Ocean Bottom Node Acquisition

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Ocean Bottom Node Acquisition – What is it?

**OBC Acquisition**

4 component seismic sensor:
3 geophones (XYZ) - also MEMS or optical for OBC
1 hydrophone

**Node Acquisition**
Outline

• OBN Acquisition – Why is it done?
• Equipment and node operation
• Full azimuth survey
• Data processing
OBN Acquisition

Why is it done?
OBN Acquisition – Why is it done?

Complex imaging with full azimuth broad band data

Figure 6. Comparison of narrow-azimuth towed streamer (A), and receiver-migrated OBS node (B). The node images benefit from an improved salt model.

Atlantis field, GoM

Beaudoin, SEG 2010
OBN Acquisition – Why is it done?

High resolution both vertically and laterally

Best towed streamer common azimuth wave equation migration

Interim OBS node mirror (multiple) migration

Figure 6: Comparison of extra-salt images at the Miocene level at Atlantis. Higher resolution and improved fault definition are apparent in the OBS wide-azimuth node image on the bottom compared to the narrow-azimuth towed streamer image above.

Atlantis field, GoM

Howie et al, SEG 2008
OBN Acquisition – Why is it done?

4D Repeatability

“Time-lapse noise measurements [...] are among the lowest in BP’s experience even when compared to permanent installation surveys.”

Atlantis field, GoM  Reasnor et al, SEG 2010

“...high repeatability with a NRMS of around 6%.”  Stopin et al, EAGE 2011
OBN Acquisition – Why is it done?

Illustration of the main surface and subsea obstructions on the Dalia field: OBN will be located on the seabed very close to obstructions.

Dalia field, Angola
OBN Acquisition – Why is it done?

Infill under obstructions, congested oilfields

- FPSO (=Floating Production, Storage and Offloading unit)
- ..another FPSO
- Offloading buoy
- Supply boat
- Drilling ship
- Hugin Explorer
OBN Acquisition – Why is it done?

Infill under obstructions, congested oilfields

110° F

Source array firing
OBN Acquisition – Why is it done?

- Nodes can be hand-placed almost anywhere
- Passive recording, long offsets...
- Ocean bottom nodes can carry many types of sensors

Deep water, Unconventional methods
OBN Acquisition – Why is it done?

Converted wave imaging
Shown are classic OBC examples

Lomond field, North Sea

Alba field, North Sea

Grane field, North Sea

Fjellanger et al, SEG 2006
Why Converted Waves?

PP AVO inversion → P impedance
PS AVO inversion → Shear impedance
..also better handle on density.

Strong shear impedance contrast from lithology change within reservoir zone.

Kvitebjorn field, North Sea
Ao & Areklett, TLE 2010
Why Converted Waves?  

**PP & PS = Better anisotropic velocity model building**

PP reflection, isotropic NMO correction

PS reflection, isotropic NMO correction

Note polarity reversal at critical angle

Double Scan

Offset/Angle of incidence

Epsilon

Delta

PP

PS

PP & PS
OBN Acquisition

Equipment and node operation
Option 1: Throw node overboard, let it float up by itself

Typically glass or titanium sphere
Disposable heavy anchor
Internal or external sensor package
Mostly used for academic research or refraction lines
OBN Equipment – Nodes

Option 2:  Hand-place node, pick it up manually

- Node can be custom shaped
- Recorder in cylindrical pressure vessels
- Internal or external sensor package
- Mostly used for commercial 3D surveys
OBN Technology – Vessel and equipment

Hugin Explorer – Node/Source/ROV vessel

Node and sensors

3 geophones (8Hz)
1 hydrophone (1.5Hz analogue low cut)
2 inclinometers

Low frequency gain compared to other systems:

Node storage capacity: 1200+

- Usually operates in dual-boat mode with a separate source vessel
- In one survey the Hugin operated alone, deploying/retrieving nodes AND shooting while towing a 600m mini-streamer
OBN Equipment – Node Handling

ROV

Node basket
OBN Operation – Node Placement
OBN Operation – Node Placement

Sensor skirt (cutaway view)

“Added mass” contribution from soil

Unperturbed soil

www.fugro.com
OBN Operation – Node QC

- Recorder status
- Battery status
- Hard disk status
- Power usage
- Tilt values
- Seismic data RMS amplitudes
- ...various other system information

Acoustic modem communication between OBN and vessel
OBN Acquisition

Full azimuth survey
OBN Acquisition – Full azimuth survey

Basic node survey design consists of regular node grid and encompassing shot grid. Illustration of contributing receivers/shots for two example bins:
OBN Acquisition – Full azimuth survey

**Rose diagram** – Offset/azimuth fold:

(similar OBN survey)

**Offset fold diagram** for the 2 example bins:

(OBN survey design - Fold in 800m offset bands, two example CMP bins)

Poor near offset fold??
OBN Acquisition – Full azimuth survey

OBN offset/azimuth distribution is best viewed in common-offset vector tiles (OVTs). For every CMP bin, contributing shot-receiver pairs are evenly distributed on a regular inline/crossline offset grid. → Pre-stack migration is best performed in OVTs.

Even offset distribution in every azimuth direction

Within the limits of survey area, every CMP bin has one trace in each offset vector tile.
OBN Acquisition – Full azimuth survey

Size of OVT is governed by **node spacing**

Size of CMP bin is governed by **shot spacing**
OBN Acquisition
Data Processing
Active shots need to be extracted from continuous record, using shot time.
Shot time needs to be mapped to time of internal clock.
Clocks used in OBNs are very accurate, but can still drift by several 10ms per month.
New clocks only drift \(\sim 0.1\text{ms}\) per month.
OBN Data processing – Spectral analysis

- **Electrical “1/f” noise**
- **Ocean wave noise**
- **Active shot energy. Ripples due to bubble**
- **Decay due to sensor responses and diminishing shot energy**
Raypath geometry for one node/receiver gather:

Pre-processing is done mostly in 3D receiver gather domain.
OBN Data processing – Raw data example

Example raw receiver gather, deep water (~1km)

- Zero offset
- P-wave reflection
- PS converted waves
- Direct arrival
- First water bottom multiple
- Second?
- Shear noise
- Bubble
OBN Data processing – Multiple path imaging

Conventional imaging
Primary reflections, up-going wavefield

Multiple path imaging
Receiver side multiple, down-going wavefield
OBN Data processing – P-wave imaging

Essential data processing steps (fast-track)

- Pre-conditioning
- Noise attenuation
- PZ calibration
- Source designature
- Vz noise removal
- Wavefield separation
- Up/down decon
- TTI PSDM
- Radon demultiple
- Mute & Stack
- Post-stack processing
- Acquisition-related corrections: Positions, clock drift, tides…
- Seismic interference, ground roll (shallow water)
- Match hydrophone and geophone
- At least: Remove bubble oscillations
- Shear induced noise on Z component
- Separate into up- and downgoing energy, process separately
- Apply to upgoing energy
- Kirchhoff migration, using existing velocity field. Normal/multiple path
- Q compensation

Advanced data processing steps

- Surface consistent processing
- Timing corrections
- 3D SRME
- Offset vector tiles
- Interpolation / regularisation ?
- Anisotropic velocity model building
- RTM / Kirchhoff ?
- Azimuthal velocity correction
- Surface consistent scaling, deconvolution, statics
- Advanced tidal and water velocity corrections
- Apply to downgoing energy
- Binning
- ..more generally: • Use 3D methods (noise attenuation..)
  • Integration of well data
  • Attention to details
OBN Data processing – Multiple path imaging

Conventional imaging
Primary reflections, up-going wavefield

Multiple path imaging
Receiver side multiple, down-going wavefield

...from Dash et al (2009)
OBN Data processing – Multiple path imaging

Illustration from single 16-node line mini 2.5D survey (essentially 2D geometry)

Upgoing migration  

Downgoing “mirror” migration
OBN Data processing – Low frequency content

Raw data, band-pass filtered, $T^1$ gain

1Hz - 2Hz

2Hz - 3Hz

3Hz - 4Hz

4Hz - 5Hz
OBN Data processing – Low frequency content

1Hz - 2Hz
2Hz - 3Hz
3Hz - 4Hz
4Hz - 5Hz
1Hz - 20Hz

Fully migrated 2D section, band-pass filtered

Basalt layer

..different scaling
OBN Acquisition – Summary

Upsides

- **Operationally efficient** in presence of...
  - Surface obstructions (impeding use of towed streamer)
  - Seabed obstructions, rugged seafloor (impeding use of ocean bottom cables/OBC)
- **Full azimuth**: Full & even surface azimuth/offset distribution
- **Vector fidelity**: Ideal sensor coupling, decoupled sensor, no distortion due to instrument
- **High resolution**: Naturally rich in low frequencies, no compromise at high end
- **Low ambient noise**: Swell/flow noise (streamer), water current noise (OBC)
- **4D repeatability**: Repeatability of positions, and of final processed data (low NRMS)
- **Full elastic wavefield recording**: 4 component sensor, P- and S-wave arrivals
- **Continuous recording**: Passive seismic monitoring & analysis

Downsides

- **Autonomous recording**
  - Requires high fidelity clock drift correction
  - Node reliability is crucial
- **Sparse receivers**
  - Resolved by multiple (mirror) imaging, but problematic for converted waves
- **Survey time & cost**
  - Needs good evaluation of added value
Thank You
Spectral analysis

Continuous data spectra – 4 minute traces

X Component

Shot fired
Seismic interference
Ocean wave noise
Shot lines
Test shots
Recorder noise
Ship

ROV placing node at 5m distance

Continuous data FX power spectrum - XComponent
Spectral analysis

Continuous data spectra – 4 minute traces
Y Component

Shot fired
Seismic interference
Ocean wave noise
Shot lines
Test shots
Recorder noise
Ship
ROV placing node at 5m distance
Spectral analysis

Continuous data spectra – 4 minute traces
Z Component

Shot fired
Seismic interference
Ocean wave noise
Shot lines
Test shots
ROV hoisted on deck
Recorder noise
Ship
ROV placing node at 5m distance

Continuous data FX power spectrum - Z component
Spectral analysis

Continuous data spectra – 4 minute traces

Hydrophone

- Shot fired
- Seismic interference
- Ocean wave noise
- Shot lines
- Test shots
- ROV hoisted on deck
- Recorder noise
- Ship

Continuous data FX power spectrum - Hydrophone
Spectral analysis

Continuous data spectra – 4 minute traces

Hydrophone

Earthquake/Seaslide

Same spectrum, zoomed in to 0-0.7Hz

5 hours of recording

5 hours of recording
OBN Survey – Node and source area

Boundary of shot grid (surface) 588 sq km

Boundary of node grid (ocean bottom) 229 sq km

O/W contact

Another example:
Node/shot area is optimised
OBN Survey – Node layout

- 1595 total node positions
- Node grid: 390m x 390m
OBN Survey – Source layout

- 648,648 total shot positions
- Shot grid: 30m x 30m
- Shooting vessel acquiring one shot line at a time
OBN Survey – Roll-along acquisition
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