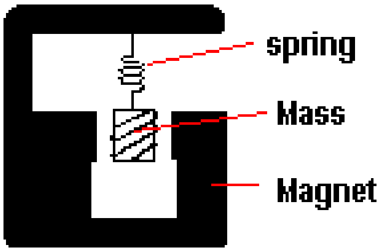
What is an Ocean Bottom Seismometer?

Seismometers acquire sound refraction information

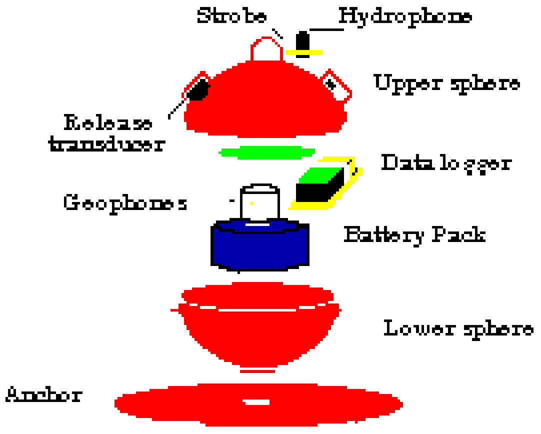


Seismometers acquire sound information through the earth. Acoustic waves (sound) travel in the form of very small motions which advance through the earth with time. The seismometer (or geophone) is a detector that is placed in direct contact with the earth to convert very small motions of the earth into electrical signals, which are recorded digitally. Each seismometer consists of a mass, which contains an electrical coil, that is suspended by a spring between the poles of a magnet. When the earth moves, the magnet and spring support move with the earth. The mass tends to remain stationary, so its motion will lag behind that of the magnet. This relative motion produces a voltage that is proportional to the velocity of this motion.

The sound waves are generated by either earthquakes at depth or by man-made devices near the surface of the earth. Motions of the earth, combined with precise timing and location information for the sound source and the receiver (the seismometer), can provide details of the velocity and the geometry of the earth structure. The USGS Ocean Bottom Seismometers (OBS) are designed to record the earth motion under oceans and lakes from man-made sources. In general, the man-made sound source is dragged behind a ship near the sea surface in the vicinity of the OBS. The acoustic waves generated at the sea surface travel at different paths, one path goes directly through the water to the OBS, another one crosses from the water layer to the sea bottom where it travels horizontally to the OBS, and other paths travel through deeper layers of the earth. Since the speed of sound is related to the density of the medium, the earth transmits the acoustic wave faster than sea water and deeper layers in the earth transmit the waves faster than shallow ones. Each OBSthen receives several acoustic waves for each generation of sound arriving at different times. Each one of these arrivals is called a ray path. By combining the time of the arrival, and the magnitude and phase of ray paths from the sound source at many different locations and from several OBS, a model of the earth's structure can be created. The horizontal geophones mounted in the OBS sometimes record S-wave (shear wave) information which can be added into the model to provide clues as to each layers composition. This method of imaging the earth is called wide-angle seismic reflection and refraction because the trajectories of the ray paths are generally at wide-angle from the vertical. The USGS OBS typically provide information about the structure of the sediments and the crust (down to 30-40 kilometers).

Seismic refraction work carried out at sea is faster and cheaper than a similar work carried out on land, because a non-explosion source can be towed behind the ship and fired repetitively while the ship is moving. On land, holes have to be drilled and explosives lowered into them. Land refraction work consists, therefore, of few shots (sound source) and many seismometers, which require many people and large amount of time to install and move around. Marine work uses fewer seismometers and many more shots. In addition, the USGS OBS provide measurement capabilities in areas where land operations cannot go. The most common mode of operation for the OBS is to "piggyback" on ships shooting seismic reflection surveys. In this case, the cost of the seismic refraction work includes only the costs associated with deployment and recovery of the OBS. The USGS OBS are compact and portable and can be deployed of any ship-of opportunity (usually a small research or fishing boat).

The OBS instrument package and its use



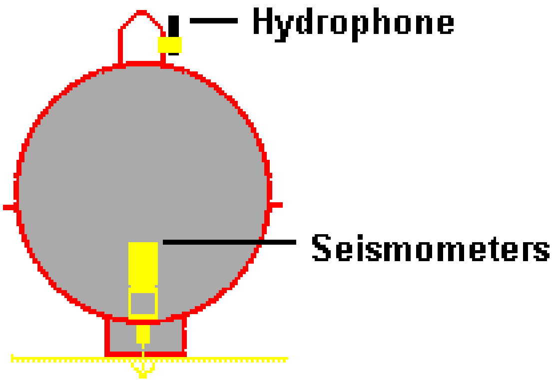
Parts of the OBS

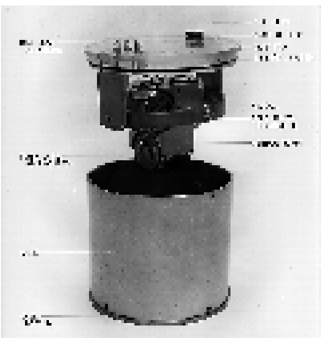
The OBS consists of an aluminum sphere which contains sensors, electronics, enough alkaline batteries to last 10 days on the ocean bottom, and an acoustic release. The two sphere halves are put together with an O-ring and a metal clamp to hold the halves together. A slight vacuum is placed on the sphere to better ensure a seal. The sphere by itself floats, so an anchor is needed to sink the instrument to the bottom. In this case, the anchor is flat metal plate 40 inches (1.02 meters) in diameter. The instrument has been designed to be able to deploy and recover off almost any vessel. All that is needed (for deployment and recovery) is enough deck space to hold the instruments and their anchors and a boom capable of lifting an OBS off the deck and swing it over to lower it into the water. The OBS is bolted to the anchor and then dropped (gently) over the side.

Prior to deployment, the data logger is programmed with the number of sensors to record, the sample rate for data acquisition, and the start time. At the designated time, information from the selected sensors is recorded on the data logger's 810 Megabyte hard disk. This information is recorded contiguously for all selected sensors until either the hard disk is filled or the OBS is recovered and the data collection stopped. The 810 Megabyte hard disk provides enough space to record 4 sensors at 100 samples per second for 280 hours.

The OBS is recovered with an acoustic release. The ship is positioned at the deployment location, and an electronics unit on the ship transmits a pulse at a specific frequency. The OBS , sitting on the ocean bottom, detects this pulse and replies with its own pulse at a different frequency. The time from the moment that the ship sent the first pulse to the time the ship receives the return pulse from the OBS is used to determine the distance between the ship and the OBS. Once the OBS's location is confirmed, a coded transmitted pulse is sent from the surface to initiate the release . The OBS then rotates a cam located on the bottom of the sphere, which releases the OBS from its anchor and enables a double pulse return (to indicate that it has released). Once the OBS has reached the surface, the instrument is retrieved and stored until a later time when the data can is downloaded. Turning the instrument around for the next deployment requires downloading the data onto another computer, replacing the batteries, testing the system, and programming in new parameters.

The USGS OBS sensors





The sensors used in the OBS consists one vertical 4.5 Hertz seismometer, two horizontal 4.5 Hertz seismometers , and one hydrophone. The seismometers are gimbal mounted to ensure that the sensor are level (they must be level to operate efficiently).The horizontal seismometers are mounted 90 degrees to the vertical and 90 degrees to each other. The hydrophone provides information that is similar to the vertical seismometer, and under certain conditions can have a better signal/noise ratio. To keep the design of the USGS OBS simple and compact, the seismometers are indirectly coupled to the earth via the sphere, release hardware, the anchor, and the spring used to hold the OBS to its anchor (the spring is needed to pull the attachment bolt away from the OBS during release). While seismometers work best if they are in direct contact with the earth, this design has proven itself to be effective in collecting data at the long shot-receiver offsets.

Timing is important

The only reference to relate the recorded data to outside events is the time of day. Each acquisition of data into the memory buffer is 1,015,808 bytes. The time and data pointer for that acquisition are placed into a header that gets recorded with each memory buffer of data. To provide the highest possible accuracy time is recorded to the nearest millisecond. Each OBS uses an oven-controlled oscillator as a stable clock reference for which the drift in time can be as little as 8 milliseconds/day. Each OBS data logger is continuously powered using a 24 volt DC power supply to keep the oscillators at a constant temperature. Prior to each deployment, the frequency of each oscillator is checked, and if necessary, re calibrated. The time-of-day is set via software in each logger using the minute pulse of the GPS satellite clock as a starting trigger. When locked on a satellite, the time is accurate to within 100 nanoseconds. Any offset from GPS time is determined by comparing the second pulse of the data logger with the second pulse of the GPS clock. After each deployment, the offset is measured again to determine the total drift.