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Oil & Gas Drilling Technology – Offshore Rigs – Part 3

Instructor: Jurandir Primo, PE

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PDH Online | PDH Center

5272 Meadow Estates Drive
Fairfax, VA 22030-6658
Phone: 703-988-0088
www.PDHonline.com

OIL & GAS DRILLING PROCESSES
OFFSHORE RIGS – PART 3

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I. INTRODUCTION:

Subsea, or commonly known as offshore drilling, is a very complex process where a wellbore is drilled through the seabed, typically carried out in order to explore and subsequently extract petroleum, which lies in rock formations beneath the seabed. Most commonly, the term is used to describe drilling activities on the continental shelf, though the term can also be applied to drilling in lakes, inshore waters and inland seas. Offshore drilling also presents extreme environmental challenges, both from the produced hydrocarbons and the materials used during the drilling operation.

In resume, an oversea oil platform, offshore platform or offshore oil rig is a large structure with facilities to drill wells, to extract and process oil and natural gas, or to temporarily store product until it can be brought to shore for refining and marketing. In many cases, the platform contains facilities to house the workforce, as well. Depending on the circumstances, the platform may be fixed to the ocean floor, consisting of an artificial island or the platform may also be a floating ship.

There are many different types of facilities from which offshore drilling operations take place. These include bottom founded drilling rigs (jackup barges and swamp barges), combined drilling and production facilities either bottom founded or floating platforms, and deepwater Mobile Offshore Drilling Units (MODU) including semi-submersibles and drillships. Remote subsea wells may also be connected to a platform by flow lines and by umbilical connections. These subsea solutions may consist of one or more subsea wells, or of one or more manifold centers for multiple wells.

The major difference between an inland/onshore and a subsea/offshore drilling is the nature of the drilling platform. In offshore drilling the drillpipe must pass through the water column before entering the lake or the seafloor. Currently, offshore wells have been drilled in waters as deep as 10,000 ft (3000 m) or deeper. In shallower waters the mobile units are anchored to the seabed, however in deeper water (more than 1,500 meters (4,900 ft) the semisubmersibles or drillships are maintained at the required drilling location using dynamic positioning instruments.

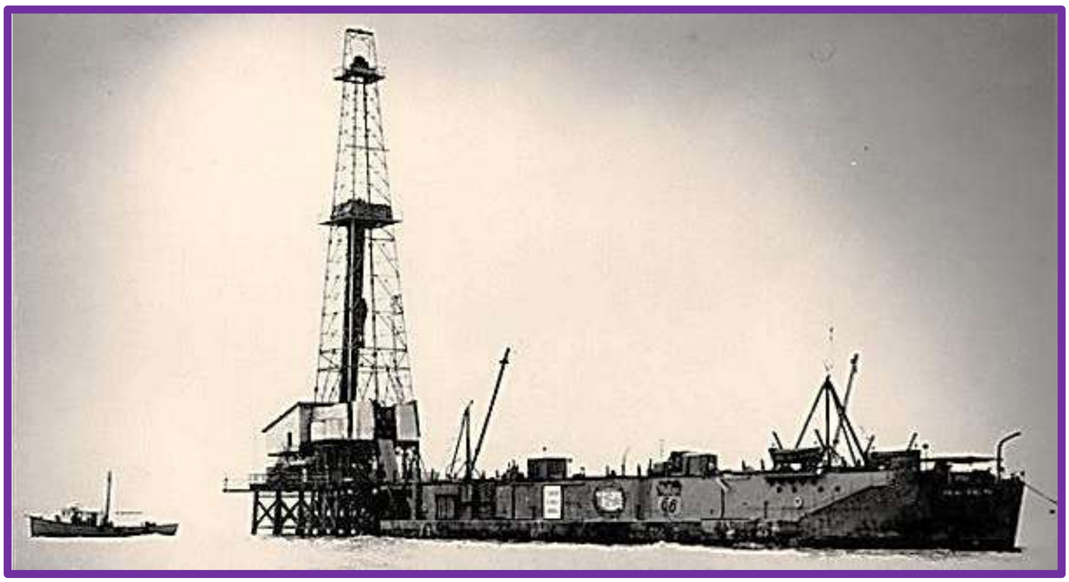
II. HISTORY

From 1837 to 1845 a wide but shallow reservoir was built to provide water to the Miami and Erie Canal. However, offshore or subsea drilling stronger beginning, dates back as early as 1869, when one of the first patents was granted to T.F. Rowland for his offshore drilling rig design. This rig was designed to operate in very shallow water, but the anchored four legged tower bears much resembled to modern offshore rigs. Later, around 1891, the first submerged oil wells were drilled from platforms built on piles, in the fresh waters of the Grand Lake St. Marys, in Ohio, developed by small local companies such as Bryson, Riley Oil, German-American and Banker's Oil.

Around 1896, the first submerged oil wells were drilled in salt water, in the Summerland field, which extended under the Santa Barbara Channel in California. The wells were drilled from piers, from land out into the channel. Submerged drilling activities also occurred on the Canadian side of Lake Erie in 1900 and in Caddo Lake, Louisiana in 1910. Thereafter, wells were drilled in tidal zones along the Gulf Coast of Texas and Louisiana. In the 1920s, a drilling rig was done with concrete platforms in Lake Maracaibo, Venezuela. In the early 1930s, the Texas Co., later Texaco (actually Chevron) developed the first mobile steel barges for drilling in the brackish coastal areas of the Gulf of Mexico.

In 1937, Pure Oil (now Chevron) and its partner Superior Oil (now ExxonMobil) used a fixed platform to develop a field 1 mile (1.6 km) offshore of Calcasieu Parish, Louisiana in 14 feet (4.3 m) of water. In 1946, Magnolia Petroleum (now Exxon Mobil) drilled at a site 18 miles (29 km) off the coast, erecting a platform in 18 feet (5.5 m) of water off St. Mary Parish, Louisiana. In early 1947, Superior Oil also erected a drilling and production platform in 20 feet (6.1 m) of water some 18 miles (29 km) off Vermilion Parish, Louisiana.

In 1947 the Kerr-McGee Oil Industries (now Anadarko Petroleum), as operator-partner with Phillips Petroleum (ConocoPhillips) and Stanolind Oil & Gas (Now BP) completed a historic Ship Shoal Block 32 well, considered the first offshore discovery and the first commercial discovery "out of sight of land". The field was drilled off the Louisiana coast, in 22 ft water depths.



The Kerr-McGee drilling platform, known as Kermac Rig No. 16

When offshore drilling moved into deeper waters of up to 30 meters (98 ft), fixed platform rigs were built, until demands for drilling equipment was needed for 120 meters (390 ft) depth in Gulf of Mexico, the first jack-up rigs began appearing from specialized offshore drilling contractors, such as the forerunners of ENSCO International. The first semi-submersible resulted from an unexpected observation in 1961. Blue Water Drilling Company owned and operated the four-column submersible Blue Water Rig No.1 in the Gulf of Mexico for Shell Oil Company.

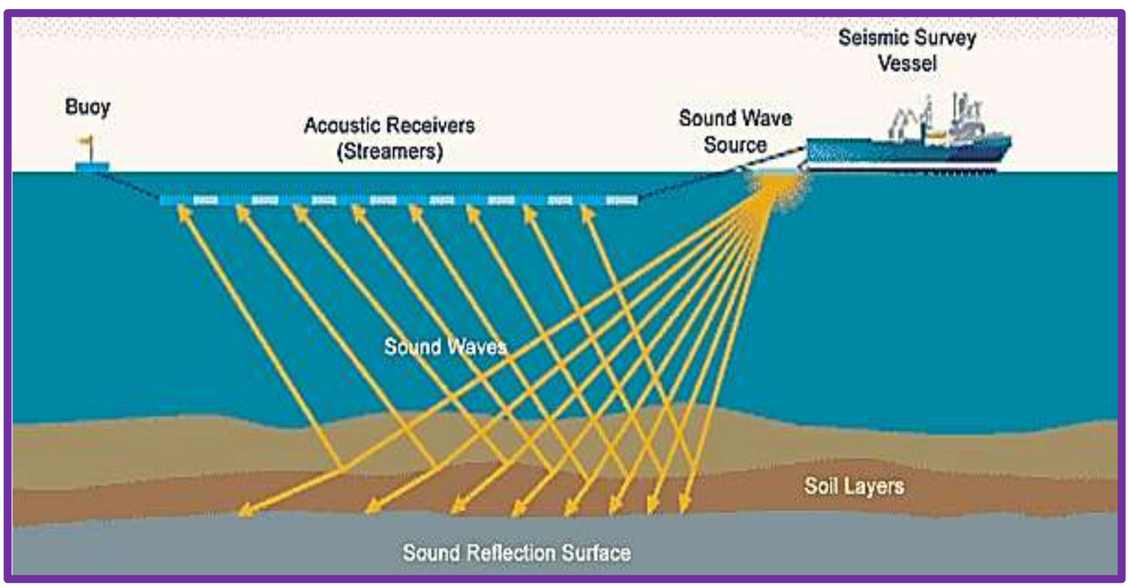
However, it was noticed that the motions at this draught were very small, then Blue Water Drilling and Shell jointly decided to try operating the rig in the floating mode. The concept of an anchored, stable floating deep-sea platform had been designed and tested back in the 1920s, by Edward Robert Armstrong for the purpose of operating aircraft with an invention known as the “*seadrome*”. The first purpose-built drilling semi-submersible *Ocean Driller* was launched in 1963. Since then, many semi-submersibles have been designed for the drilling industry, as mobile offshore fleet.

III. MARINE OIL & GAS EXPLORATION:

In essence, seismic surveys are a way to probe beneath the surface to "see" underlying features that make up the underground structure of a prospect. Such features can give companies a more astute indication if a prospect contains hydrocarbons. Fortunately, seismic surveys can save companies hundreds of millions of dollars by giving them precise information about subsurface features and even the presence of water, oil and gas. The seismic source is usually an airgun or an array of airguns deployed beneath the water surface, located between the vessel and the first receiver, but other sources are also available.

Two types of seismic surveys are available to the geophysicist: two-dimensional (2D) surveys, or three-dimensional (3D) surveys. The 2D seismic data are displayed as a single vertical plane or cross-section sliced into the Earth beneath the seismic line's location. 2D is generally used for regional reconnaissance or for detailed exploration work where economics may not support the greater cost of 3D. The 3D seismic data are displayed as a three-dimensional cube that may be sliced into numerous planes or cross-sections.

As the name suggests, seismic surveys use surface-induced seismic pulses to image subsurface formations. Basically, a seismic wave is generated underneath the earth's surface, and then picked up by sensors called "geophones or hydrophones" as the waves bounce off subsurface formaions, that is, layers of rock beneath the surface. Geophone measures the particle velocity and hydrophone measures pressure variation. This process becomes more complicated when there are hundreds or thousands of feet of water between the geophones and the earth's surface.



Commercial receiver tools use a maximum of eight geophone levels; however, hydrophones can record 48 levels simultaneously. In comparison tests, *hydrophones* are preferable to geophones for high-frequency borehole seismic applications using *first arrivals*. *Geophones* are preferable to hydrophones for borehole seismic applications using *reflector arrivals*, because later-arriving events are obscured by the source-generated tube waves in hydrophone data.

Traditional marine seismic surveys are conducted using specially-equipped vessels that tow one or more cables containing a series of hydrophones at constant intervals. The cables are known as streamers, with 2D surveys using only 1 streamer and 3D surveys employing up to 12 or more (though 6 or 8 is more common). The streamers are deployed just beneath the surface of the water and set at a distance away from the vessel. Marine seismic surveys generate a significant quantity of data, each streamer can be up to 6 or even 8 km long, containing hundreds of channels and the seismic source is typically fired every 15 or 20 seconds.

A seismic vessel with 2 sources and towing a single streamer is known as a Narrow-Azimuth Towed Streamer (or NAZ or NATS). By the early 2000s, it was accepted that this type of acquisition was useful for initial exploration but inadequate for development and production, in which wells had to be accurately positioned. This led to the development of the Multi-Azimuth Towed Streamer (MAZ) which tried to break the limitations of the linear acquisition pattern of a NATS survey by acquiring a combination of NATS surveys at different azimuths.

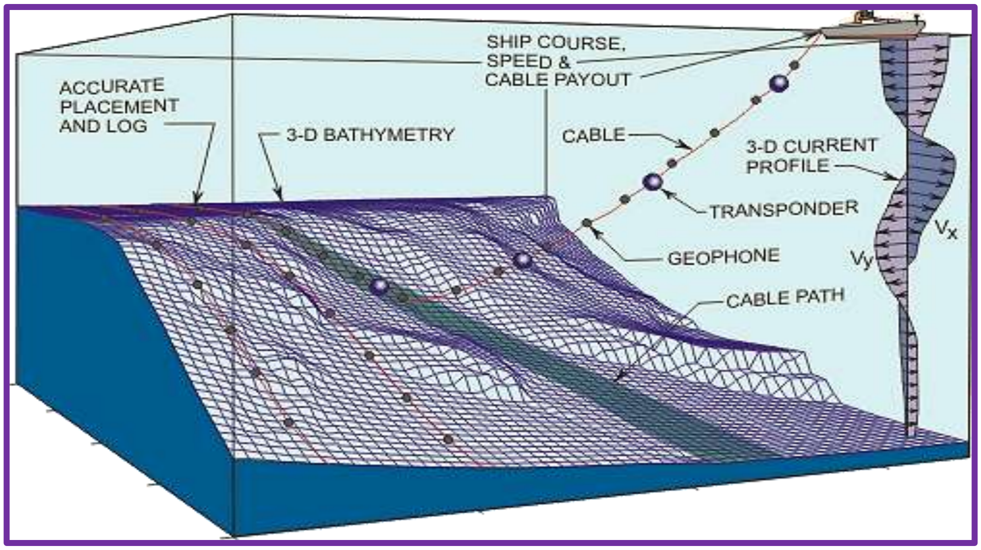
Seismometers are instruments that measure motions of the ground, including seismic waves generated by earthquakes, volcanic eruptions, and other seismic sources. Records of seismic waves allow seismologists to map the interior of the Earth, and locate and measure the size of these different sources. The word derives from the Greek *seismos*, a shaking or quake, and *metron*, measure, to describe an instrument designed by Scottish physicist James David Forbes.

Seismograph is another Greek term from *seismos,* shake and *grapho,* to draw, often used to mean seismometer, though it is more applicable to instruments in which the measuring and recording of ground motion are combined. Both *seismograph* and *seismometer* provide a continuous record of ground motion; this distinguishes them from *seismoscopes*, which merely indicate that motion has occurred, with some simple measure of how large the shake occurred.

Marine Survey Acquisition 4D: Marine survey acquisition is not just limited to seismic vessels; it is also possible to lay cables of geophones and hydrophones on the sea bed in a similar way to how cables are used in a land seismic survey, and use a separate source vessel. This method was originally developed out of operational necessity in order to enable seismic surveys to be conducted in areas with obstructions, such as production platforms, without having the compromise the resultant image quality.

Ocean Bottom Cables (OBC): Are extensively used in areas where a seismic vessel cannot be used, for example in shallow marine (water depth <300m) and transition zone environments, and can be deployed by ROVs in deep water, when repeatability is necessary. Conventional OBC surveys use dual-component receivers, combining a pressure sensor (*hydrophone*) and a vertical particle velocity sensor (*geophone*), but more recent developments have expanded the method to use four-component sensors, i.e. a hydrophone and three orthogonal geophones.

Four-component sensors have the advantage of being able to also record shear waves, which do not travel through water but can still contain valuable information. In addition to the operational advantages, OBC also has geophysical advantages over a conventional NATS (Narrow-Azimuth Towed Streamer) survey that arise from the increased fold and wider range of azimuths associated with the survey geometry. However, much like a land survey, the wider azimuths and increased fold come at a cost and the ability for large-scale OBC surveys is severely limited.



Ocean bottom cables

Life of Field Seismic (LoF): This method has this designation, when a number of 4D surveys have also been set up over fields in which ocean bottom cables have been purchased and permanently deployed. The 4D surveys and 3D seismic surveys are repeated over a period of time in order to observe reservoir depletion during production and identify areas where there are barriers to flow that may not be easily detectable in conventional seismic, basically conducted by OBCs because the cables can be accurately placed in their previous location after being removed.

Seismic Data Processing: There are three main processes in seismic data processing; *deconvolution*, *common-midpoint stacking (CMP)* and *migration*. In seismic data processing, *deconvolution* is a process that tries to extract the reflectivity series of the Earth, as a seismic trace is just the reflectivity of the Earth convolved with distorting filters. The concept of *deconvolution* is widely used in the techniques of signal processing and image processing. In mathematics, *deconvolution* is an algorithm-based process used to reverse the effects of convolution on recorded data.

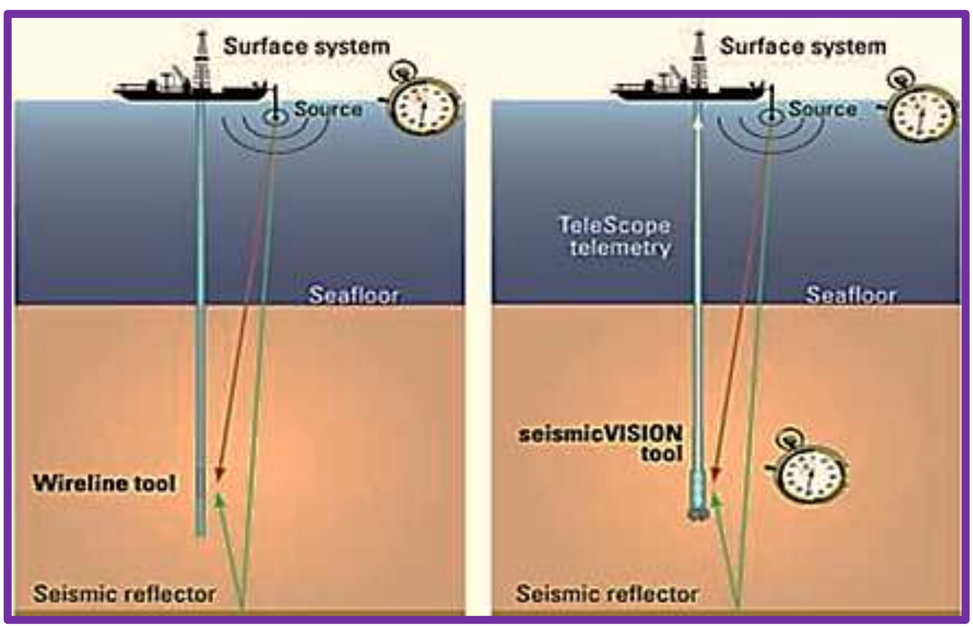
CMP stacking is a robust process that uses the fact that a particular location in the subsurface will have been sampled numerous times and at different offsets. This allows a geophysicist to construct a group of traces with a range of offsets that all sample the same subsurface location, known as a *Common Midpoint Gather*. The average amplitude is then calculated along a time sample, resulting in significantly lowering the random noise but also losing all valuable information about the relationship between seismic amplitude and offset.

Seismic migration is the process by which seismic events are geometrically re-located in either space or time to the location the event occurred in the subsurface rather than the location that it was recorded at the surface, thereby creating a more accurate image of the subsurface. In hydrocarbon exploration, the features that the seismic interpreter must try are to delineate the parts that make up a petroleum reservoir, the source rock, the reservoir rock, the seal and trap. At its most simple level, seismic interpretation involves tracing and correlating along continuous reflectors throughout the 2D or 3D dataset and using these as the basis for the geological interpretation.

Seismic Attribute Analysis: Seismic attribute analysis involves extracting or deriving a quantity from seismic data that can be analyzed in order to enhance information that might be more subtle in a traditional seismic image, leading to a better geological or geophysical interpretation of the data. Examples of attributes that can be analyzed include mean amplitude, which can lead to the delineation of bright spots and dim spots, coherency and amplitude versus offset. Attributes that can show the presence of hydrocarbons are called direct hydrocarbon indicators.

Crustal Studies: The use of reflection seismology in studies of the Earth's crust was pioneered in the 1970s by groups such as the Consortium for Continental Reflection Profiling (COCORP). The British Institutions Reflection Profiling Syndicate (BIRPS) also initiated as a result of oil hydrocarbon exploration in the North Sea. The effort produced some significant results and showed that it is possible to profile features such as thrust faults that penetrate through the crust to the upper mantle with marine seismic surveys.

Seismic-While-Drilling (SWD): The Seismic-While-Drilling (SWD) or the Logging-While-Drilling (LWD) technology provides real-time surveys during the drilling phase. Target depths can now be updated before they are drilled, reducing uncertainty and risk through better-informed decisions, which can be particularly valuable in offshore developments. The SWD is a key technology enabler, using a ruggedized *ultra-high precision clock* in the downhole tool, which can maintain a millisecond accuracy of the Global Positioning System (GPS) time over periods of several days.



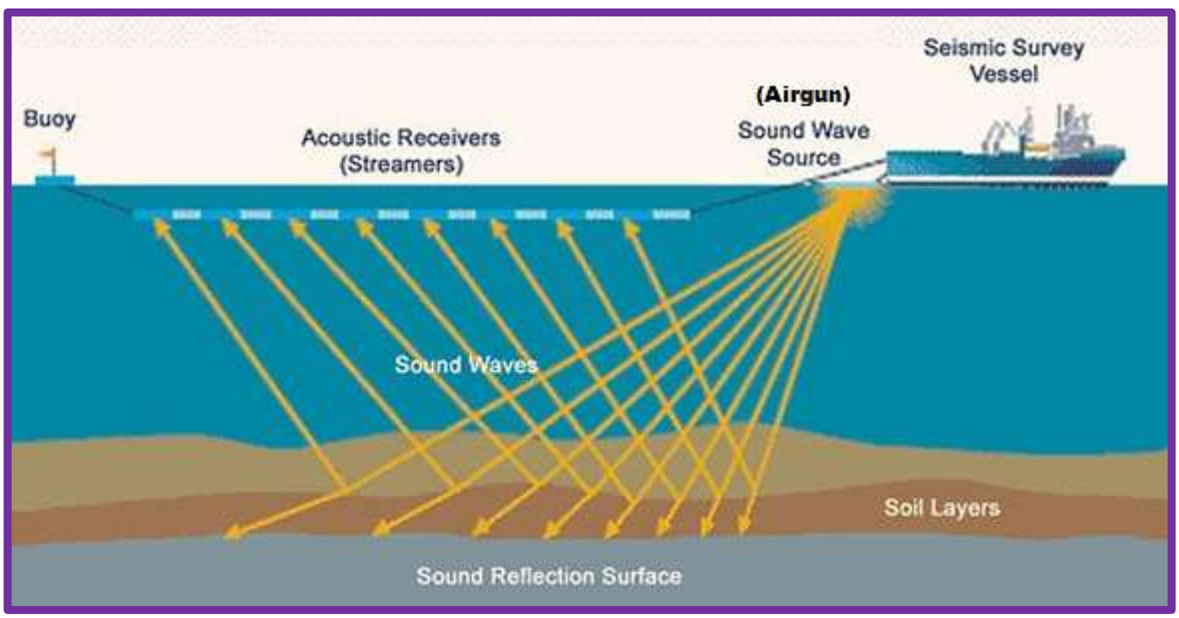
Vertical Seismic Profile (VSP): Is a technique of seismic measurements used in correlation with surface seismic data. The defining characteristic of a VSP (there are many types) is that either the energy source, or the detectors (or sometimes both) are in a borehole. In the most common type of

VSP, hydrophones, or more often geophones or accelerometers in the borehole, can record reflected seismic energy originating from a seismic source at the surface. This seismic source is the same as is used for a wireline survey, a high-pressure airgun array controlled by a digital auto-tuning gun controller.

Seismic Airguns: In airguns, the high pressure air is stored in a firing chamber and explosively released through portholes by the action of a sliding shuttle with pistons at each end. The seismic energy is generated by the rapid, explosive release of compressed air through the airgun's ports into the surrounding water. This produces a primary energy pulse and an oscillating bubble. Typically, multiple airguns are towed behind the vessel, several meters below the sea surface, in a predetermined combination or “array” of different chamber volumes, designed to generate an energy output of desirable sound frequencies.

Compressed Airguns: Or seismic airguns, is used for marine reflection and refraction surveys. It consists of one or more pneumatic chambers that are pressurized with compressed air at pressures from 14 to 21 MPa (2,000 to 3,000 psi). The air gun array is submerged below the water surface, and is towed behind a ship. When the air gun is fired, a solenoid is triggered, which releases air into a fire chamber which in turn causes a piston to move, thereby allowing the air to escape the main chamber and to produce a pulse of acoustic energy.

Air gun arrays are built up of up to 48 individual air guns with different size chambers, the objective is to create an optimum initial shock wave with minimum reverberation of the bubble after the first shot. Gun arrays can be fired in flip-flop mode; typically this would be 48 guns per source, selected and fired alternately. Large chambers (i.e., greater than 1.15 liters or 70 cu in) tend to give low frequency signals, and the small chambers (less than 70 cubic inches) give higher frequency signals. The airgun is generally made from the highest grades of corrosion resistant stainless steel.



Plasma Sound Source: A plasma sound source (PSS), otherwise called as *spark gap sound* source, or simply a *sparker*, means making very low frequency sonar pulse underwater. For each firing, it stores electric charge in a large high-voltage bank of capacitors, and then releases all the stored energy in an arc across electrodes in the water. The underwater spark discharge produces a high-pressure plasma and vapor bubble, which expands and collapses, making a loud sound. Most of the sound produced is between 20 and 200 Hz. The PSS has also been used for sonar. There are also plans to use PSS as a non-lethal weapon against submerged divers.

Boomer Seismic Sources: Boomer sound sources are used for shallow water seismic surveys, mostly for experimentation engineering survey applications. Boomers are towed in a floating sled behind a survey vessel. Similarly to the plasma source, it stores energy in capacitors, but it discharges through a flat spiral coil instead of generating a spark. A copper plate adjacent to the coil flexes away from the coil as the capacitors are discharged. This flexing is transmitted into the water as the seismic pulse.

Originally the storage capacitors were placed in a steel container (the bang box) on the survey vessel. The high voltages used, typically 3,000 V, required heavy cables and strong safety containers. Recently, low voltage boomers have become available. These use capacitors on the towed sled, allowing efficient energy recovery, lower voltage power supplies and lighter cables. The low voltage systems are generally easier to deploy and have fewer safety concerns.

Boomer Seismic Source

Noise Sources: Correlation-based processing techniques also enable seismologists to image the interior of the Earth at multiple scales using natural (e.g., the oceanic microseism) or artificial (e.g., urban) background noise as a seismic source. For example, under ideal conditions of uniform seismic illumination, the correlation of the noise signals between two seismographs provides an estimate of the bidirectional seismic impulse response.

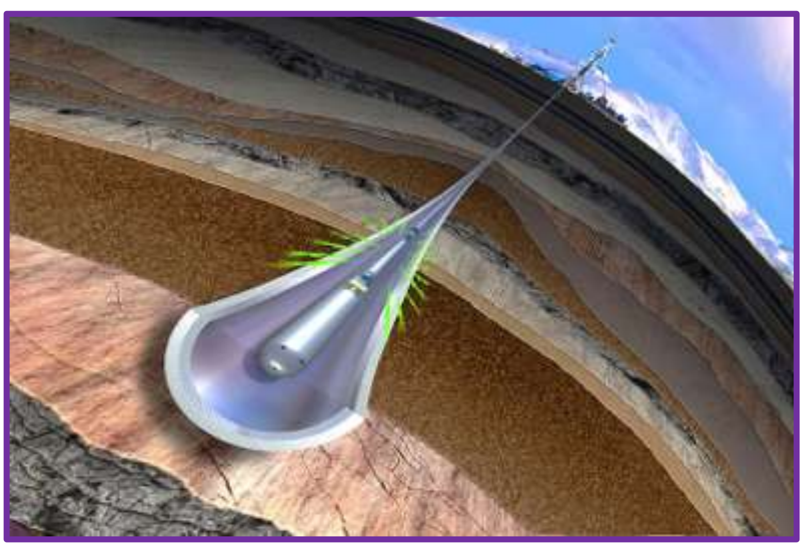
Environmental Impact: As with all human activities, seismic reflection surveys have some impact on the Earth's natural environment and both the hydrocarbon industry and environmental groups are trying to investigate these effects. The main environmental concern for marine seismic surveys is the potential for noise associated with the high-energy seismic source to disturb or injure animal

life, especially cetaceans such as whales, porpoises, and dolphins, as these mammals use sound as their primary method of communication with one another.
A study found that male humpback whales were attracted to a single operating airgun as they were believed to have confused the low-frequency sound with that of whale breaching behavior. In addition to whales, sea turtles, fish and squid all showed alarm and avoidance behavior in the presence of an approaching seismic source. High-level and long-duration sound can cause physical damage, such as hearing loss, whereas lower-level noise can cause temporary threshold shifts in hearing, obscuring sounds that are vital to marine life, or behavioral disturbance.

The gray whale avoids regular its migratory and feeding grounds by >30 km in areas of seismic testing. Similarly the breathing of gray whales was shown to be more rapid, indicating discomfort and panic. Another point of view, a joint paper from the International Association of Geophysical Contractors (IAGC) and the International Association of Oil and Gas Producers (OGP) argue that the noise created by marine seismic surveys is comparable to natural seismic noise, stating:

"The sound produced during seismic surveys is comparable in magnitude to many naturally occurring and other man-made sound sources. Furthermore, the specific characteristics of seismic sounds and the operational procedures employed during seismic surveys are such that the resulting risks to marine mammals are expected to be exceptionally low. In fact, three decades of worldwide seismic surveying activity and a variety of research projects have shown no evidence which would suggest that sound from E&P seismic activities has resulted in any physical or auditory injury to any marine mammal species."

Wireline Logging: Can be defined as being "the acquisition and analysis of geophysical data performed as a function of the wellbore depth, together with a provision of recording services". Note that "wireline logging" and "mud logging" are not the same, but are closely linked by integration of the data logging. The measurements are made referenced to "TAH" - True Along Hole Depth, and associated analysis, or can be used to infer further properties, such as hydrocarbon saturation, formation pressure, and to make further drilling and production decisions.



Wireline Logging