DOSITS Webinar: Seismic Sources (May 1, 2019)
Questions and Answers

Question: How are seismic surveys run on a "smaller scale"?
Answer: There are a lot of different seismic surveys. Site selection, picking cabling routes, etc. for offshore wind farms is one type of survey. Generally, surveys that don't need the depth penetration required for geological research or location of potential deep reservoirs of oil and gas will use a smaller array of perhaps one string of small sources or a single element or a cluster of two to four elements. More often surveys looking in the upper layers of the bottom (a few tens or hundreds of meters) will typically use multibeam sonars or sparkers, or small clusters of compressed array sources rather than a full array of the type I described in my talk. The people conducting these types of surveys are usually only interested in the upper layers of geology- sediment and perhaps one rock layer. They are interested in whether there are obstacles, as you wouldn't want to lay a trench to bury a cable and run into something (e.g. sewer lines or electric lines). If there is rock in these upper layers, they would want to know that as well. If driving piles for a wind farm, one would want to drive pile through the soft (unconsolidated) sediments and have the pile then resting on rock; and this depth varies from place to place.

Question: Could we hear more about vertical seismic profiling; stationary and walk away?
Answer: This is when an ongoing drilling operation wants to know about the life of the field, how drilling is going (exploiting that resource), etc. Individuals conducting this type of work will put receivers in the bore hole of the well, but may use nodal or towed receivers as well. A source may be hung off a crane on the drilling platform or from a vessel, including using autonomous vehicles (unmanned craft) that will run around in a circle or out and back from the well site to get sound to bounce from different angles. The source is not on all the time, rather the geology is checked periodically (once a week or once a month or less often) to assess progress in drawing down the reservoir. While towed listening devices similar to the streamers used in large scale seismic operations may be used, more often there are receivers that are in the bore hole, or one could have listening nodes sitting on the bottom (somewhat like a streamer sunk to the bottom but with different sensors that pick up vibration of the solid bottom and not sound in the water).

If receivers are in the bore hole, is this a permanent installation, or just put in when want to listen?
Temperatures inside the borehole can be quite hot, so the sensors are lowered into the borehole only when data collection is needed. They are not left permanently in the borehole.

Question: Bottom nodes as receivers? Bore hole seismic, is there another reason/situation where you would use bottom nodes?
Answer: Yes, bottom nodes are used in shallow waters. Towing traditional survey equipment in 10-20m is not a good idea for a variety of reasons, so groups will use the bottom nodes for that type of shallow work. The technology is advancing rapidly. The industry now sees ships that are

automated and can lay out the strings of bottom nodes or individual stand-alone nodes, and pick them back up after the survey faster than they used to do it. Obviously if covering a 100-400 km track, using cabled bottom nodes is not the way to go. They are expensive and you need to get them back. The receiving nodes should be cabled or not cabled (working with modems that communicate data from the nodes back to a receiving manned or unmanned platform). For covering large areas, like in 2D surveys, bottom nodes would be expensive and logistically complicated, but bottom nodes are a rapidly advancing technology and are seeing increased use.

Question: With ghost cavitation, does that add to higher frequency sounds? Does it confuse the signal you are looking for?
Answer: No. First, it's not a cavitation. Cavitation occurs when you exceed the speed of sound and pull a vacuum. Propellers do that: they make a vacuum, that is they create a "hole in the water," faster than the surrounding water can fill it, and when this hole collapses, there is a pop or clap (as the bubble collapses in on itself). The "ghost" in a seismic pulse, on the other hand, is merely the surface- reflected sound that is out of phase with the sound that is emitted directly.

This succession of acoustic pulses out of phase with each other could make a difference to fish, as their ears are particle motion detectors. Fishes can detect the direction of movement of the water particles by the direct and reflected pulse. The pulse and its ghost resemble a dipole source- and this is what fish are evolved to detect. A swimming fish, such as a predator or a piece of food, is a dipole source. That s-shaped motion of the fish through the water produces positive pressure and then negative, positive then negative, et cetera as it swims. Thus, the signal and its surface-reflected inverse may be more readily detected and responded to than to a simple monopole source (e.g. a loudspeaker or sonar). Marine mammal ears are pressure sensors, and do not detect particle motion.

The depth of the source is positioned specifically to put that ghost notch out of the frequencies of interest for seismic. The interaction between the original pulse and reflected pulse typically reduces the overall high frequency energy through destructive interference between the pulse and its reflection. The geophysicists don't want the reflection interfering with the signal at the frequencies of interest to geologists, 2-100 Hz, so the depth of the array is positioned so that the notch is usually around 125Hz which means the source needs to be about 6-10 m below the water's surface. The two-way travel time of a sound in water traveling at roughly 1500m/s tells you where the notch will appear. At 10 meters depth, the two-way travel distance for the surface-reflected signal would be 20 meters and the interference would occur at 1500/20 = 75 Hz, so usually the source is towed at 6 meters depth (1500/12 = interference at 125 Hz and multiples thereof).

Question: Is registering a survey typically done or obligatory? Is there an accessible registry of surveys? Are the shot logs (time/position) registered, and if so downloadable from a registry?

Almost all surveys fall under one national jurisdiction or another and are required to have permits to operate. Essentially, the issuance of permits is critical to the industry and its freedom to operate and serve the world's energy needs.

In the US, and many other nations, the permits are posted publicly. The Bureau of Ocean Energy Management (BOEM) is the permitting authority, and permits can be found on the BOEM website. More specifically, the permits specify an area and time for the survey, but detailed tracklines are usually not published because weather, repairs, and shutdowns for protected species mean that scheduling needs to be somewhat flexible. In addition, the exact specifications of the survey reveal a lot about what the survey is looking for and how, so some aspects of the survey tend to be competition-sensitive. Moreover, most surveys around the world now carry Protected Species Observers and the PSO reports are also a matter of public record. Daily, weekly, monthly or end-of-survey reports may be required. The reports don't convey information about source operations but do document observations of marine mammals, turtles, seabirds, fish or other marine life, as well as mitigation measures employed such as shutdowns, avoidance maneuvers and ramp-ups (soft starts) following shutdowns.

Question: The stats on the number of vessels operating over the last few years - is this globally? and how would it compare if only developing countries were included? I get the feeling that industry is targeting developing countries as the laws are under-developed or less strict?

The numbers of vessels shown in the slide were global. Targeting countries with less developed or less restrictive rules is not a factor in decisions about when and where to survey. The ships go where they must in order to make a living, and obtain whatever permits are needed for that area. The most active survey area in the world is the US Gulf of Mexico. Australia and the North Sea are also high on the list. So, developing countries are not targeted for any sinister exploitative purpose. This is the 21st Century and even under-developed countries have a good sense of global standards and practices. That said, developing countries are not denied the opportunity to benefit from their resources if they desire to do so. Permitting is a regular part of the process in both developed and developing countries. Nations tend to pick up on what other nations are doing and generate similar requirements. And as noted during my talk, the IAGC provides recommended mitigation and monitoring practices that our members have elected to encourage within the industry. These standards are basically the same as US (BOEM) and UK (JNCC) standards, the main differences being local species and habitats of special interest to a given nation.