Onboard data quality control and processing for ocean-bottom nodes

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When we use streamers or ocean-bottom cables, we have the data in real time. When we use autonomous ocean-bottom nodes, we have the data only when we retrieve them. With 100 days endurance, we may be shooting blind for three months without knowing if we are recording good data, or not. This may cause anxiety for some people.

Getting information from ocean-bottom nodes without retrieving them is neither reliable nor practical. Optical modems have good bandwidth but too short a range; you must send down a remotely operated vehicle (ROV) or an autonomous underwater vehicle to harvest data. Acoustic modems have the range but do not have the bandwidth to provide reliable quality control (QC). You cannot get data; you can get some information but the compute power in nodes is too limited to avoid many false alarms and detect all problems. Whether the nodes have optical modems, acoustical modems, or no modems at all, we are eager to see what we have on the nodes when we retrieve them.

The main objective of onboard QC is to verify that the survey can proceed as planned, or not! Sometimes the data are acceptable but they tell us to change the operation. For example, to keep at a distance from noisy seabed facilities, or to avoid shooting while certain noisy field activities like drilling are performed. Above all, if a problem cannot be fixed in processing, then nodes must be redeployed in previous stations. The party chief and the client must know it as soon as possible, certainly before the crew leaves the area.

Another obvious objective of the QC is to verify that we have copied the data before the nodes are cleared for redeployment. The memory on autonomous nodes is reused so new data clobber old data. Obviously we don't want to redeploy a node in a new station before we know that the data from the old station are safe and complete onboard. The data are copied from the nodes' flash memory to disk onboard, and then to tape. The data on the nodes must not be clobbered before we verify that the copy on disk is good. The copy on the disk must not be cleared before we verify that the tapes are good.

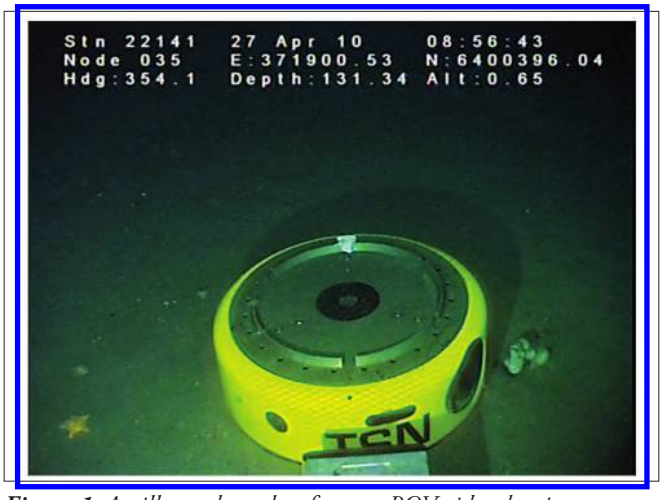


Figure 1. *A still snapshot taken from an ROV video showing an ocean-bottom node. The state of the seabed, as well as the heading of the ROV and the horizontal orientation of the node are visible.*

In addition to the above mission-critical objectives, onboard processing is an opportunity to reduce the turnaround time of data processing. The value of information is strongly time-dependent; information that arrives too late to influence decisions has no value. The main risk of time delay is in processing. Surveys in new areas often require new processing tools. The earlier we identify problems, the earlier we develop the solutions.

Quality-control methods

The main QC method is an automatic processing sequence that loads the data and generates QC products in a browsable format. Ideally, the automatic procedure can be reproduced interactively to analyze problematic data and check if problems can be fixed in processing. Another QC method is data drops to onshore processing centers. In addition, it is recommended to start surveys with preproduction tests in which some nodes are retrieved after some shooting before production shooting commences.

Auxiliary (nonseismic) data

ROVs take videos. Still frames are saved as pictures. Horizontal orientation is taken visually from pictures. Nodes with magnetic geophones do not have compasses. ROVs have gyros, and their heading is registered on the pictures they take. If the ROV aligns the node with the camera, it measures the node's horizontal orientation (Figure 1). The pictures also show the state of the seabed and the node deployment.

In addition to hydrophones and geophones, some nodes have sensors that measure tilt, temperature, and voltage. These measurements are recorded continuously and are downloaded from the nodes as auxiliary nonseismic data. Tilt sensors measure vertical orientation (Figure 2).

Built-in test

Some nodes have a built-in test that is conducted by the ROV after deployment and before retrieval. Although the results of the BIT are binary pass/fail, there are some details that motivate retaining the results of the BITs at the beginning and at the end of the deployment within the node QC report.

Geometry

In addition to the above seismic and auxiliary data, the actual survey geometry (post-plot) and the differences between the actual and the intended geometry (pre-plot) are reported (Figure 3). These differences happen because the ROV operator can change the final deployment location if the pre-plot is deemed less suitable, especially in the vicinity of seabed facilities. Also, the control of source positions is limited, especially in the vicinity of surface obstructions. It is important to evaluate the effects of such differences on the illumination.

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Passive and active seismic data

Autonomous nodes record data continuously; the nodes are not told to start recording when we shoot and stop recording at a certain time later. The continuous data are called "passive data." Passive data could be in long traces whose length could be months, but for practical reasons the passive data are cut into traces (e.g., 61-s traces that start every minute). To produce "active data", the continuous data are cut into traces that start at the time of every shot and are typically 15 s. Active data are similar to what streamers and cables produce. However, the trace length can be longer than the shot interval to a certain extent without the previous shot or the next shot interfering with the signal.

In processing, the active data are used to image and characterize the targets. Passive data can be used for interferometry and for QC purposes.

Passive and active data have different QC procedures. Passive data (Figure 4) provide good information mainly about noise (ambient and seismic interference). Active data provide information about the signal quality, and more accurate information about shot positions and node positions, orientations, and accuracy of the clocks.

Active data QC

It is unrealistic to plot all data recorded. What is realistic is automatic plotting of inline data from the line of shots that went over each node, and the perpendicular crossline. In the case of spiral shooting, it is possible to display as many shots as practically fit on a page. The data are displayed

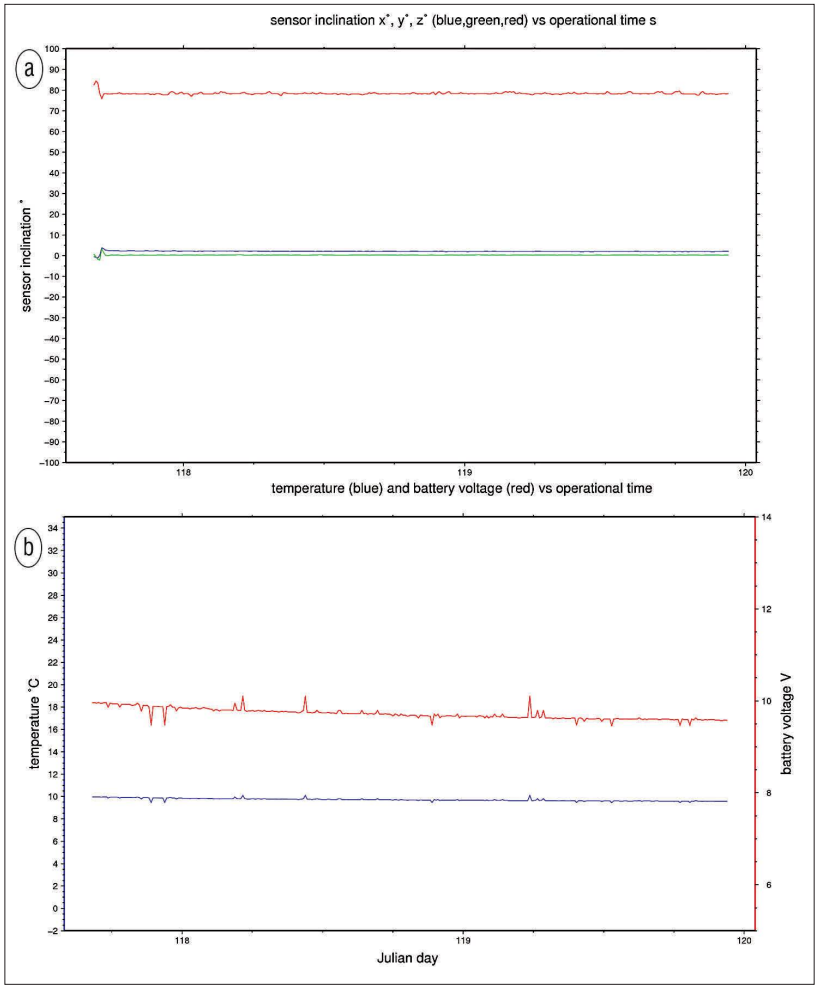


Figure 2. *Auxiliary nonseismic data. (a) Two horizontal and one vertical tilt meters. If a node is physically disturbed, this plot would show it. (b) Note the correlation between the temperature and the voltage.*

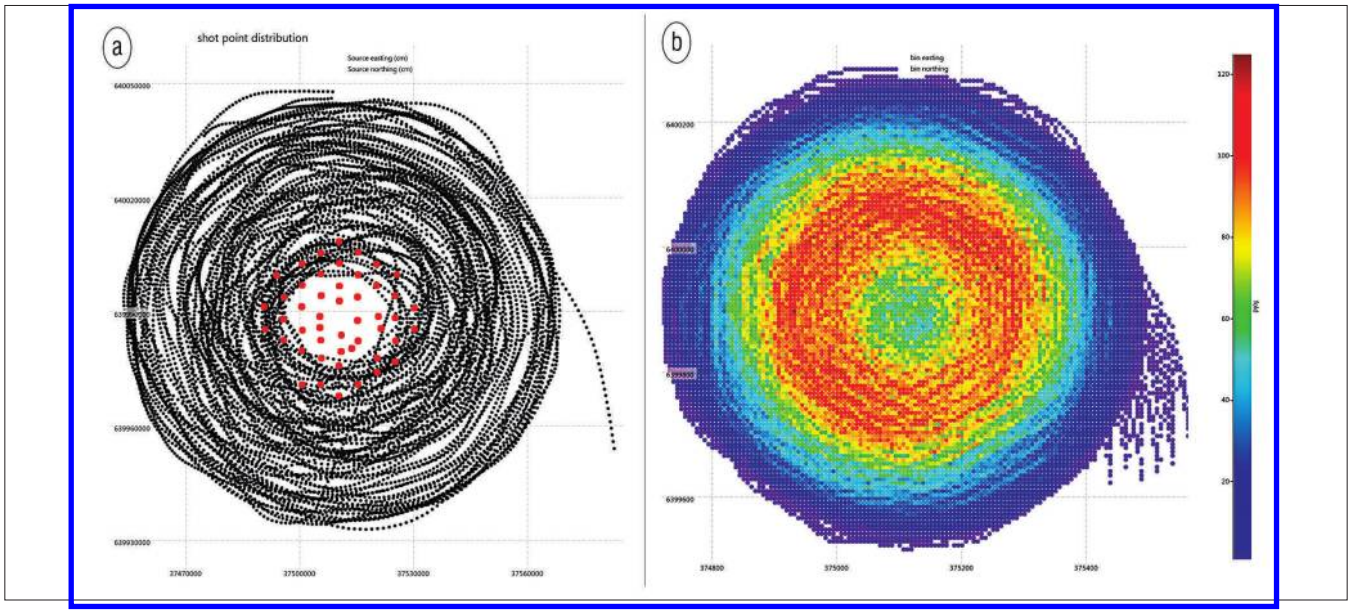


Figure 3. *Post-plot geometry displays: the actual positions of the shots and the nodes. Shot positions in black and node positions in red. Note the hole in the shot carpet due to a production platform in the middle. (a) Post-plot geometry nodes are in red and shots in black. (b) Post-plot common midpoint fold map showing that, even with position irregularities and the hole in the shot carpet, there is ample CMP coverage as per the survey design.*

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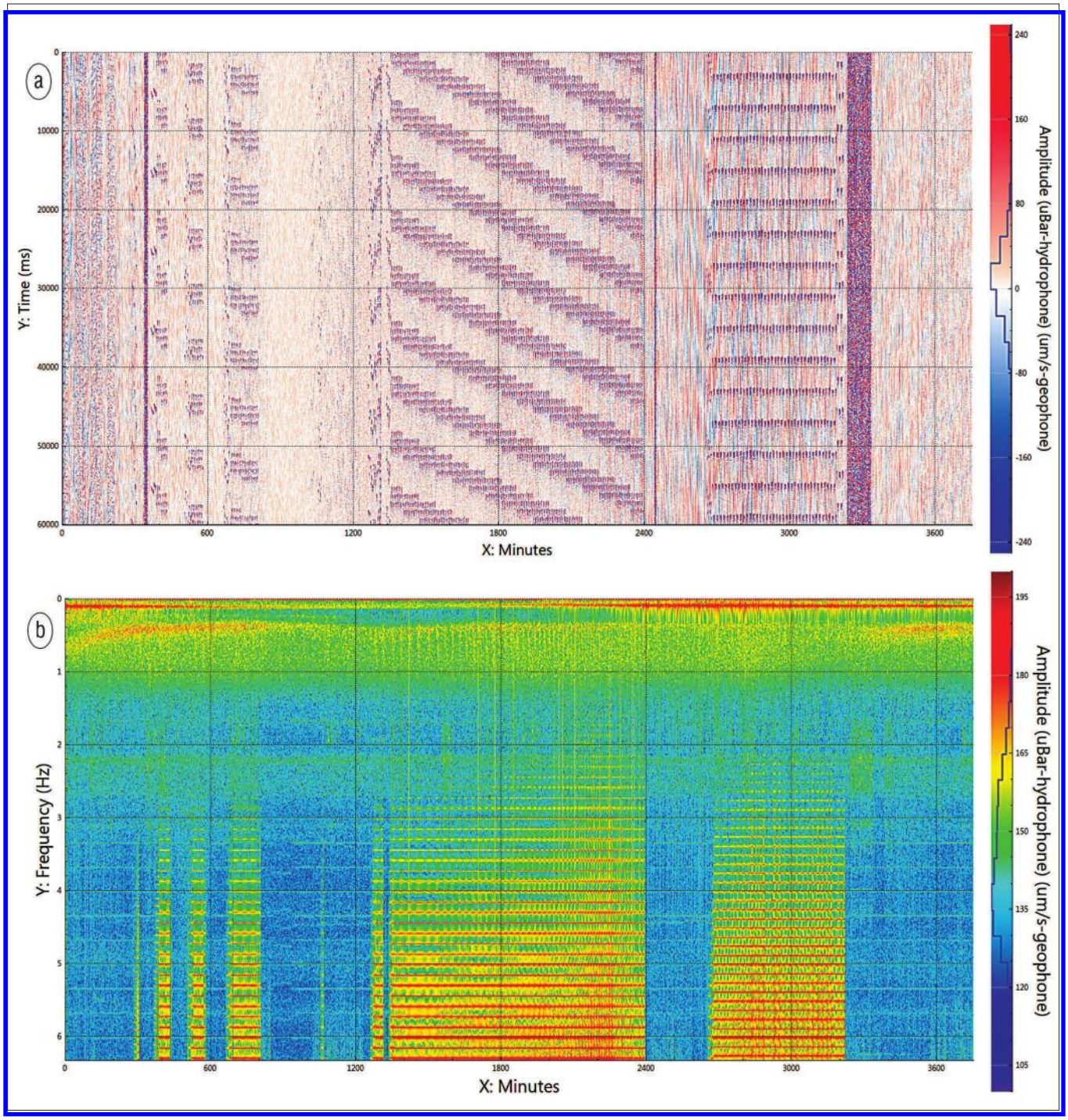


Figure 4. *Passive data displays showing 3700 minutes of passive data. The data were cut into minute-long traces. (a) Time domain display. Note times of shooting (for example, the long shoot from 1300–2400 minutes), platform noise (for example, at 3300 minutes), and the swell as the weather was increasing at about 2200 minutes. Also note noise from the ROV deploying nodes at 0–250 minutes. (b) Spectra of lowest 6.3 Hz. Note the air-gun energy starting at approximately 24 Hz. The horizontal striping is due to a shot interval which is much shorter than the trace length. The swell has two modes: a 10-s mode (0.1 Hz) and a 2-s mode (0.5 Hz).*

(Figures 5–8) in the time domain, frequency domain, and space and wavenumber domains before and after normal moveout (NMO) and hyperbolic moveout (HMO). Time and frequency slices can also be generated.

First-break picking provides an opportunity to check the accuracy of node positions and orientation, and source positions and directivity, as well as the clock accuracy. For each shot, there is a time difference between the expected and the picked arrival time of the first break (Figure 9). These time differences are displayed on a map and against time of shot. Together, these plots provide insight into the accuracy of positions, clocks, and water velocity profile.

The energy in various time windows provides an opportunity to verify signal and noise strengths as well as node orientation (Figure 10). Areal maps of rms amplitudes are produced for pressure, vertical, east, and north components, mapped by shot

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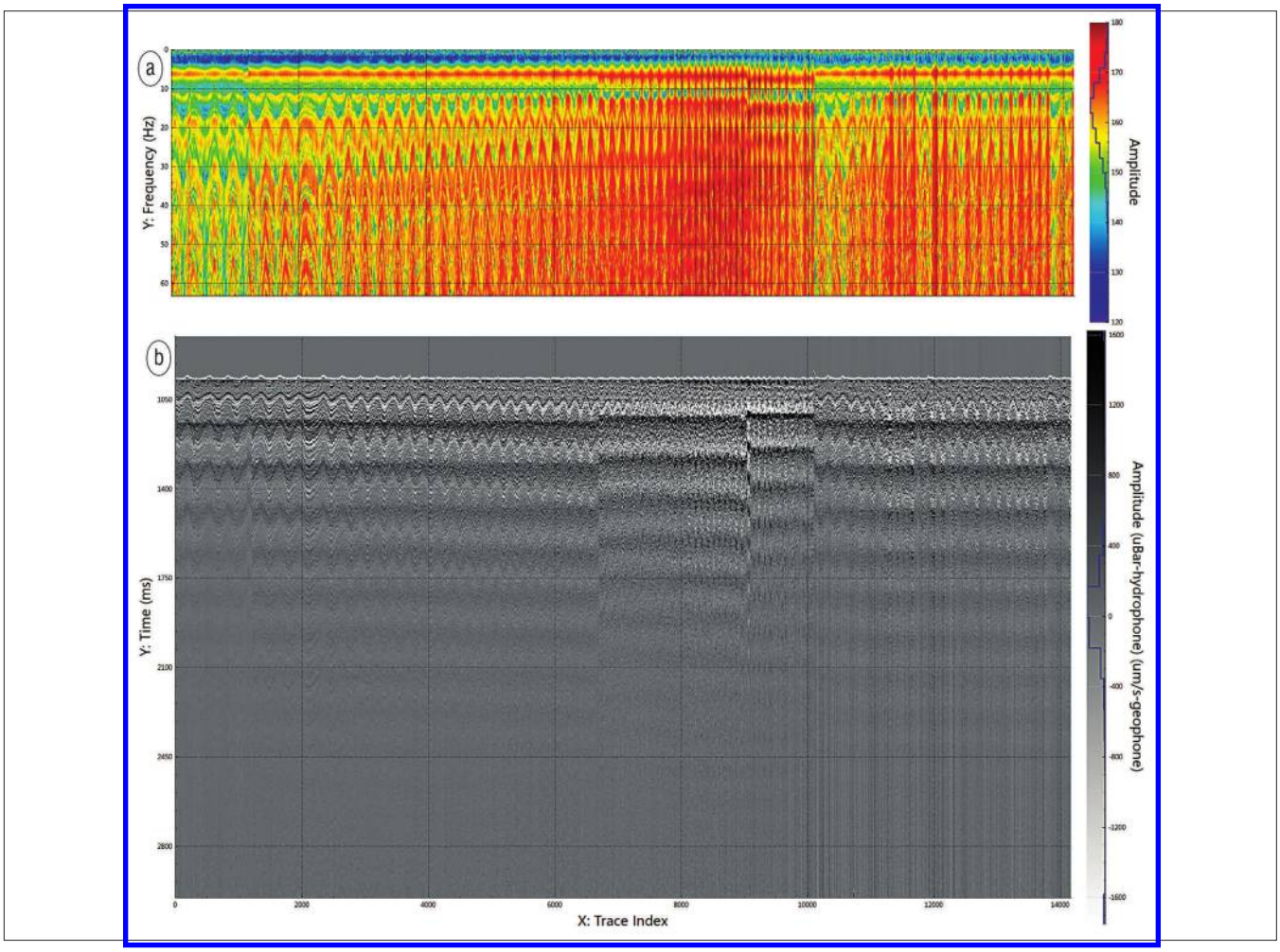


Figure 5. *Raw data after hyperbolic moveout. Hydrophone component of a common receiver (CRG). (a) Frequency-space (FX) spectra display. (b) Time-space (TX) display. We can see the air-gun bubble ringing about 10 times in 2.5 s. Three changes of the air-gun source signature are seen during the second part of the deployment due to air leaks and gun malfunctions. In each event, the air-gun bubble frequency changed.*

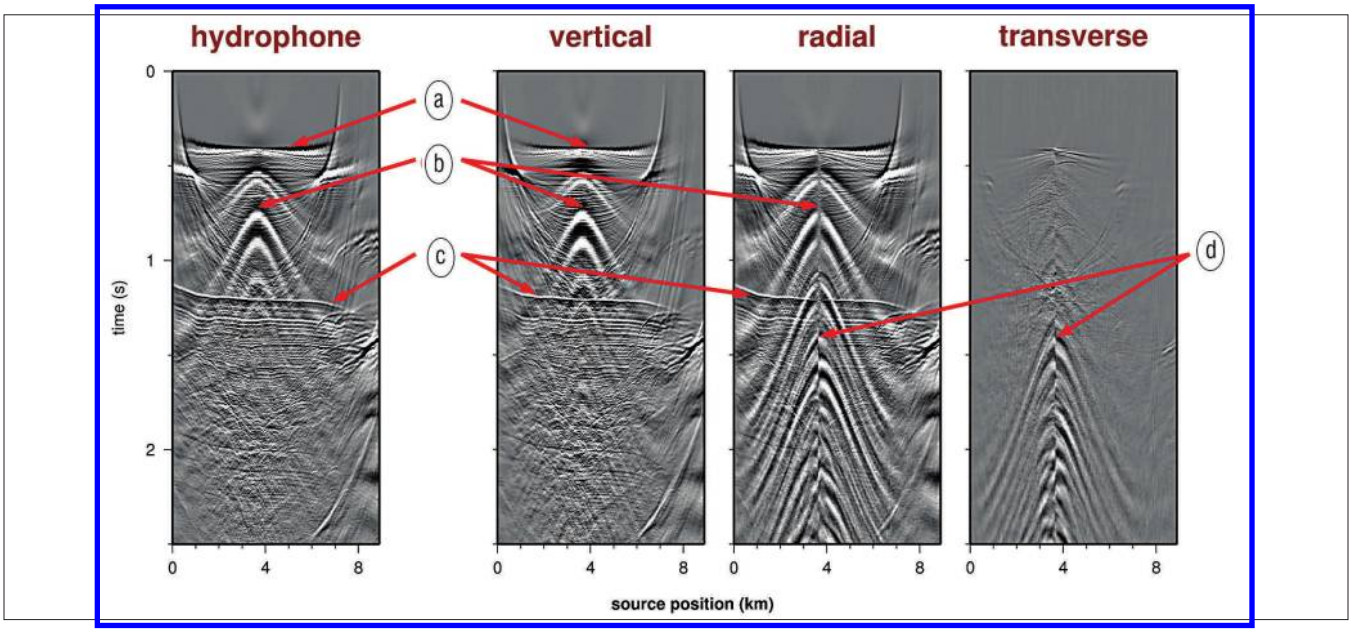


Figure 6. *Four components of one shot line over one node after normal moveout. NMO with water velocity is used to show the mirror image of the seabed. (a) Direct arrival. (b) Air-gun bubble. (c) Mirror image of the seabed. (d) Shear waves.*

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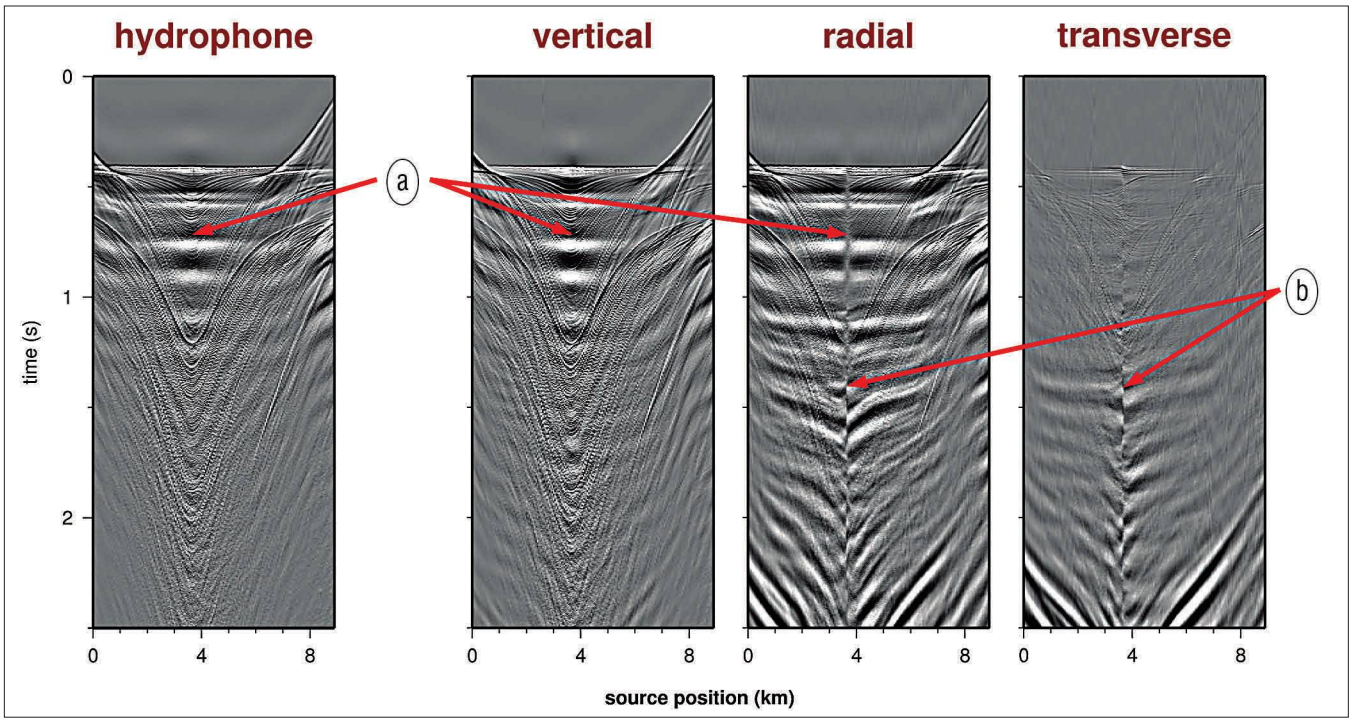


Figure 7. *Four components of one CRG after hyperbolic moveout. HMO shows the difference between the air-gun bubble (a) and the shear waves (b). After HMO, the bubble is flat but the shear waves are not.*

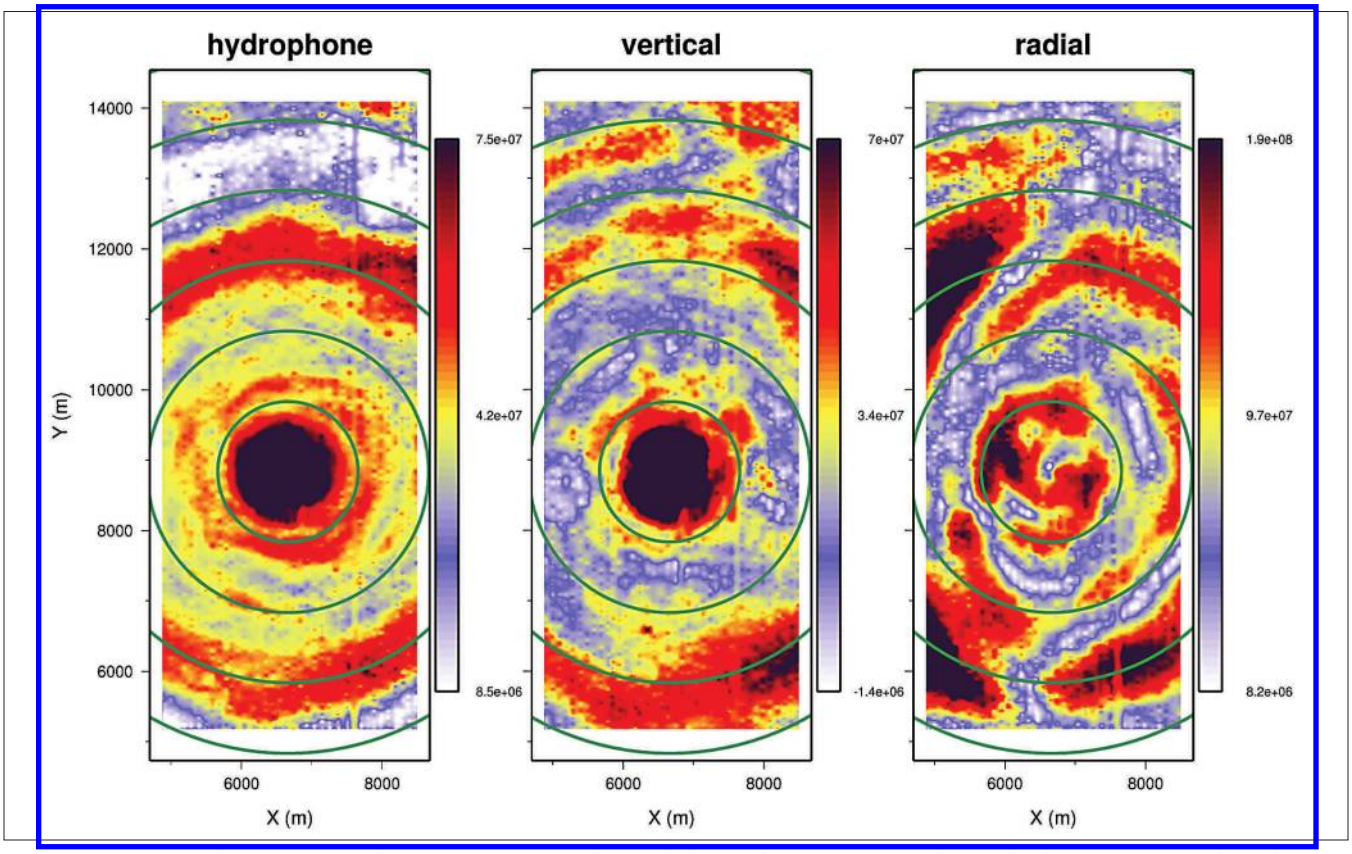


Figure 8. *Frequency slice at 3 Hz. In this common receiver gather, each shot produces one trace. Each trace has been Fourier-transformed and the absolute value of the spectra were extracted at 3 Hz. Three components are shown: hydrophones, vertical, and radial. The green circles annotate 1-km radii around the node location. P-waves have a circular pattern and shear waves appear distorted.*

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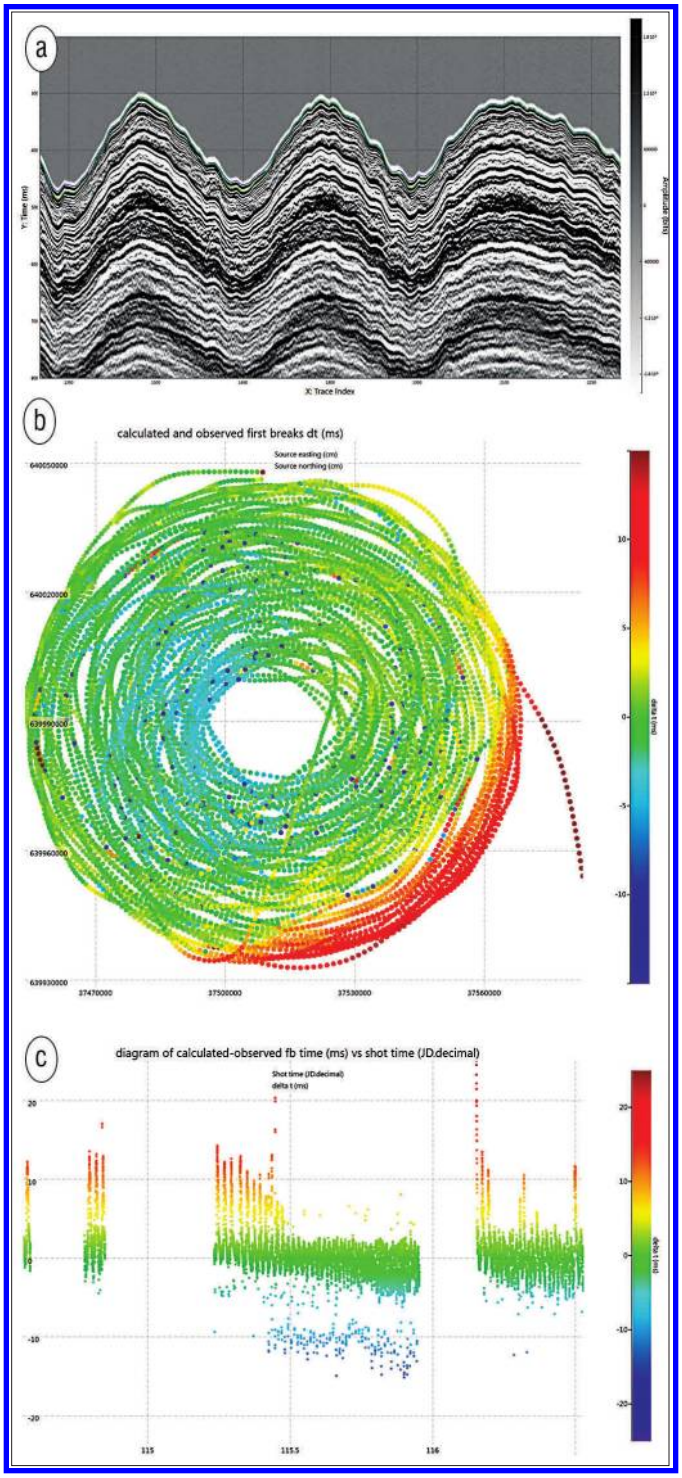


Figure 9. *First-break picking quality control. (a) FBPs overlaid on the data. (b) FBP time errors displayed on a map. This QC product is useful to detect position errors. (c) FBP time errors (in ms) crossplotted against shot time (in days). This QC product is useful to detect clock drift.*

location. The rms amplitudes for a time window on the direct arrival are used for signal analysis, and another time window is used to measure ambient noise.

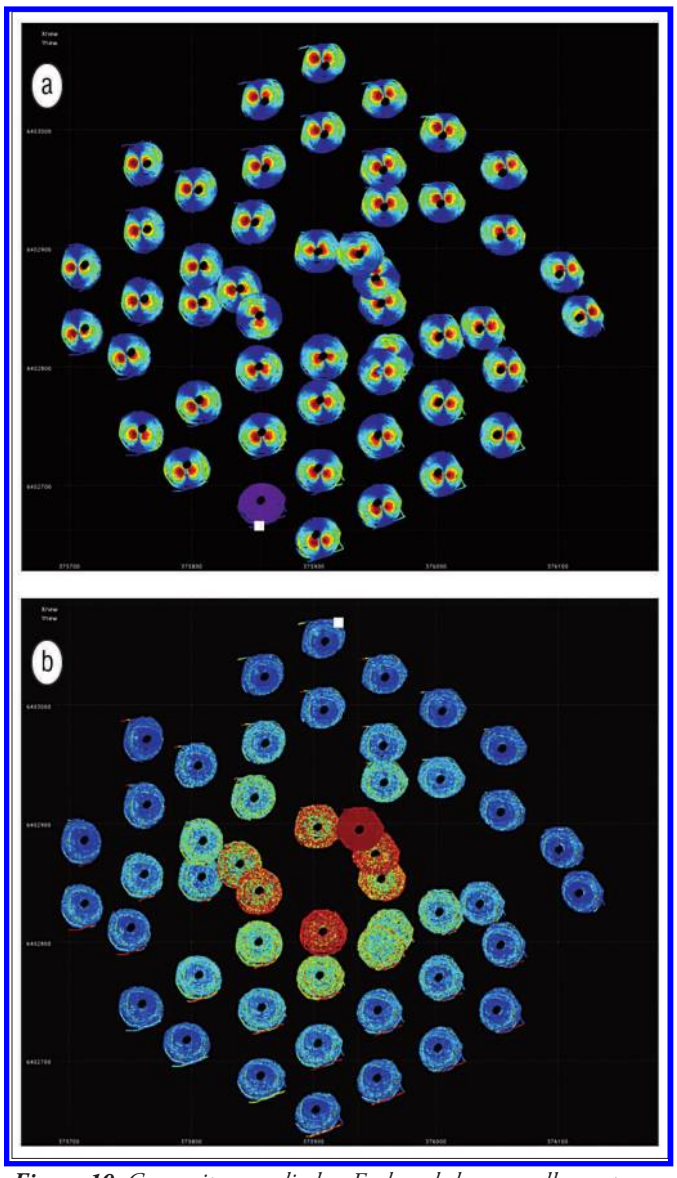


Figure 10. *Composite map display. Each node has a small map to represent the shots around it. There is a production platform in the middle of the maps. (a) Easting horizontal component energy in a narrow time window calculated on the direct arrival. Shots to the north and to the south should have no energy. Heading inaccuracies are, as expected, up to a few degrees. There are three nodes that are rotated about 90°. One node had a bulk time shift. These problems were all minor and would be fixed in processing at little extra cost. (b) Energy in a late time window showing more ambient noise near the production platform.*

Summary

Quick and thorough data analysis is an essential task of a node crew. Within hours after node retrieval, the crew and the client know if they can proceed with survey as planned, or not. It also increases the value of information by saving time in data processing. TLE

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