the earth was covered with ancient seas, lush tropical forests, and vast numbers of living organisms. Beasts roamed the earth. Insects thrived. The oceans were full of both large and small fish. Much of the life; however, was so small that it could only be referred to as microscopic. Everyday, millions upon millions of these creatures and organisms were both born and died. This picture is the beginning of the oil and gas industry.

As these decaying plants and organisms settled to the bottom of rivers, lakes, swamps, and oceans, their remains became blended with mud and sand. Layer upon layer of sediments settled on top of the remains until the organic material became compressed and integrated in the mix. Over time, hundreds or thousands of feet of sediments would combine with the organic material. With each additional layer came added weight and pressure. This pressure created heat and the sediments eventually became sedimentary rocks such as sandstone, limestone and shale. However, the heat and pressure was doing a different type of work on the decayed plants and animals within the rock. They were being transformed into what is known as hydrocarbons (oil and natural gas). Worldwide, over six hundred such sedimentary basins have been located. Each varies in thickness. The rock sediment thickness in some is over 50,000 feet thick.

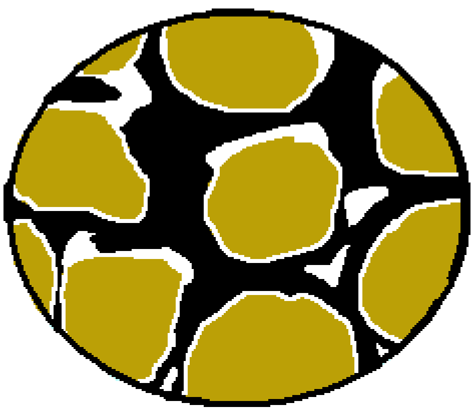
Money in the Ground: Fourth Edition. April, 2006, John Orban III, Meridan Press, Oklahoma City, p 32.

The Migration of Oil and Gas

The only thing that looks and feels as solid as a hunk of steel is most rocks. Yet, it is within rocks that oil and gas is found. Many people have the misconception that hydrocarbons are located in subsurface caverns or in some sort of underground river or lake. Instead, crude oil and natural gas occur in rock formations—sometimes buried thousands of feet below the surface of the earth.

If one were to place a sedimentary rock (sandstone or limestone) under a microscope, they would see hundreds of tiny pores. It is within these pores that hydrocarbons exist. Rocks that are more *porous* (or have greater *porosity*) can contain more hydrocarbons. Scientists often call rock formations that hold hydrocarbons "reservoirs."

Another characteristic of reservoir rock that becomes important for a petroleum company is that the reservoir is also *permeable*. This means that the pores are connected allowing the oil and gas to move or flow.



This illustrates both porous and permeable rock. The spaces between the grains of rock contain both oil (black) and water (white). The pores are also connected allowing the oil to move.

All of the known sedimentary basins in the world have three common characteristics:

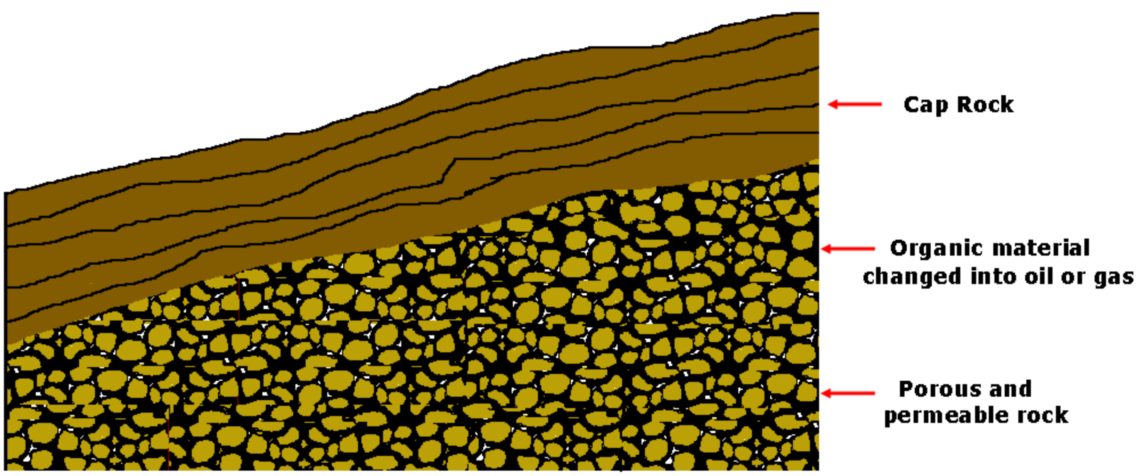
1. The deepest basins are under greater pressure from the rock formations above.
2. The deepest basins contain the greatest heat.
3. The pores between the rocks originally contained water.

With that in mind, travel again back in time. As the sedimentary rocks, filled with decaying particles, were being formed by heat and pressure, portions of the planet were still unstable. Earthquakes occurred. Formations of rock cracked. Others folded upward or shifted downward. Volcanoes spewed molten lava. Great rock formations moved sideways and faults occurred, changing the shape of the layers of rock. New sediments buried the old and the process continued.

With each new layer came added pressure. The weight pushed downward and the hydrocarbons began to move or migrate through the permeable source rock finding other cracks, faults or fissures. Because oil and gas are less dense than water, which occurs in huge quantities in the earth's subsurface, the oil and gas moved upward. The movement was a slow process. Over many years this upward migration continued until the hydrocarbons became trapped beneath solid rocks.

Reservoir Traps

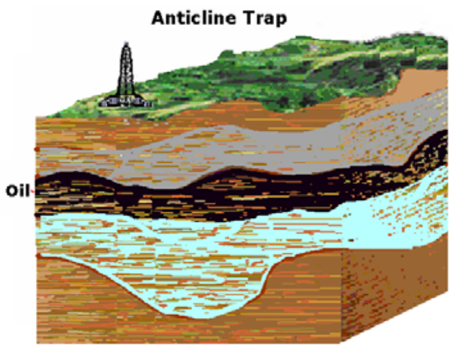
The rock that creates these traps can be referred to as *cap rock* and is non-porous (*impermeable*) in nature. The rock will also have a distinctive shape that will prevent crude oil or natural gas from any further migration.



A structural trap occurs when some type of movement in the earth has taken place that has caused the migration of hydrocarbons to stop. There are three basic forms of a structural trap:

1. Anticline Trap 2. Fault Trap 3. Salt Dome Trap

Anticline Traps

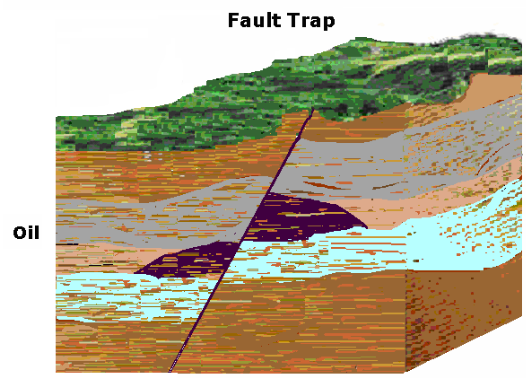


This illustration of an Anticline Trap depicts rocks that were previously flat but, over time, have folded or become bent into an arch. Oil and gas migrate upward through the porous rocks into the crest of the arch. Here the hydrocarbons become trapped beneath the impermeable cap rock. These arches that are not completely filled with oil will also contain large amounts of salt water.

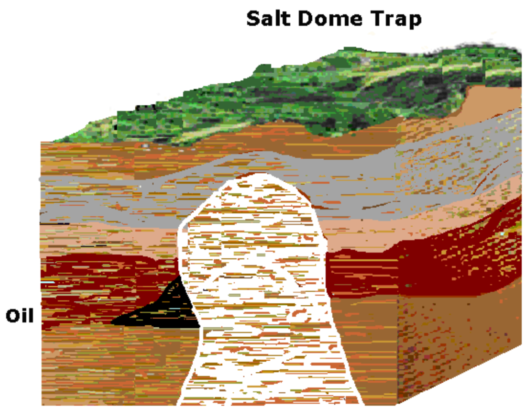
Fault Trap

This illustration shows a break in the layers of rock (fault). A trap occurs when the formation of rock on either side of the fault move. The formations create a natural trap for oil and gas because impermeable rock on one side of the fault will not allow the oil to escape.

In some cases, the fault is layered with substances that block oil from moving from one side of the fault to the other. This is known as a *fault gouge*.



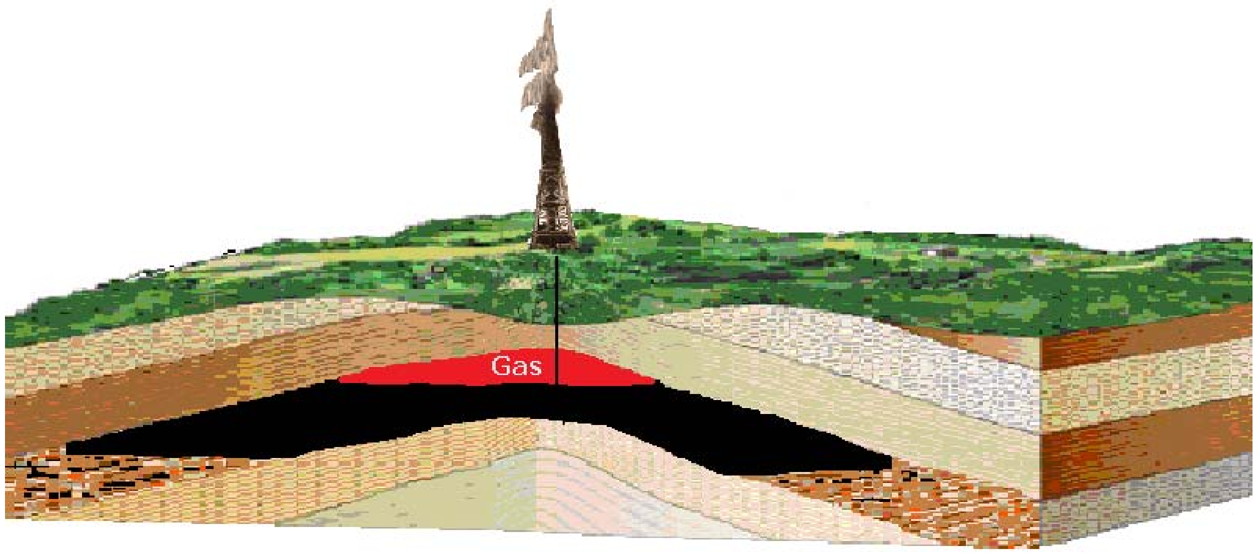
Salt Dome Trap



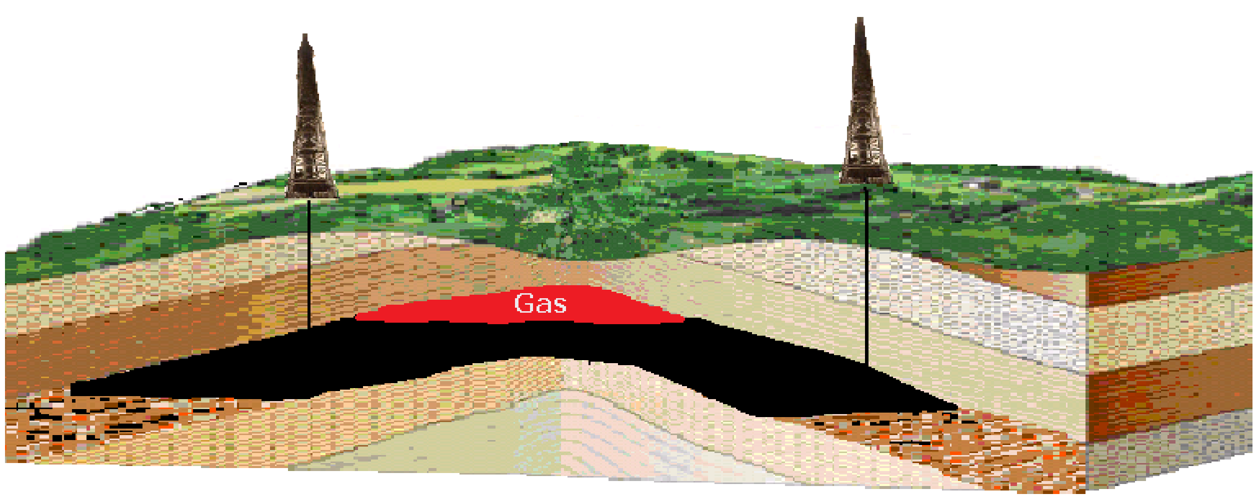
Salt is an interesting substance. Given enough heat and pressure, it will act similar to that of a glacier. Although glaciers move downhill seeking their lowest elevation, salt actually moves upward seeking the surface of the earth. On this journey, thousands of feet of rock formations are dislodged, bent or moved out of the salt's path. The movement of these rock formations is what creates a salt dome trap.

Beneath a normal trap, an oil company will find natural gas, oil and water (either fresh or salt water). Because natural gas is less dense than oil, the gas will sit on top of the oil; and since both oil and natural gas are less dense than water, they will sit on top of the water.

Since gas is expansive, it will help to create pressure that will push the oil to the surface (as seen in the illustration).

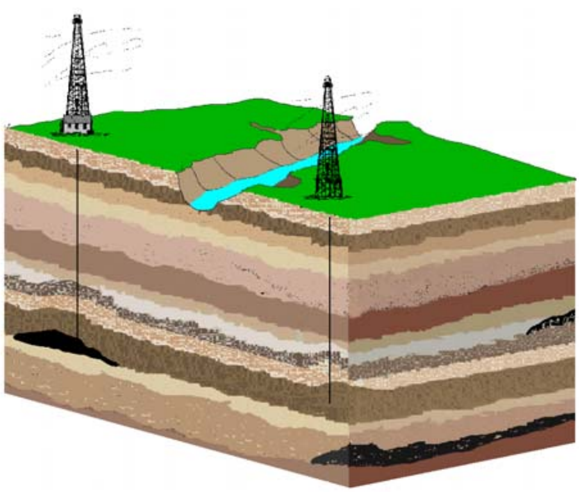


Because of the expansive nature of natural gas, engineers will often use this property to help in the extraction of oil from the reservoir. Notice that in the following illustration the two wells were drilled on either side of the gas. Such a method would leave the gas in place, allowing it to continue to expand and help push the oil to the surface.



Locating Oil and Gas Reservoirs

Most of the commercial oil fields are located at depths between 2,000 feet and 15,000 feet. Most natural gas fields are located at depths between 2,000 and 25,000. In order to locate such a field at these incredible depths, oil and gas companies must use petroleum geologists who are experts at interpreting these types of rock formations. The petroleum geologist has two main tasks. First, is to locate a sedimentary basin. Next, is to locate a trap in the basin that would hold crude oil or natural gas. In the illustration, the geologist has indeed located a sedimentary basin; however, was only successful in locating one trap in the basin.



During the early developmental days of the oil and gas industry, pioneers were working blind. Seismic data was only science fiction and men would often use divining rods or clairvoyants as their tools for locating drill sites. Knowledge of deep reserves was unknown and often a discovery was the result of stumbling rather than intention. The earliest wells were drilled by hammering a cable tool into the earth rather than the use of a rotary drill. Well casing technology did not exist and water from shallower zones would often flow into the wells preventing the deeper oil from being produced. Since that time, technology and man's knowledge of the earth's subsurface has expanded immensely.

Today, when an oil or gas company wants to drill a well, the first thing they must look at is the geology. If the geology in a given area looks promising, the engineers become involved and then the land department.

Types of Geophysical Processes Used

In an attempt to gather valuable information about the oil and gas reservoirs, several geophysical processes can be used. Although none of these methods can state conclusively what exists at 20,000 feet below the surface, they can point both geologists and geophysicists in the right direction.

The Gravity Process

Since the earth is not a perfect sphere and since many parts of the planet have a significant elevation from other parts, the gravitational pull is not always consistent in every place on the planet. Also, when a large mass of solid rock exists, the mass will tend to increase the pull of gravity. This can offer clues to the underlying formations and geologic faults in the earth.

Gravity is measured by an instrument called a gravity meter and what the geologist or geophysicist is looking for is horizons of thick sedimentary rocks that lay below the thick solid rocks. Sedimentary rocks such as limestone, dolomite, sandstone and shale cover approximately 75% of the earth's mass. It is in these formations that oil or gas is most likely to be found.

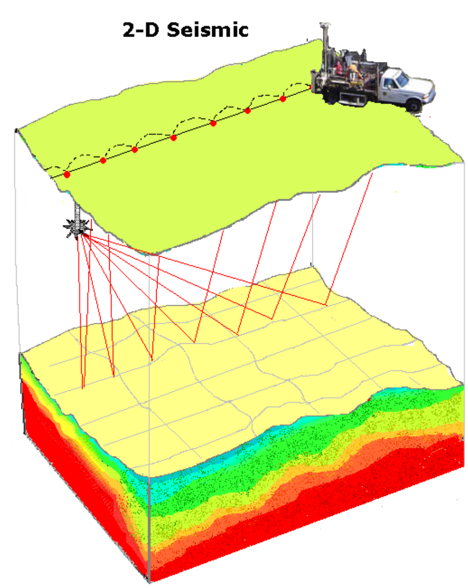
The Magnetic Process

Just as gravity varies from one location to another, so does the earth's magnet pull or *magnitism*. This variation is caused from rocks that contain a high concentration of a mineral called *magnetite.* Granite and sandstone contain a higher level of magnetite than do rocks such as limestone and shale.

The instrument used to measure the magnetism of the rocks is mounted from an airplane and is called a Magnetometer. Again, what the geologist or geophysicist is looking for are horizons of thick sedimentary rocks with a low degree of magnetism.

The Seismic Process

Seismic surveys have been in use in the oil and gas industry for over 60 years. During this time, the technology for the seismic process has greatly improved: thus, this method of survey has become a powerful technique for underground exploration.



Seismic survey studies or *reflection seismic studies* are an exploration technique that uses small explosions or vibrations that send sound waves into the strata of the earth. These waves then bounce or reflect back to the surface giving the geologist or geophysicist general characteristics of the subsurface geological rock formations.

Characteristics of the sound waves:

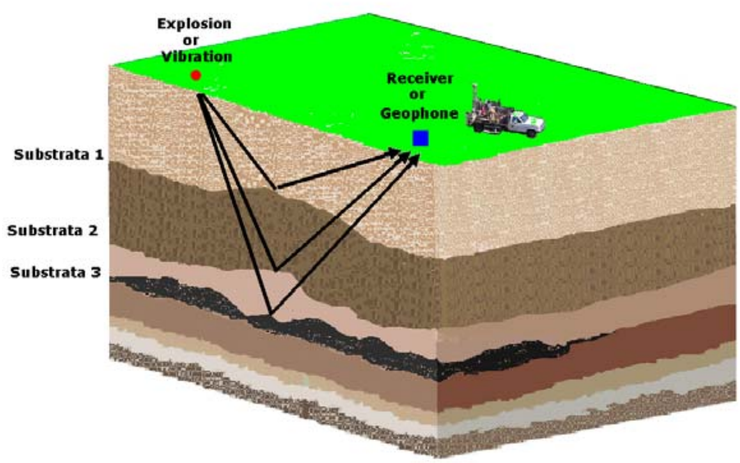
The vibrations or sound waves are generated from an explosive charge near the surface or from large trucks equipped to send vibrations into the earth.

1. The sound travels at velocities of two to four miles per second
2. The sound travels slower through solid masses and faster through more porous masses.
3. When one geologic layer of rock sits on top of another layer of rock, there will often be a change in either rock density or wave velocity.
4. The echo of the sound waves are retrieved through listening devices called geophones located on the surface.

Pictures of the substrata formations are thus generated by measuring the elapsed time of the explosion and return of the sound waves to the surface, the velocity at which the waves travel through different strata, and the mass-density of the strata.

The sound receivers located on the surface of the earth are called *geophones.* Once the geophones pick up the echoes from sound waves, they are transmitted to a recording truck. The truck is equipped with a seismograph machine which amplifies the sound and then records the same on a digital tape. It is this tape that is later analyzed.

As can be seen in the illustration, the sound waves bouncing off of substrata 3 would take longer to reach the geophone than would the sound waves bouncing off of substrata 1 or 2. Also, it would take longer for the sound waves to pass through granite than it would take them to pass through sandstone.



Usually, when a company is using 2-D seismic, multiple receivers or geophones are set up along a straight line and each of the receivers would pick up the echoes from the sound waves. The illustration also shows a single explosive charge fired in a drilled hole to provide a source of seismic waves for a seismic-reflection survey.

Seismic reflection is very similar to the ultra-sound used to create pictures of unborn babies in the mother's womb. High-frequency sound waves pass through the mother's skin and send back imaging of the structure, internal organs and even the blood flowing through the unborn child. As seen in the 2-D ultrasound, a baby can clearly be seen.

These 2-D pictures can show significant details to the experts who read them. To the novice, the details are usually limited to the outline of the baby.

In the past few years, imaging technology has greatly increased and taken not only ultrasonic imaging but seismic imaging to a new level.

Today, expectant parents can view 3-D imaging of the unborn child as seen in the image.

Even the novice can make out details in this picture of a 28-week old unborn baby.

If you were an expectant parent, which type of imaging would you rather see?

- ☐ 2-D
- ☐ 3-D

If you were an oil company, which type of seismic imaging would you rather see?

- ☐ 2-D
- ☐ 3-D

Differences between 2-D and 3-D seismic imaging

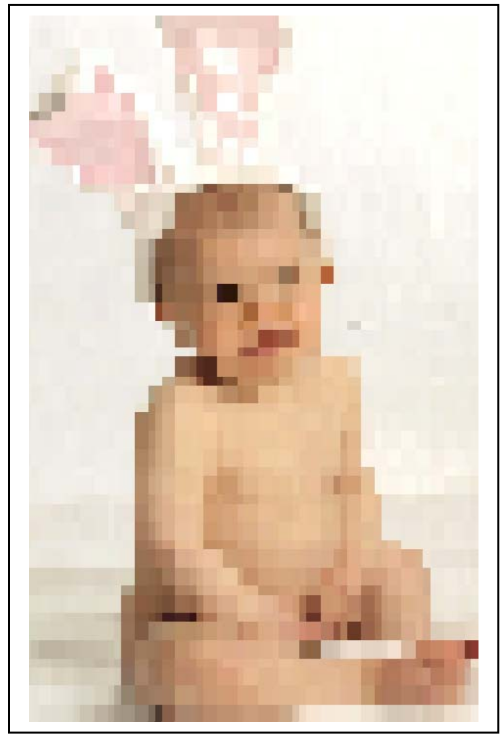
There are two main differences between 2-D and 3-D seismic imaging. They are the amount of receiver lines used to gather information and the tremendous cost difference between the two methods.

2-D seismic gathers its information along straight lines. There can be more than one straight line, as illustrated. Each of these lines would contain several geophones. In this illustration, the 2D seismic reveals only strips of information (only a portion of the larger picture as seen to the right).

By looking at the 2-D imaging, what can be determined?

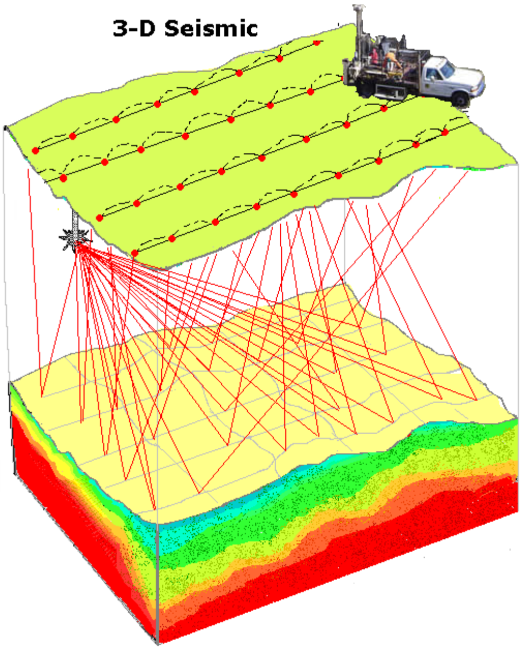
The picture is clearly incomplete.

For oil and gas exploration purposes, if one could expand the 2-D lines so that the entire picture would come into view, the geologist or geophysicist would still have a very blurry picture, as illustrated.



The alternative is to pay for imaging that would deliver optimal resolution. That would be through 3-D imaging. However, it is important to note that the price difference can be staggering. Companies can pay thousands of dollars for a 2-D linier mile surveyed but might pay ten times as much for a 3-D square mile image. Often, companies are faced with the question, “Will the cost of 3-D justify the benefits that we might receive?”

3-D imaging uses many lines of receivers set out across the earth’s surface. Each of the lines contains several geophones and will gather information from echoes reflected back to the surface. In doing this, the information gathered is constant and unbroken. The illustration only depicts one explosive charge, whereas many charges may be used in 3-D imaging: thus, the picture is even more complete.



Because the operations necessary to conduct 3-D seismic surveys are more intricate and detailed, the price is greater. 2-D charges are based on how many linier miles of line will be surveyed. 3-D charges are based on how many square miles will be surveyed. The costs associated with surveying a square mile compared to a linier mile involve more than just time. There are added crew costs, permitting costs, and equipment costs. However, the industry has seen value that, in many cases, out numbers the increased costs.

Remember the baby picture on the previous page? Compare that picture to this one. The features in the 2-D illustrated picture were blurry. You could make out where the eyes or nose was but there were no distinct features that could be seen.

It is possible that an exploration company is working in an area where the truly distinct features are not necessary to be seen. The outline of the area is all that is needed. In this case, 2-D seismic might be satisfactory. On the other hand, an exploration company might be working in a wildcat area. If the company only had general outlines of the structures, there would most likely be a higher degree of dry holes and clearly finding the optimal well locations would be a geologist's best guess. In this situation, 3-D seismic might be necessary and spending the extra money to obtain a clearer, more distinct image, would be cost effective.

When an exploration company is working in a wildcat area and only 2-D imaging is used, there tends to be

1. A greater occurrence of dry holes
2. Less likelihood of finding the optimal well locations

Exercise 8:

Using the Tucker Gap Prospect map below and the 3-D seismic data for the Tucker Gap Prospect on the following page, develop a drilling program for the area. Determine the optimal drill site location and secondary drill site locations.

Assume that you work for an oil and gas company that wants to drill a well at these locations. If you had no oil and gas leases in place, what would be your leasing strategy? ________________________

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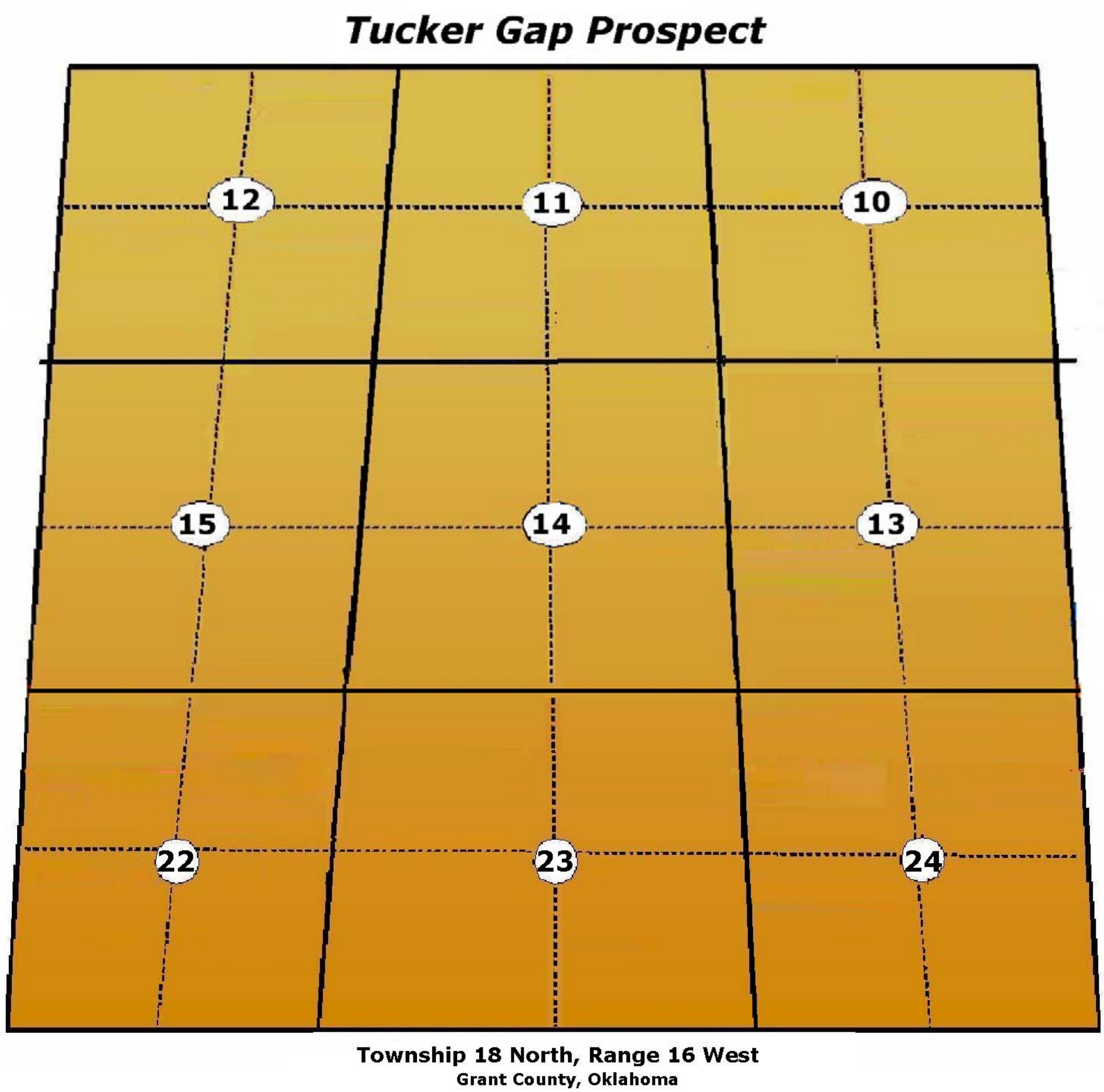
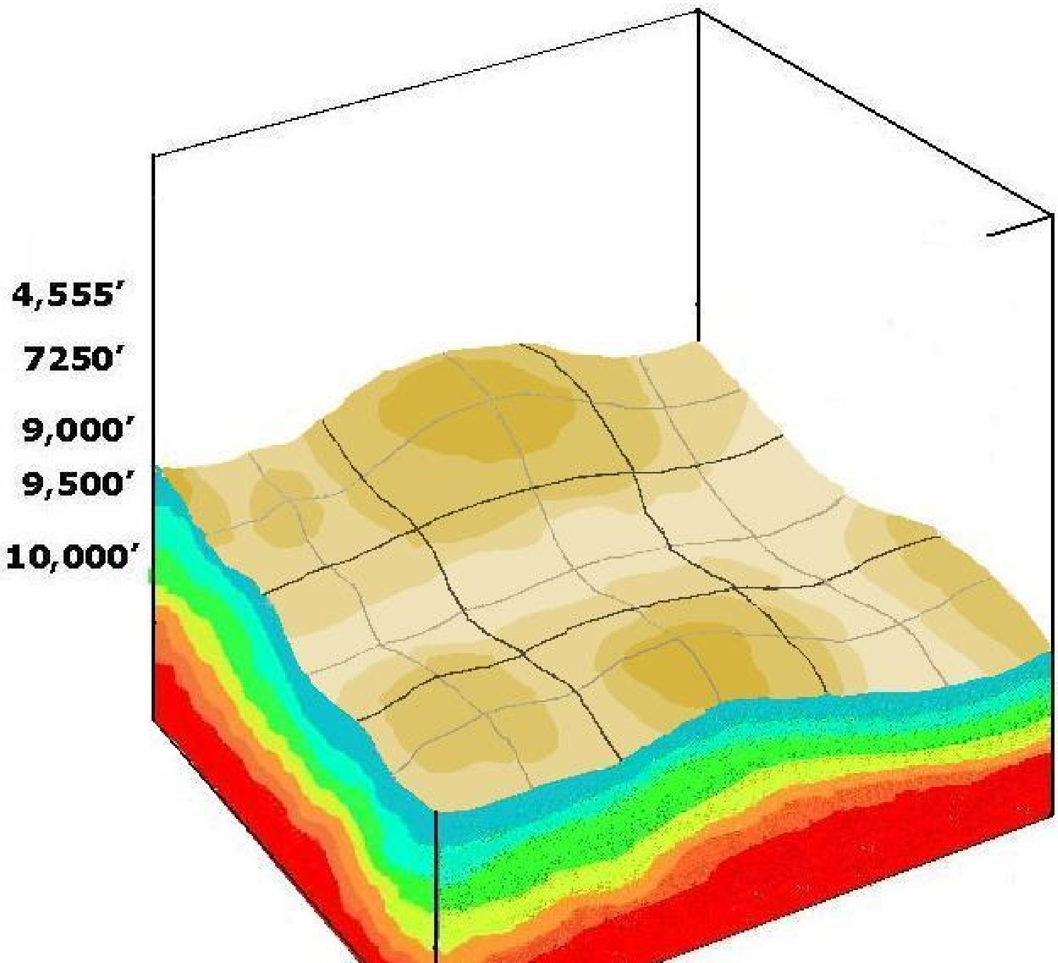


3-D Seismic

Tucker Gap Prospect

Township 18 North, Range 16 West



EXERCISE 9:

Using the Tucker Gap Prospect map and the 3-D seismic data, develop a leasing strategy for the area if the courthouse records revealed that several companies had already acquired leases in the area.

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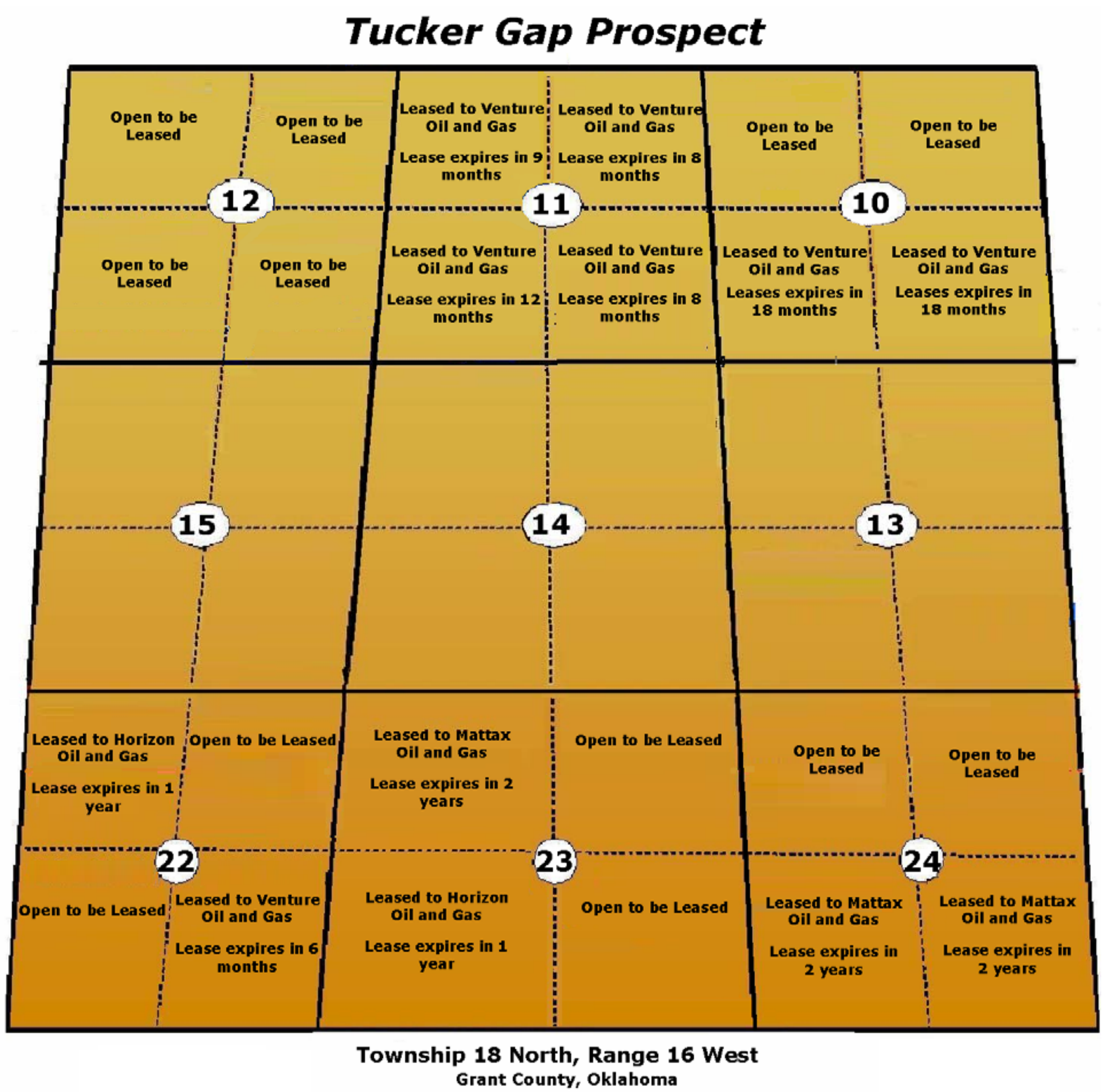
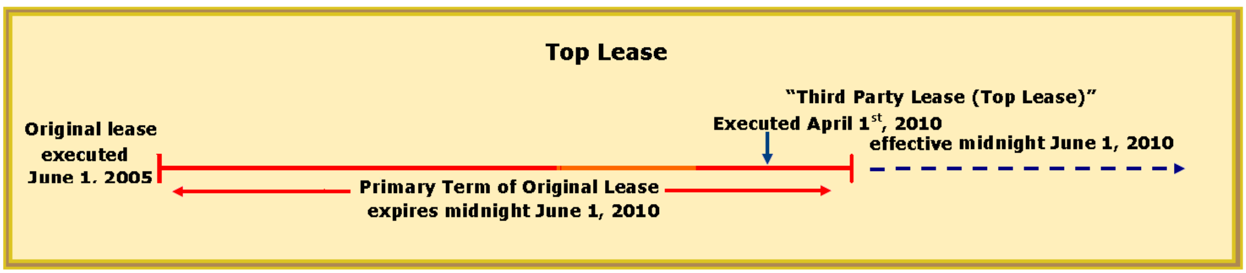


Top Leasing

Top leases do not occur often but when they do, there is one of two reasons for the top lease.

First, the original lessee or its successors have failed to begin any type of operations during the primary term of the lease. They do, however, wish to retain the mineral interest for an extended period of time past the primary term of the original lease. In this case, the original lessee or its successors might negotiate a second lease that covers the same mineral interest. This second lease is said to sit on top of the first lease. The top lease would be executed before expiration or termination of the existing lease but would only become active at the time the first lease expired. This situation is known as a "two-party" or "same party" top lease.

Secondly, there are times when a different company is interested in leasing a mineral interest that has previously been leased. This is called a "three party" or "stranger" lease. During the term of the existing lease, the third party company cannot suddenly step in and displace the previous lease with



a new lease. However, they can enter into a top lease agreement with the mineral owner. Again, the top lease would be taken during the primary term of the existing lease. On the expiration date of the existing lease, the primary term of the top lease would begin.

There is a risk to a third party company taking a top lease because the lessor cannot guarantee that the original lessee will not begin operations during the remaining time on the primary term of the first lease. At the time the top lease is taken, the third party company must pay the lessor a signing bonus. If the first company were to begin operations during the primary term of their lease, this bonus money would be lost and the top lease would have no effect.

EXERCISE 10:

Assume that your company and Venture Oil and Gas were both actively acquiring leases in the area. The competition between the two companies has been driving the terms of the leasing up. What strategy might you consider in order to develop the area?

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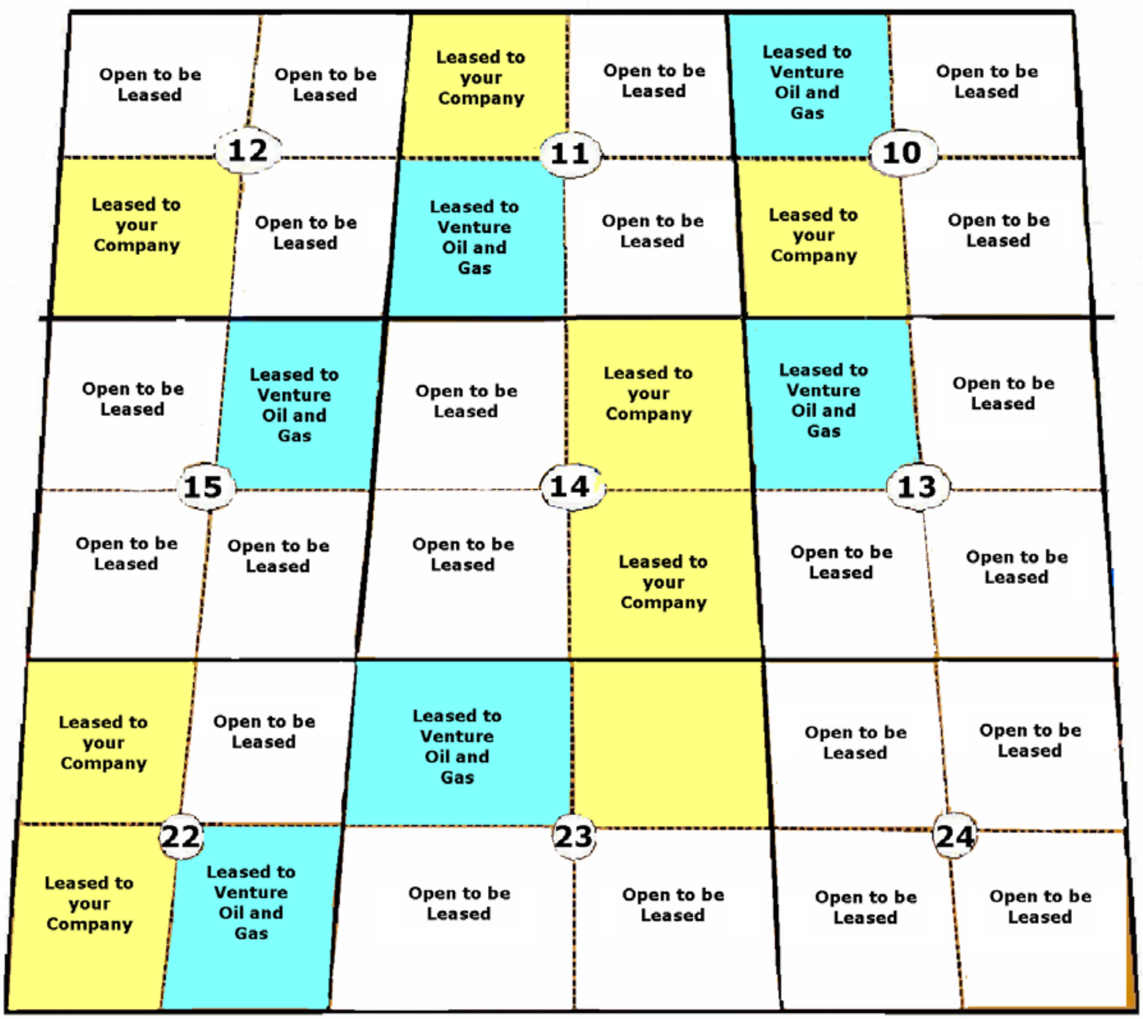
Tucker Gap Prospect



Township 18 North, Range 16 West
Grant County, Oklahoma

Area of Mutual Interest Agreements (AMI)

One type of contract often used when two or more companies are leasing in the same area is called the Area of Mutual Interest Agreement (AMI). An AMI is formed in a discovery area where one or more companies already have a *mutual* interest and can bring to the table existing oil and gas leases.

Generally, AMI's do not cover huge areas of ground. The reason is because of the exploratory nature of the venture. Since the area is a wildcat area, the risks can be very expensive. The smaller the AMI, the less risk would be involved.

This type of agreement provides that if, during the term of the AMI, a company were to acquire new oil and gas interests in the contract area they must offer either some or all of the interest to the other party.

Once an AMI is signed, none of the partners can benefit to the exclusion of the other partners from information gained through a seismic shoot, leasehold acquisition, or drilling.

Advantages of the AMI

1. An AMI will create a *potential uniformity of interest* throughout the Contract Area. This uniformity of interest is not guaranteed.
2. An AMI also eliminates needless competition. AMI's create what would be similar to a partnership, not competition between two or more companies.
3. If a competitor company has more money to spend in the area, a greater number of leasehold acres in the area, or better geologic knowledge in the area, it would be to the other company's benefit to partner with the competitor in order to benefit from their resources, leasehold acres or knowledge.

EXERCISE 11:

Assume that Venture Oil and Gas has locked up the following tracts of land with leases in the area. The only "Open" tracts are those seen on the plat. What strategy might you consider in order to develop the area?

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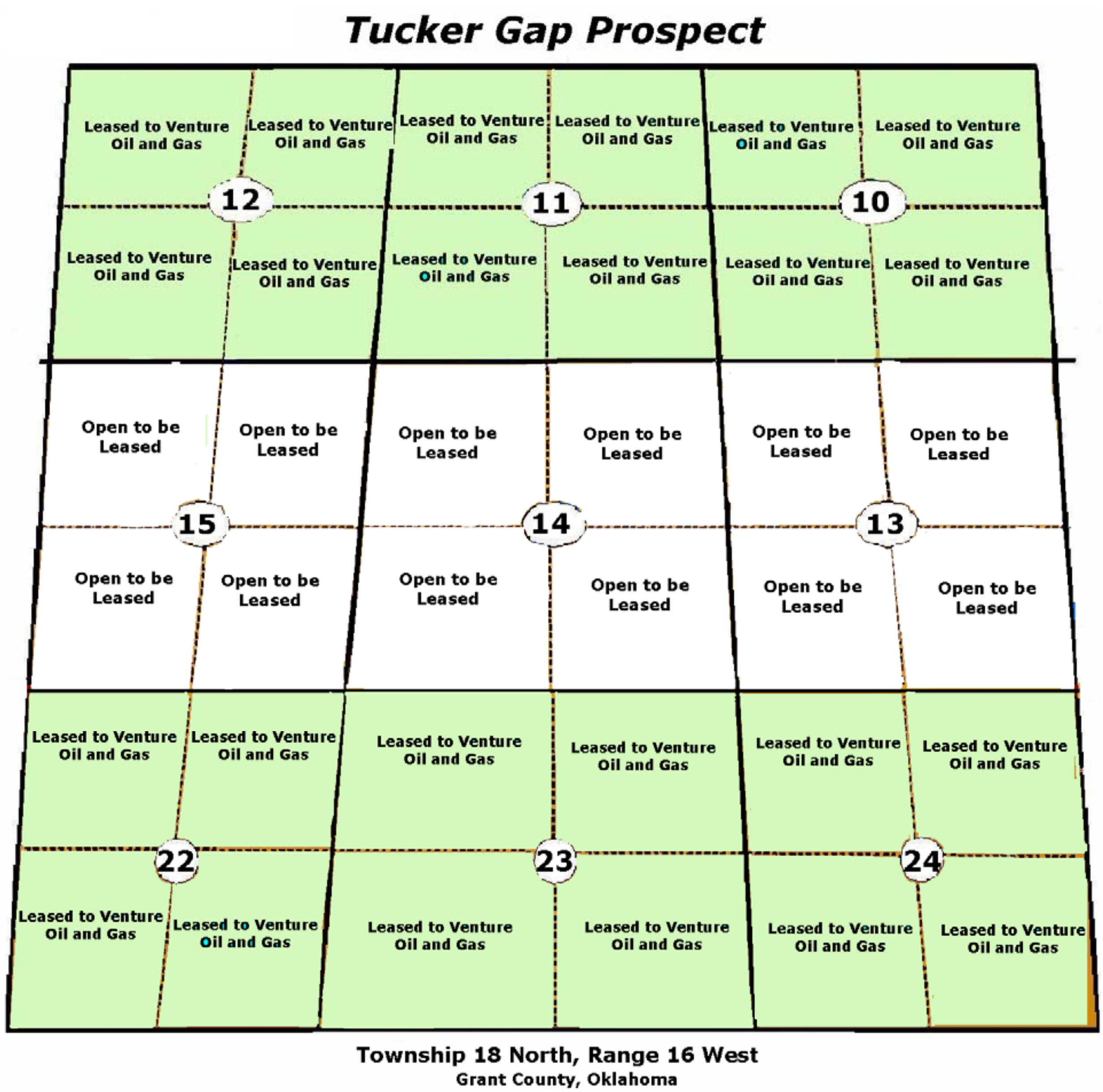

Joint Venture Agreement (JVA)

Whereas, an AMI is designed to bring two or more parties together who each own oil and gas leasehold interests or geologic information in a given area or both, the Joint Venture Agreement (JVA) is designed for a totally different purpose.

The JVA forms a type of partnership among two or more parties; however, one of those parties is only bringing finances to the table.

Joint Ventures are generally…

1. Created for a single project, thus have a term.
2. Have one partner who owns both geological data and leasehold interest but do not want to carry the entire risk of the project.
3. Have one partner who is looking for a drilling prospect. They are bringing to the table only investment money.
4. The JVA will outline the specific amount of consideration the investing party is bringing to the table.
    1. A percentage of the lease acquisition costs
    2. A percentage of seismic costs
    3. A percent of the drilling costs

Often the party bringing the financial investment to the table is "promoted". Promoted means this party will be bringing more money to the table than they will be receiving in leasehold interest. The "promote" might be to pay for 1/3 of the drilling costs but only receive 1/4 of the interest. In a case like this, the investing party will be "carrying" a portion of the other party's interests. This portion is only carried to a certain point.

A Farmout

A farmout agreement is a contractual agreement between two parties. The first is an owner of a working interest in an oil and gas lease or leases (the "farmor"). The farmor desires to assign all or a portion of that interest to a second party (the "farmee"). In exchange, the farmee agrees to fulfill specified conditions outlined in the farmout agreement. The agreement often stipulates that the farmee must drill a well to a certain depth, at a specified location, within a certain time frame. Once the farmee fulfills the stipulations, they will have earned an assignment to the lease or leases. The farmor often reserves a specified overriding royalty interest, and can include language that permits the farmor to convert the before payout overriding royalty interest to a specified working interest upon payout of the well.

The following is the farmout language used:

> **By drilling the initial Test Well and completing the same as a well capable of commercial production, Mattax Oil & Gas shall have earned an assignment of one hundred percent (100%) of Venture Oil & Gas's right, title and interest in the farmout lands.**
>
> **Such assignment shall be subject to Venture's reservation of a proportionately reduced overriding royalty interest equal to the difference between twenty-five percent (25%) and the sum of existing lease burdens.**
>
> **Upon payout of the well drilled, Venture shall have the option, but not the obligation, to convert their overriding royalty interest reserved herein into twenty-five percent (25%) of their original interest.**