Introduction to Marine Seismic Processing - ProMAX

Andrew Goodliffe
University of Alabama

Socorro, NM, Wednesday May 28

IRIS

The University of Alabama
College of Arts and Sciences
Geological Sciences

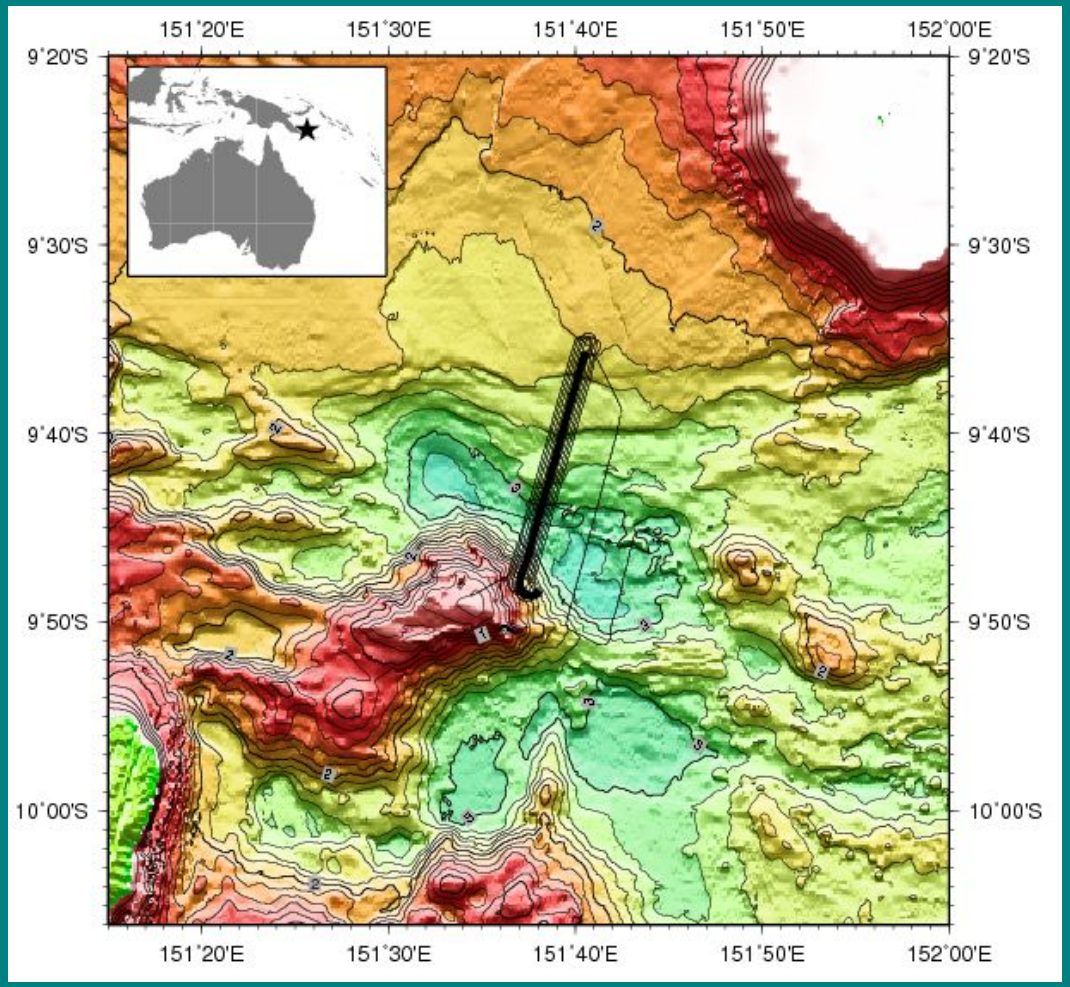
ProMAX Exercise

- What is ProMAX?
  - A software package for processing reflection seismic data
  - Commonly used in the energy industry
  - Not free!
  - There are many other programs that will do the same sort of thing – they differ mainly in their user interface (or lack thereof)
  - Runs on many flavors of UNIX

Where did the data come from?

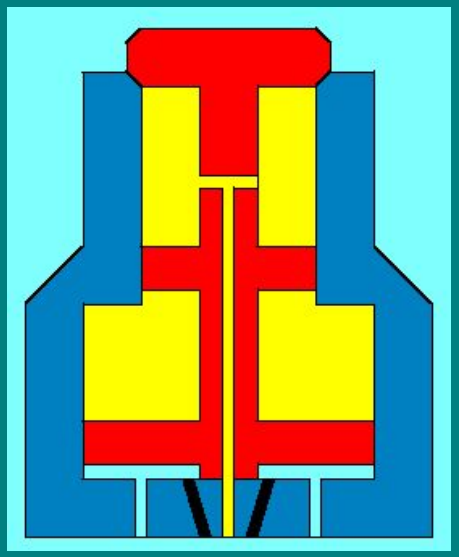
- A short seismic reflection survey in Papua New Guinea
- September 1999
- R/V Maurice Ewing
  - 1.2 km streamer
  - 48 channels
  - 25 m group interval
  - 1395 inch^3 tuned six airgun array
  - 25 m shot interval
  - 24-fold CMPs 12.5 m apart

Woodlark Basin



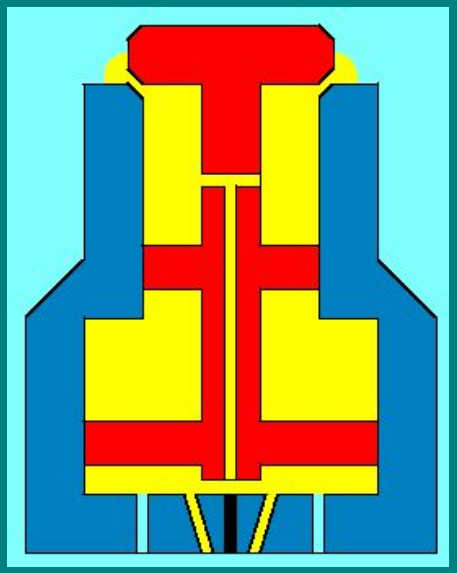
- A rift basin in Papua New Guinea
- A classic place to study the orogenic rifting to seafloor spreading transition
- The line that we will look at crosses a large rift basin close to the transition to seafloor spreading
- The survey was carried out as part of an Ocean Drilling Program site survey

High Pressure Air Sources: The Air Gun



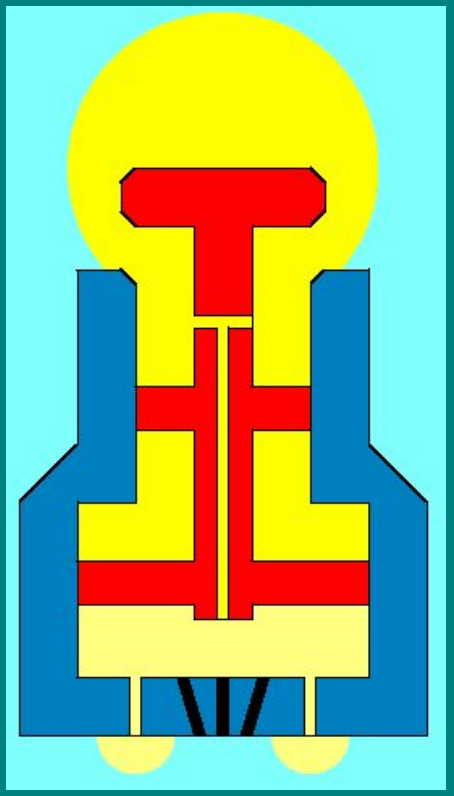
Ready

Lower chamber has a top diameter that's smaller the bottom diameter - air pressure forces the piston down and sealing the upper, firing chamber. High pressure air is filling the firing chamber through the T-shaped passage, and the firing, or actuating air passage is blocked (solid black) by a solenoid valve.



Fire!

Full pressure has built up in the upper chamber. The Solenoid has been triggered, releasing high-pressure air into the active air passage, which is now yellow. The air fills the area directly below the piston, overcoming the sealing effect of the air in the lower, control chamber. The piston moves upwards, releasing the air in the upper chamber into the water.

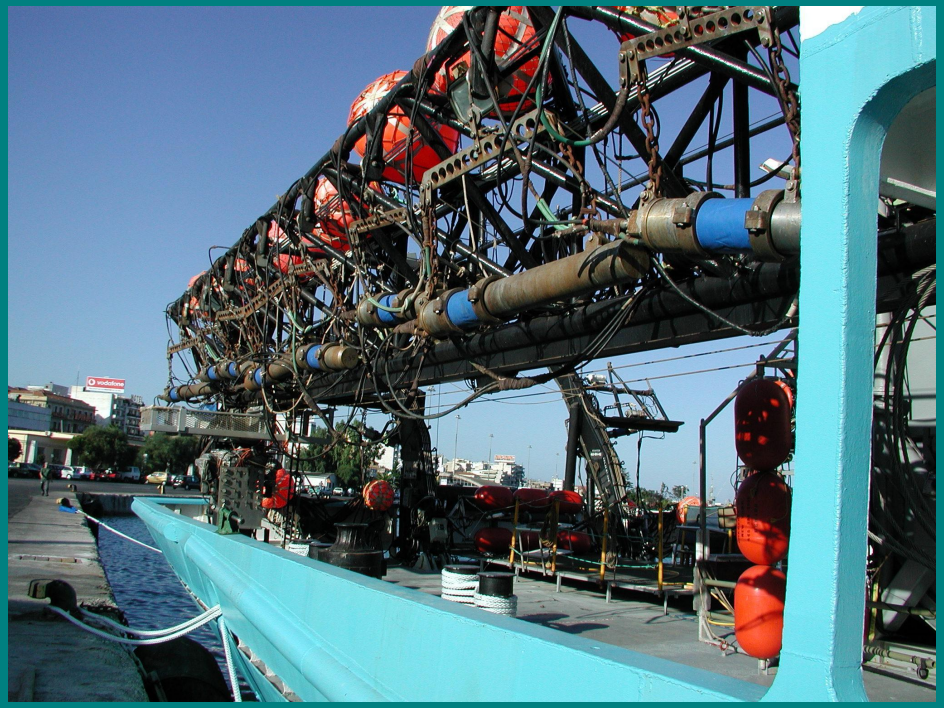


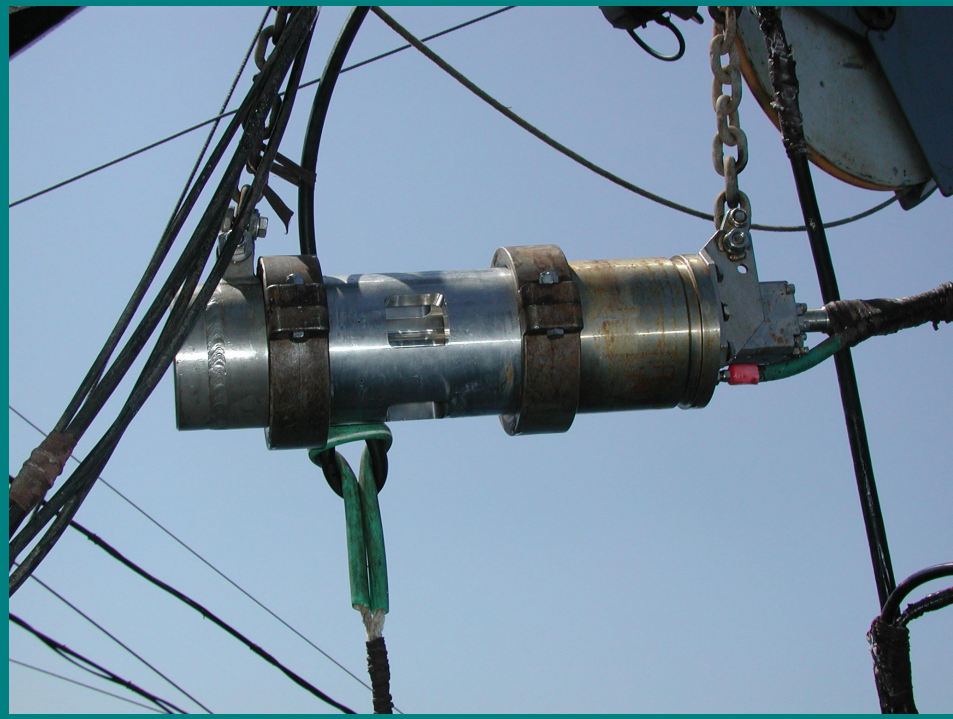
From: http://www.ldeo.columbia.edu/res/fac/oma/sss

Fired

A large bubble of compressed air is expanding into the surrounding water. The air in the lower control chamber has been compressed. The triggered air, released into the space below the piston, is fully expanded, and can now exhaust at a controlled rate through the vent ports. As this takes place, the piston rapidly but gently moves downward, re-sealing the chamber, and readying the sound source for refilling.

Air Guns



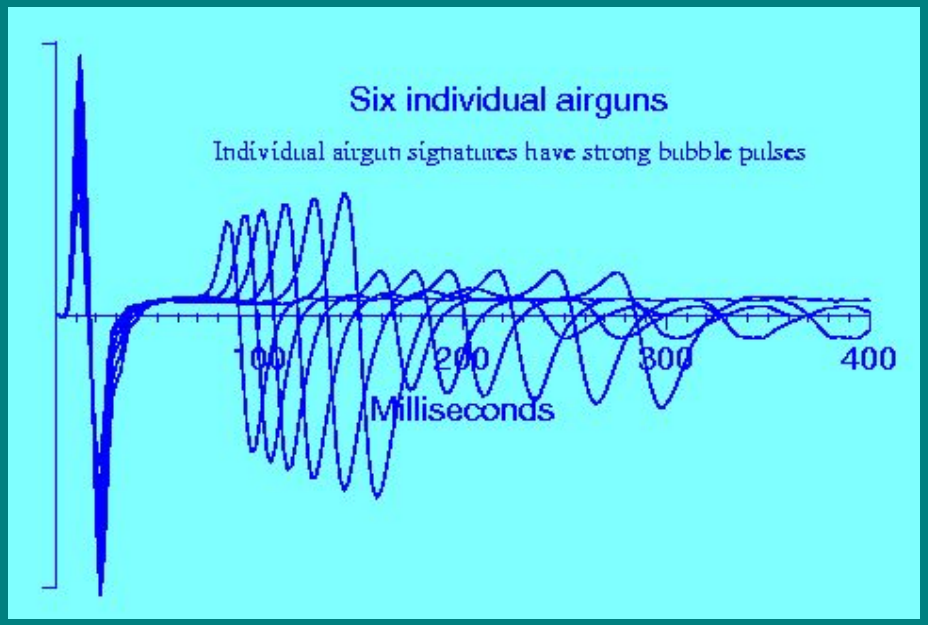


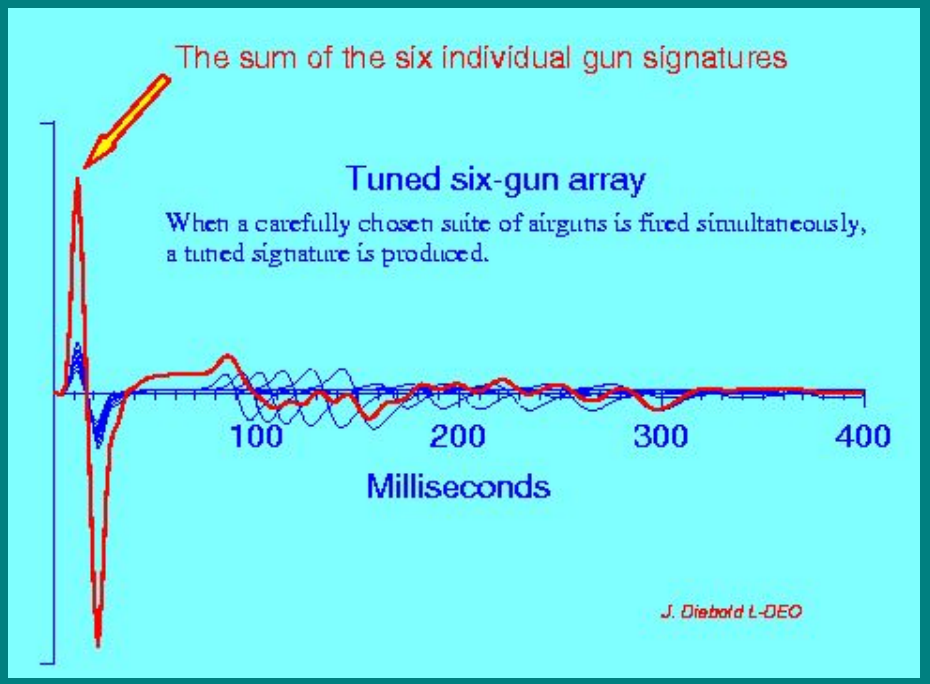
- Airguns suspended from stowed booms

- Single Air gun – note air ports

Other source?

Tuning An Air Gun Array





From http://www.ldeo.columbia.edu/res/fac/oma/sss/tuning.html

- Summing the signal of multiple guns creates a more desirable signal
- Note the relative scales of the left and right plots

Listening

- Hydrophone
  - Piezoelectric material
  - Pressure changes in the water generate small currents which are amplified
- Geophone
  - Mechanical
  - Motion of coil relative to magnet generates a small current which is then amplified

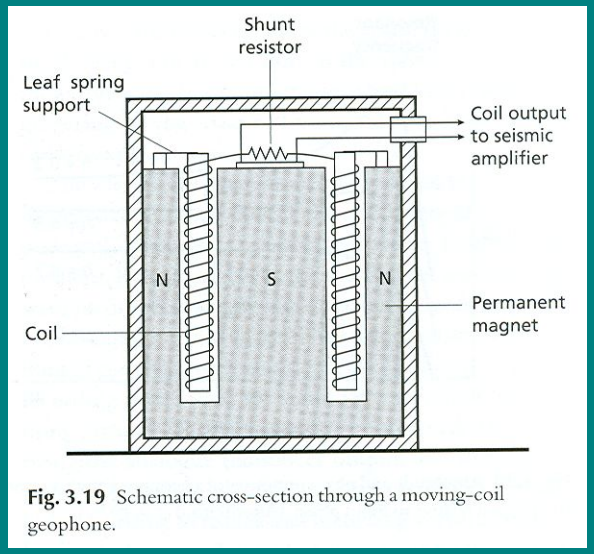


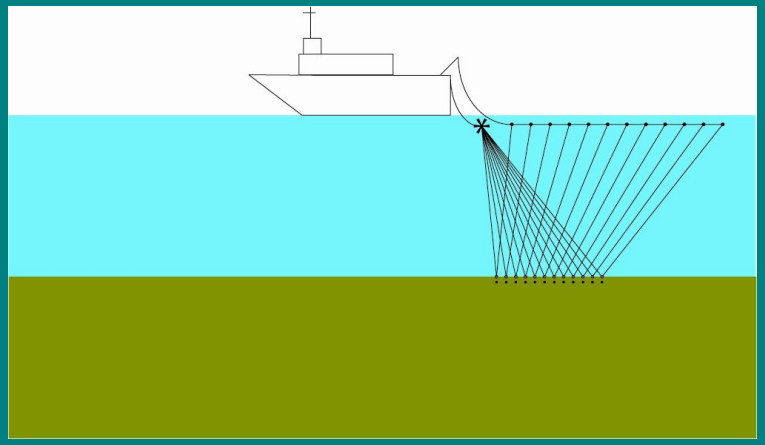
Fig. 3.19 Schematic cross-section through a moving-coil geophone.

From Kearey, Brooks, and Hill, 2002

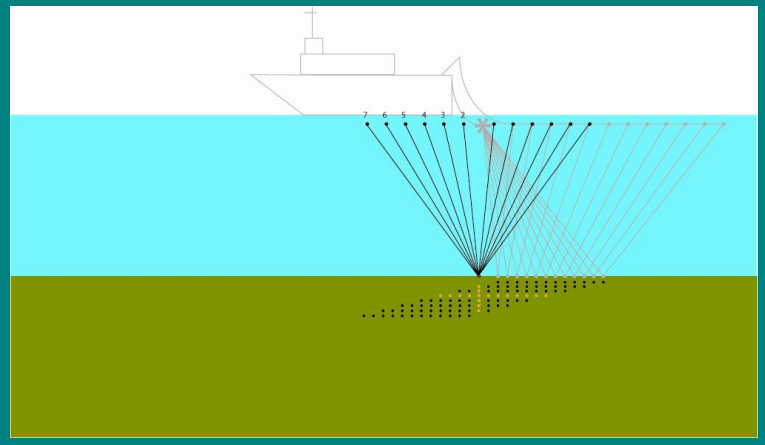
How is a Marine Seismic Reflection Survey Shot?

Definition of shot and common mid-point (CMP) gathers

Shot gather: All the data recorded on all the channels by a single shot

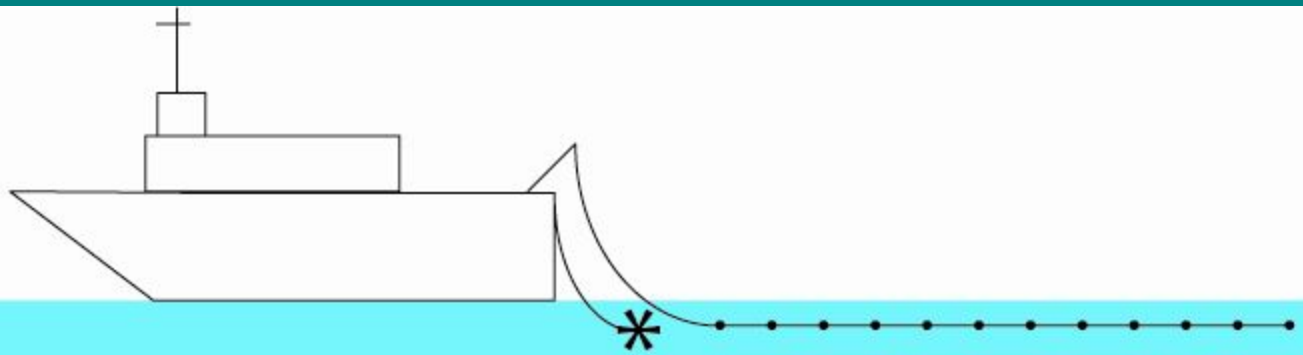


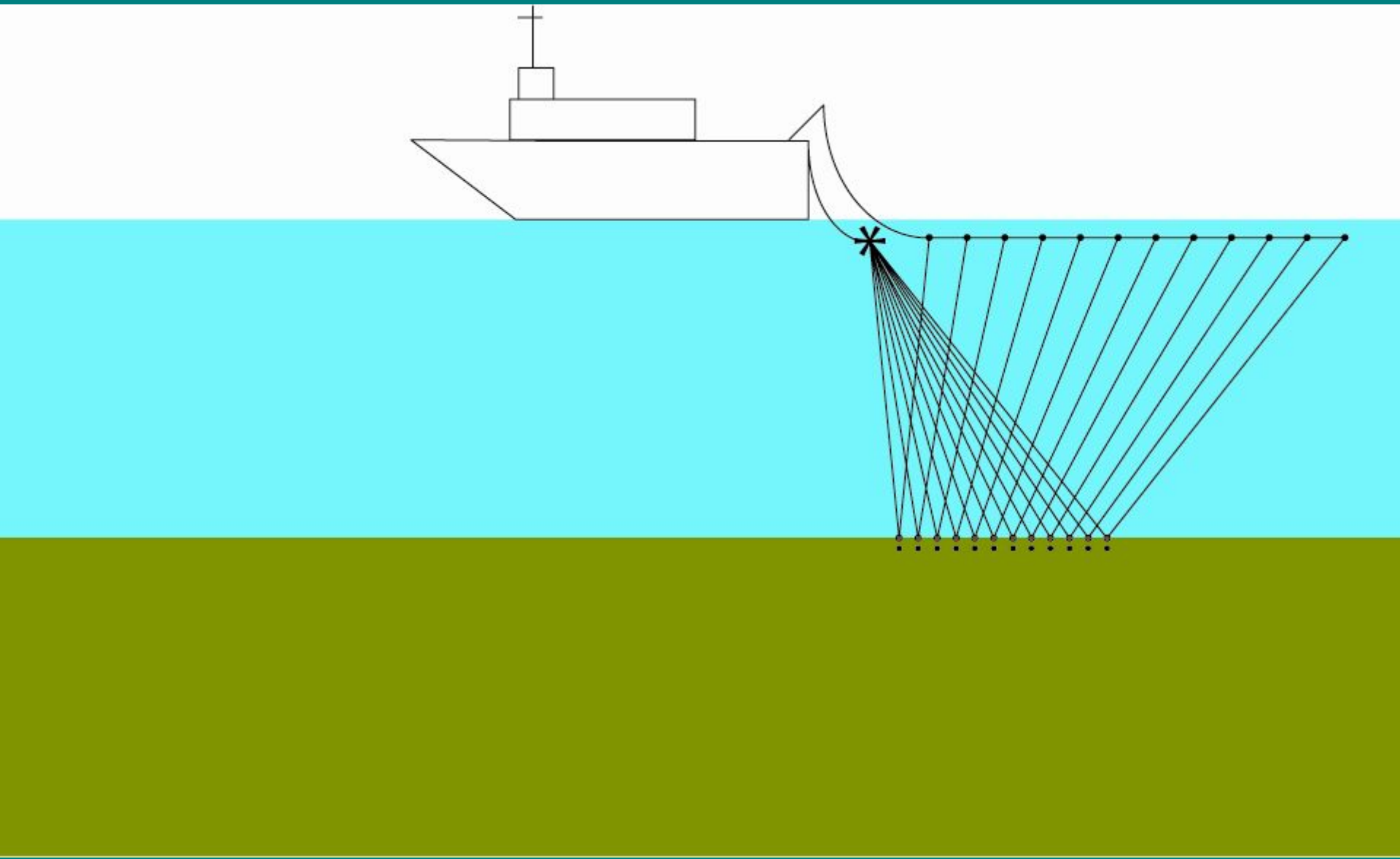
CMP gather: A collection of traces that have been recorded at the same location.

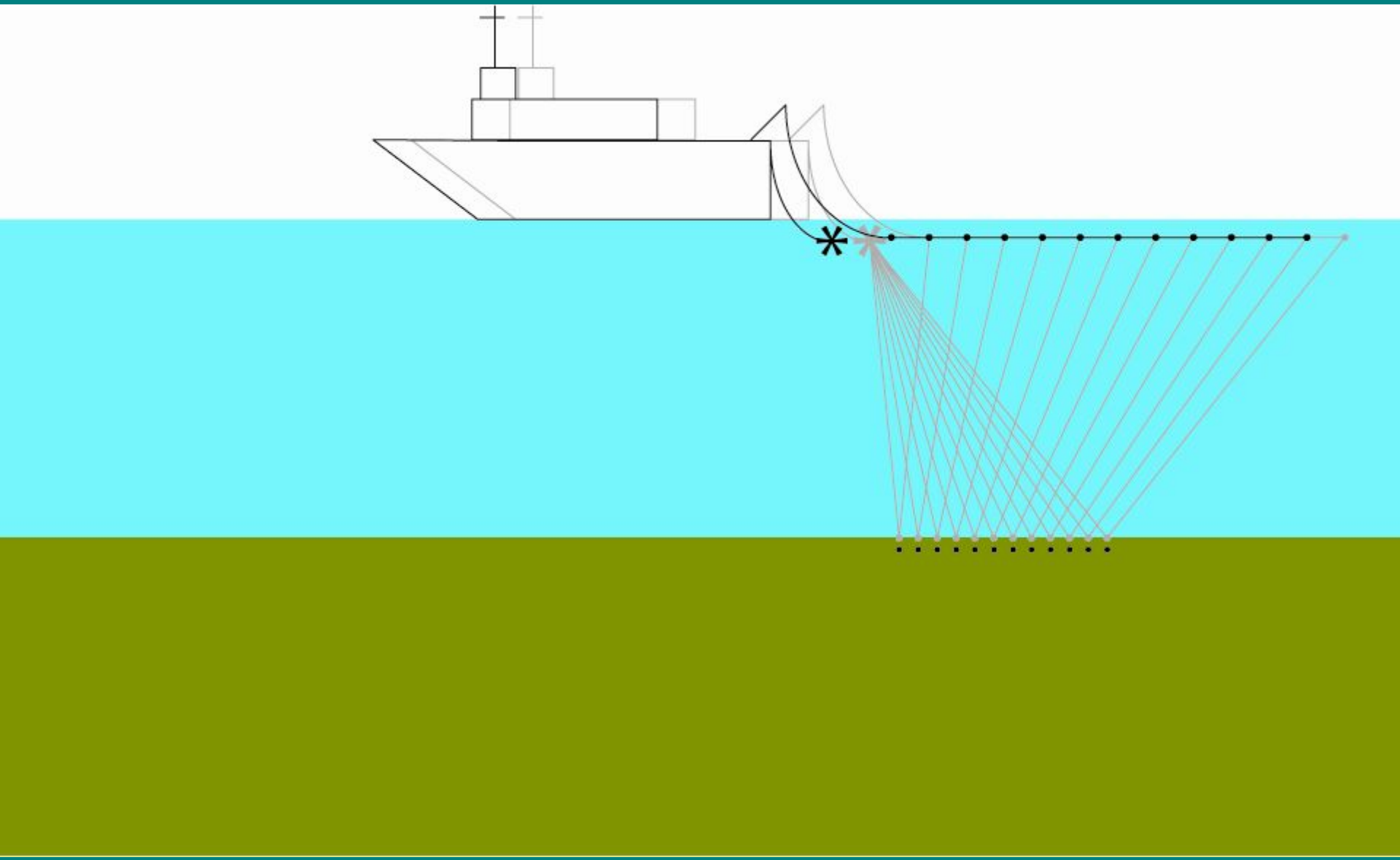


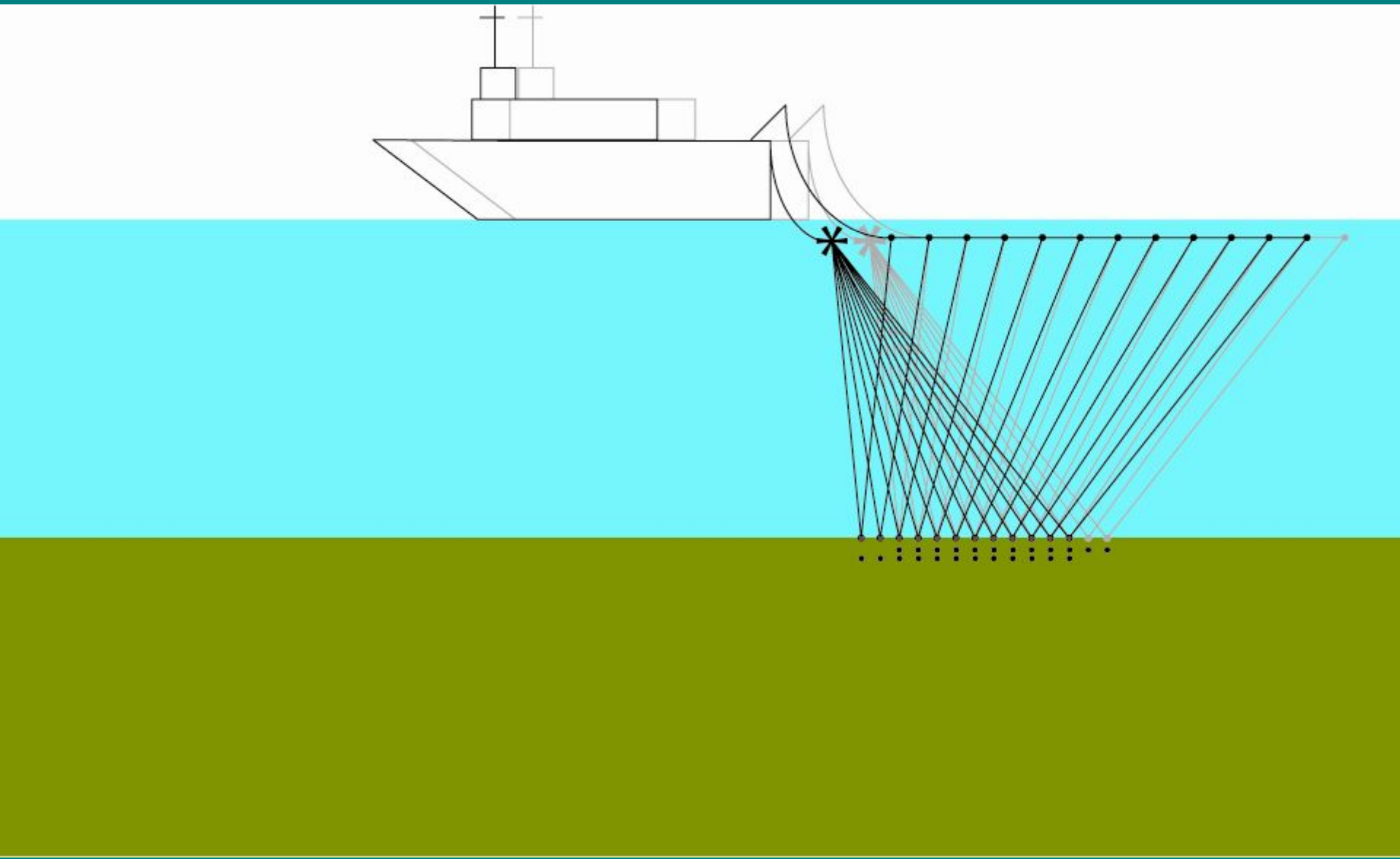
Shot and CMP gathers are simply different ways of sorting the data.

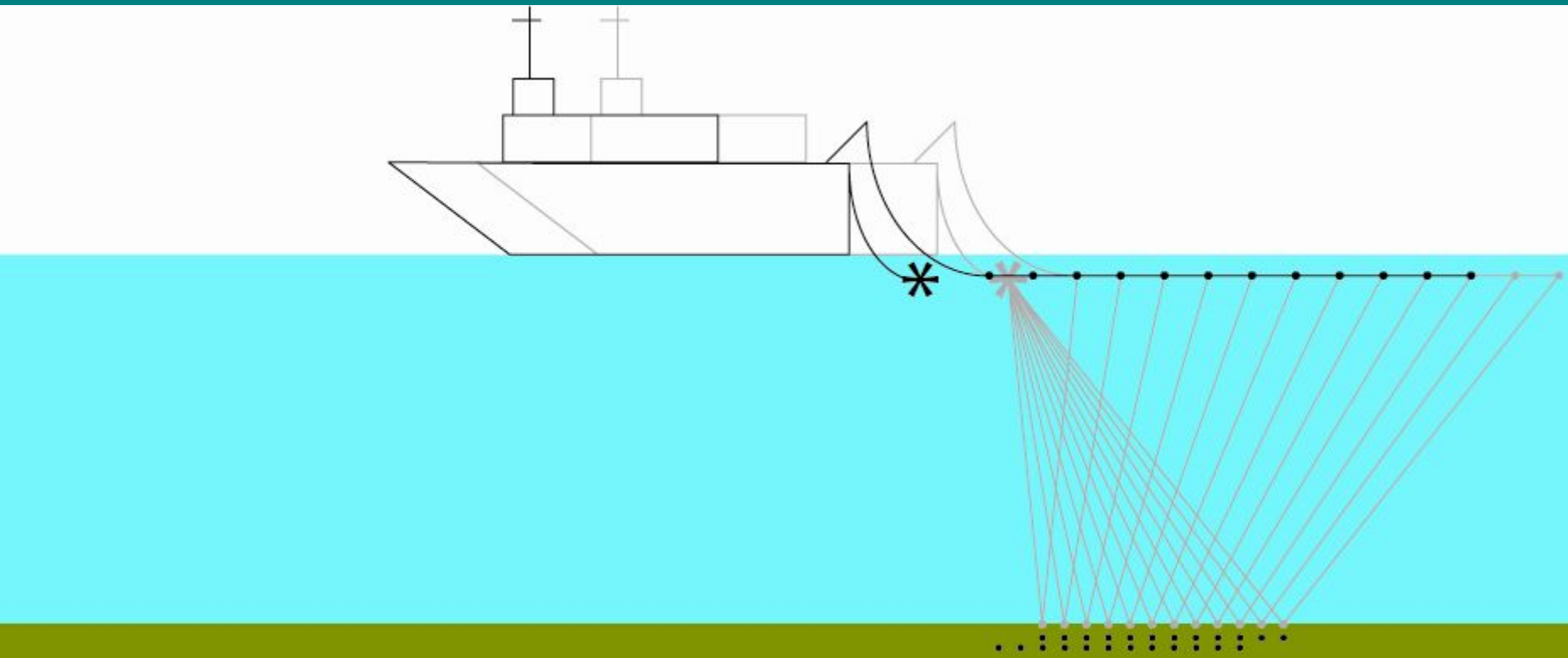
What is the natural CMP spacing relative to the group interval?

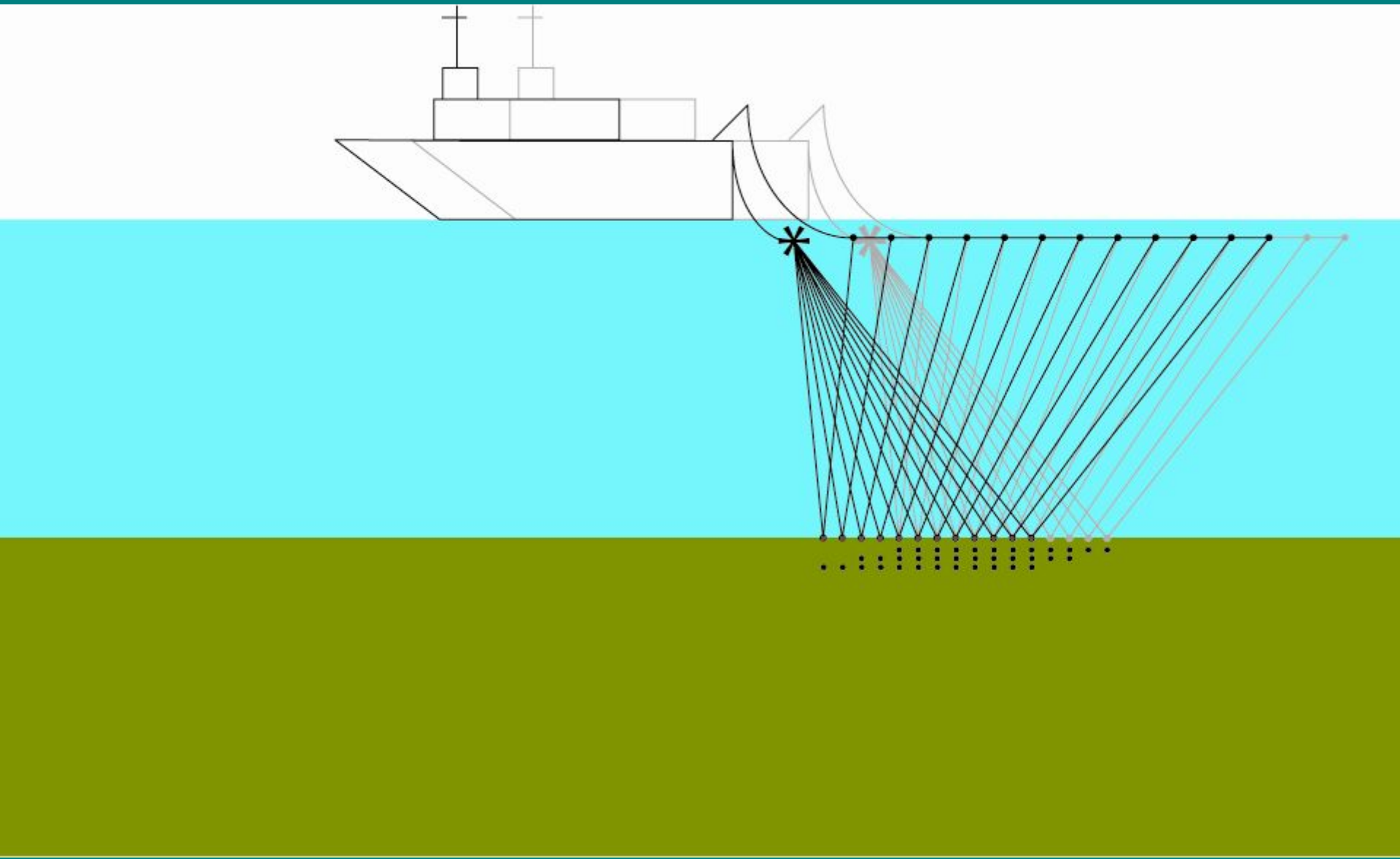


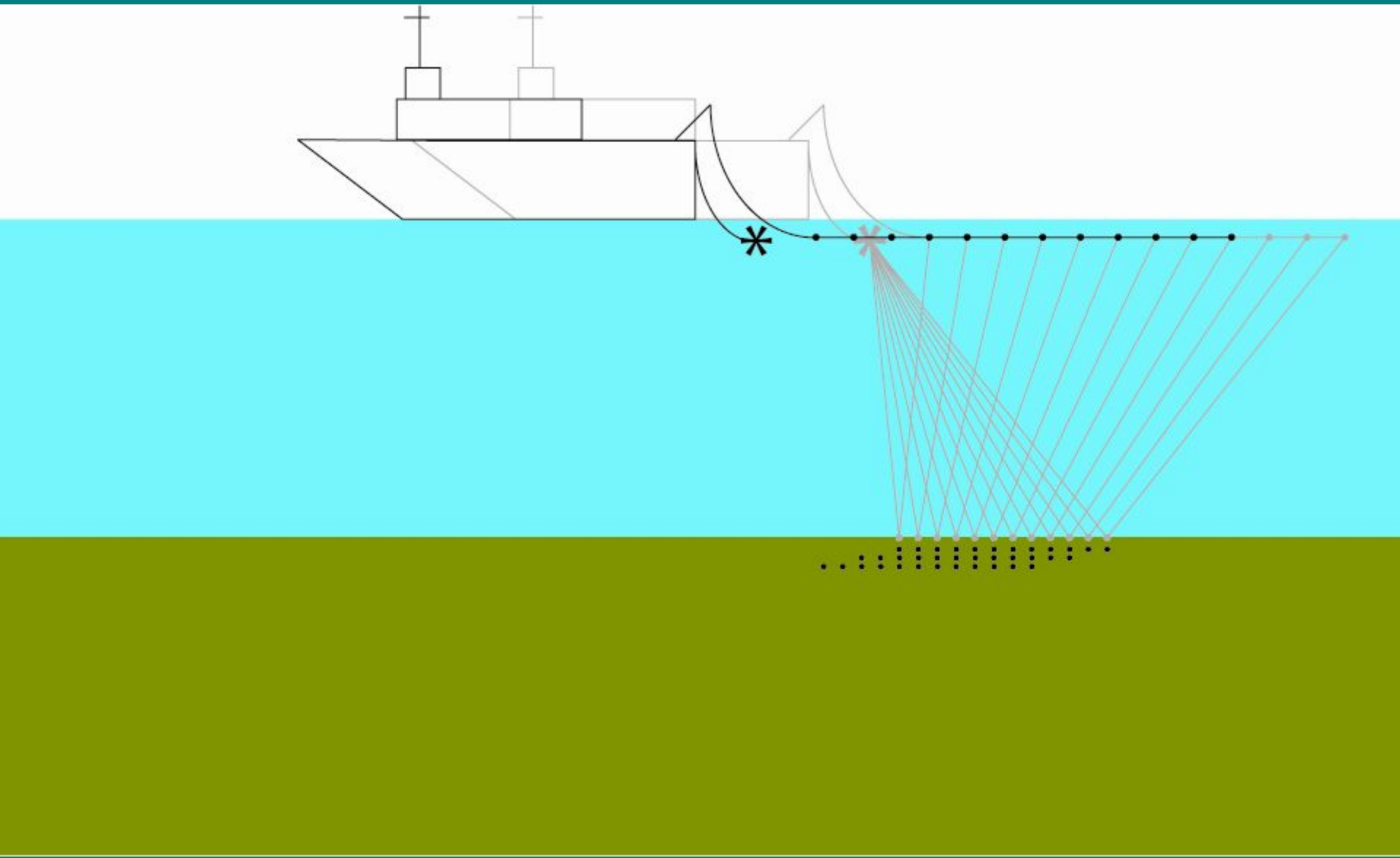


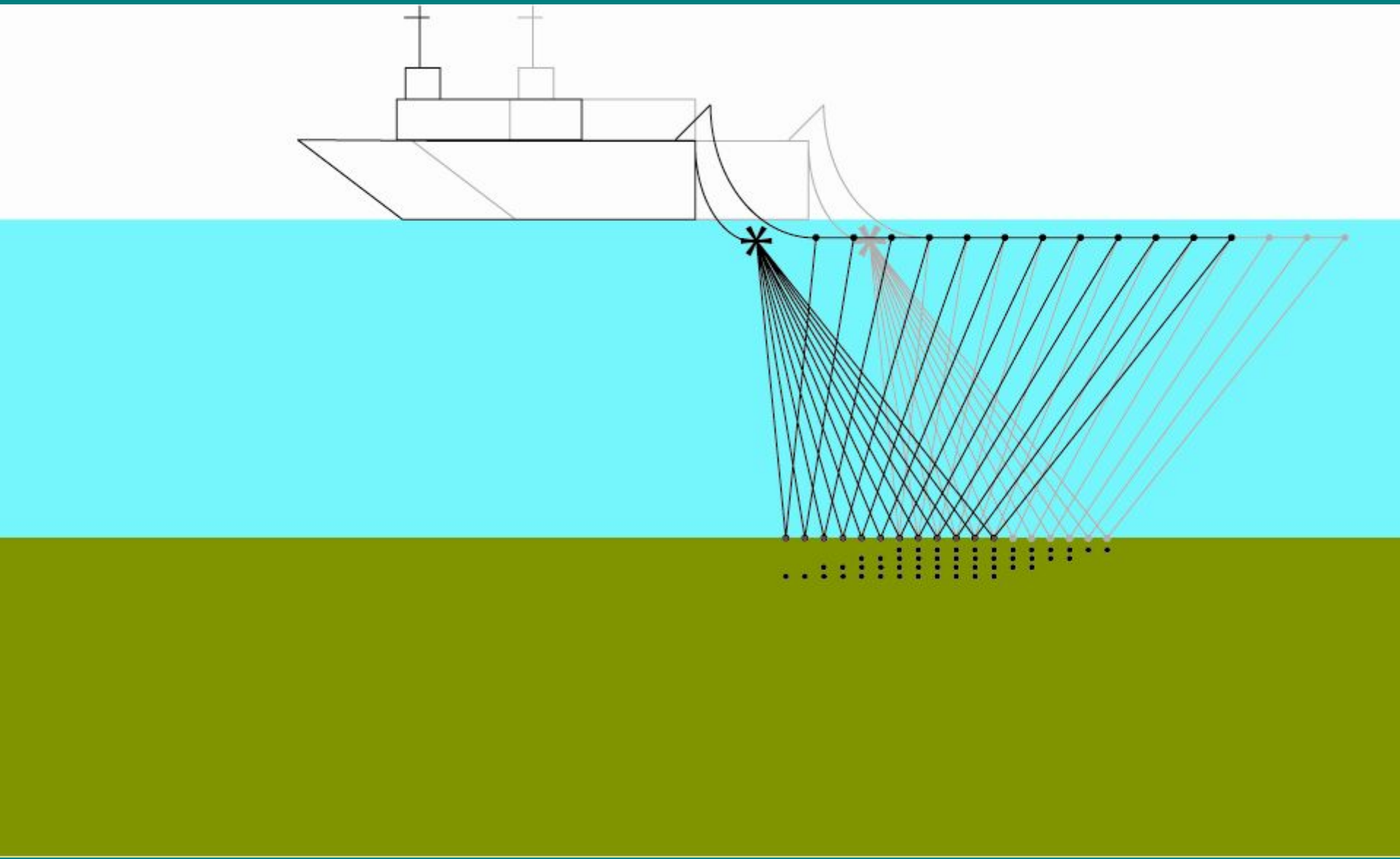


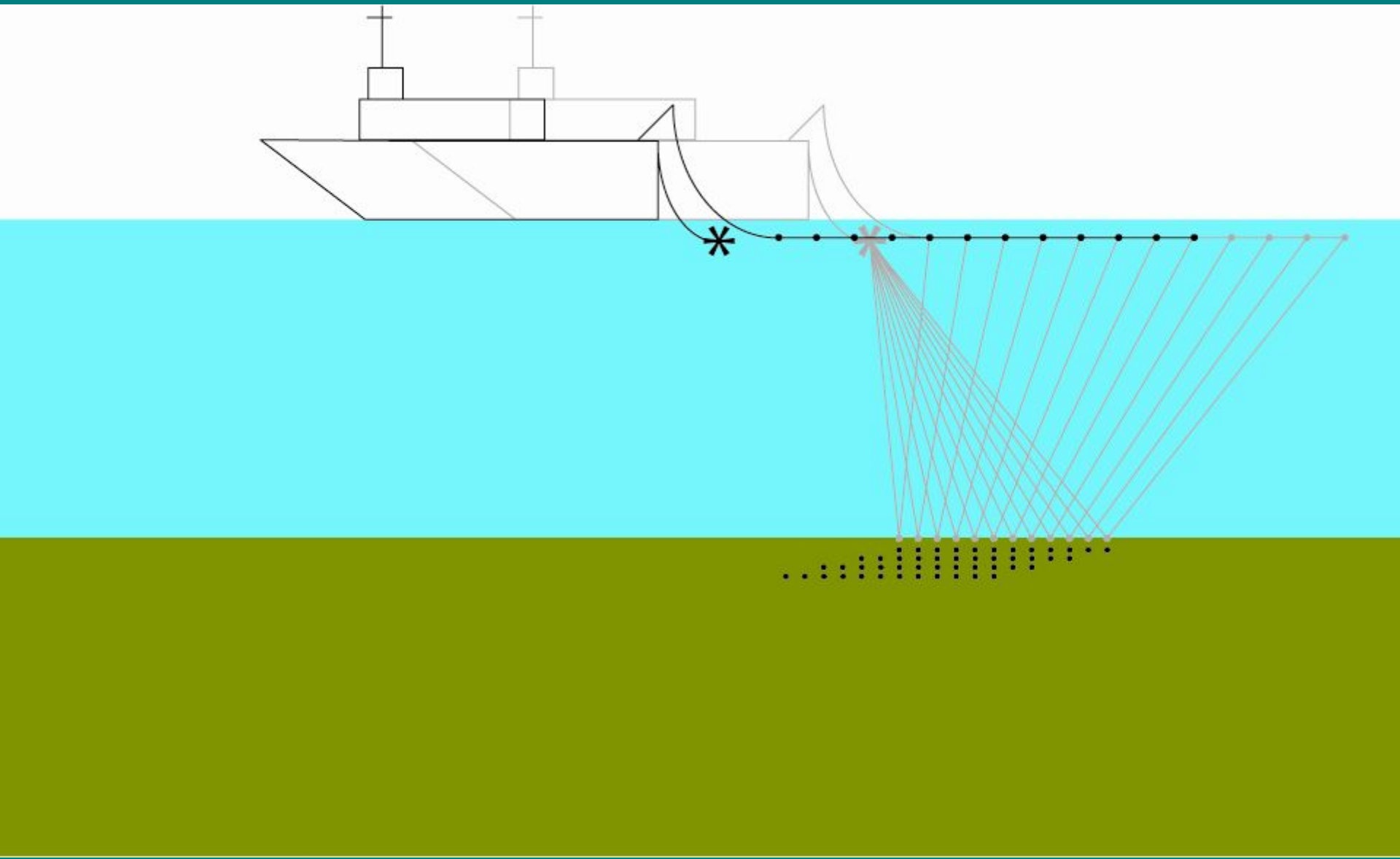


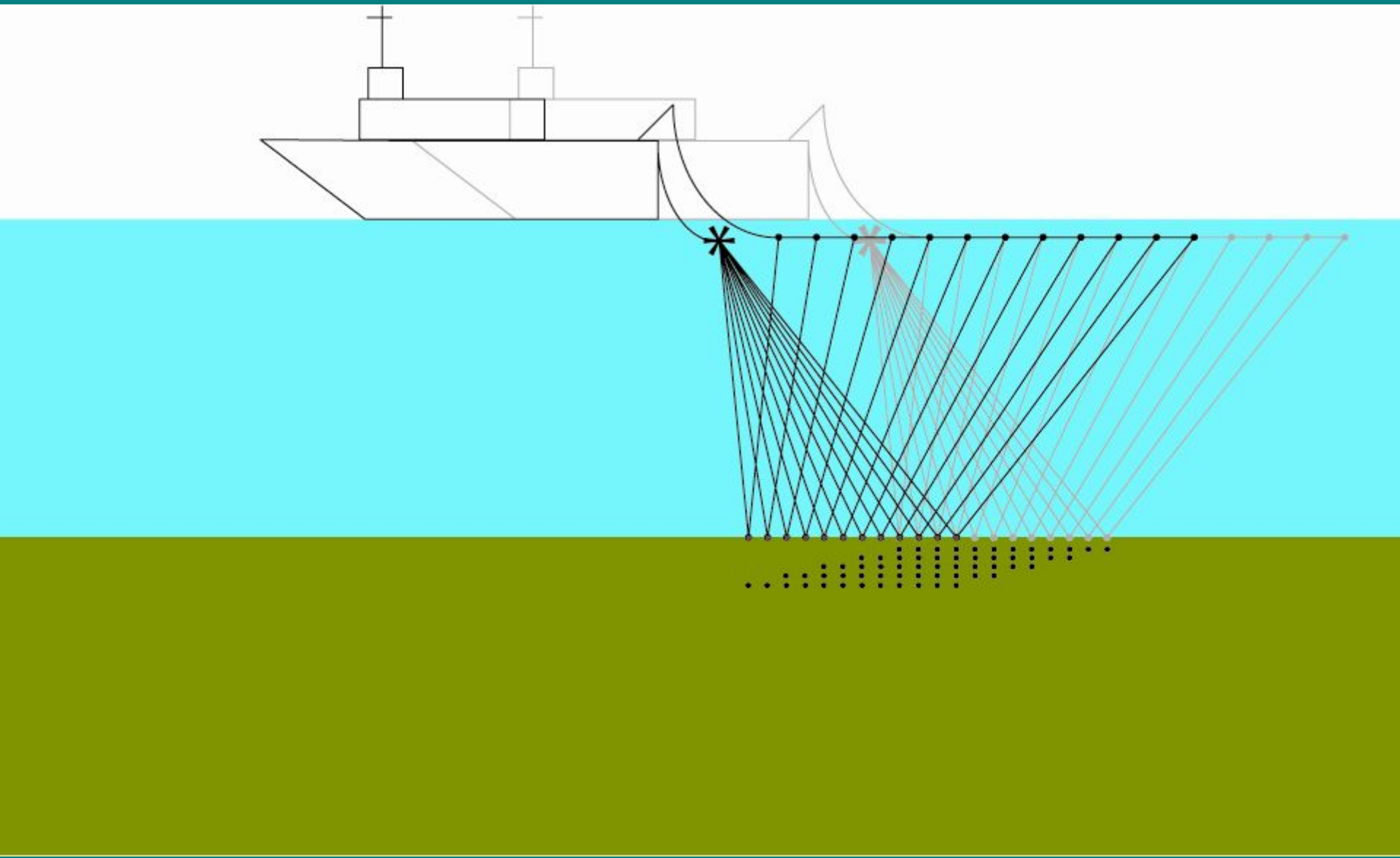


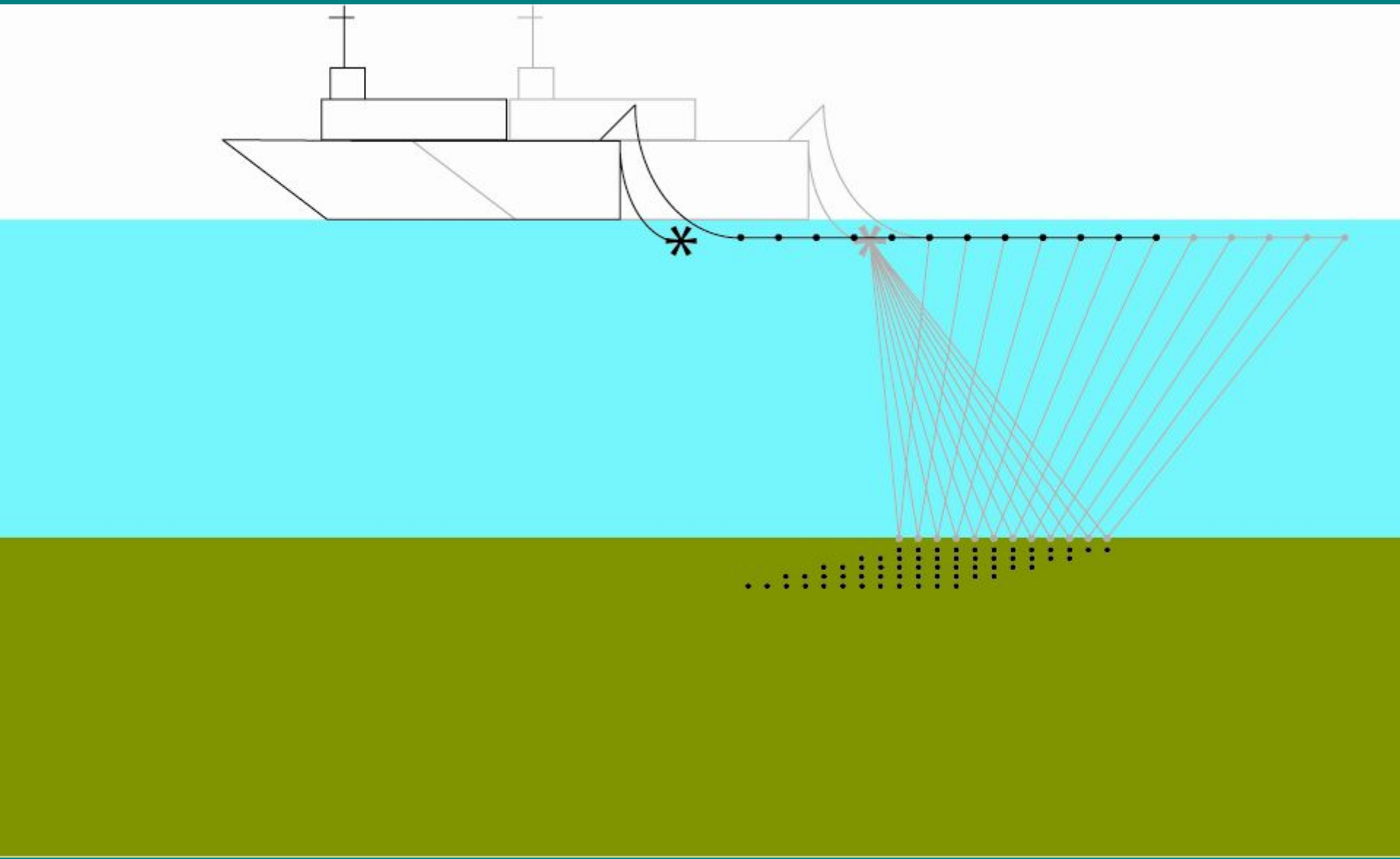


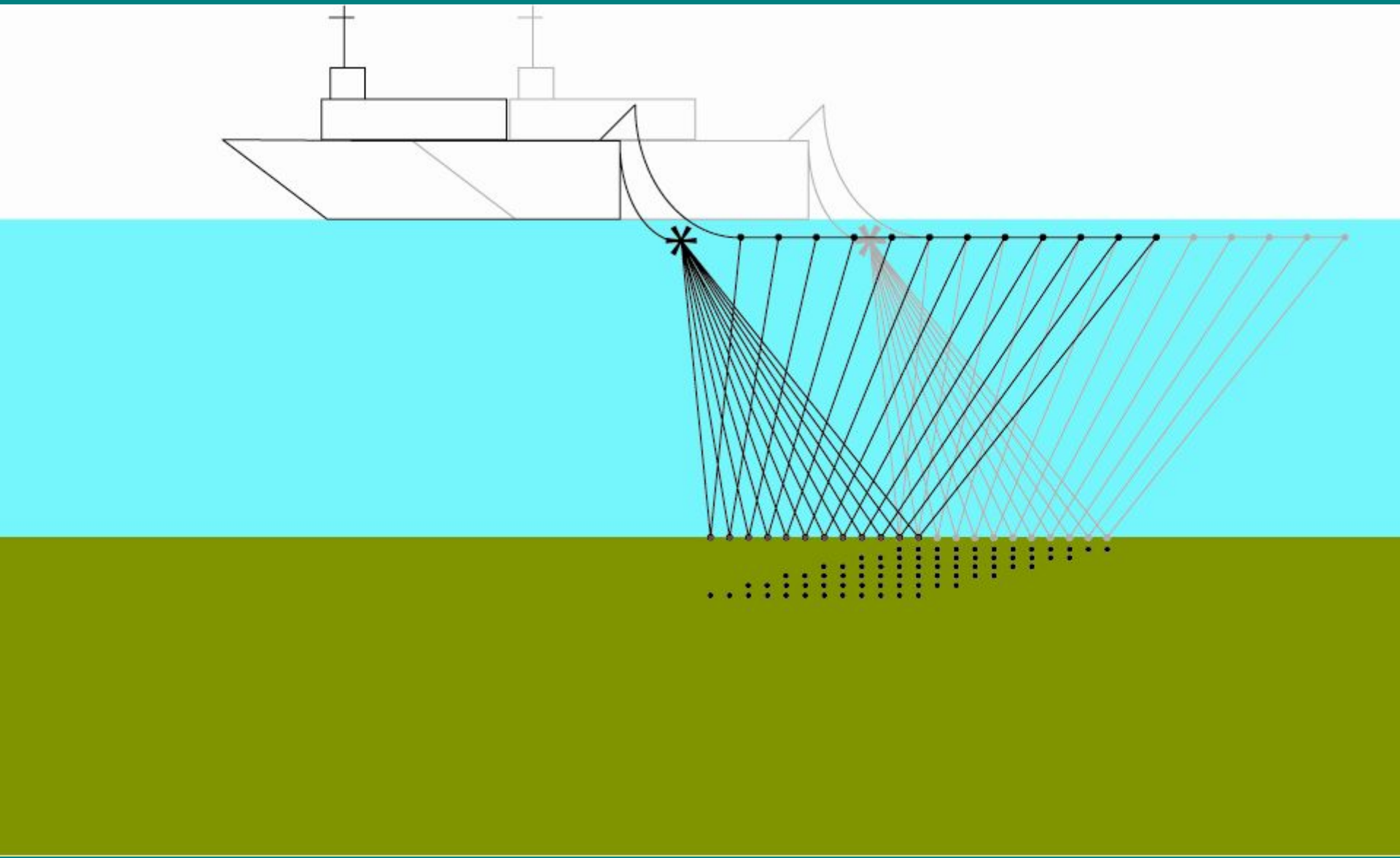


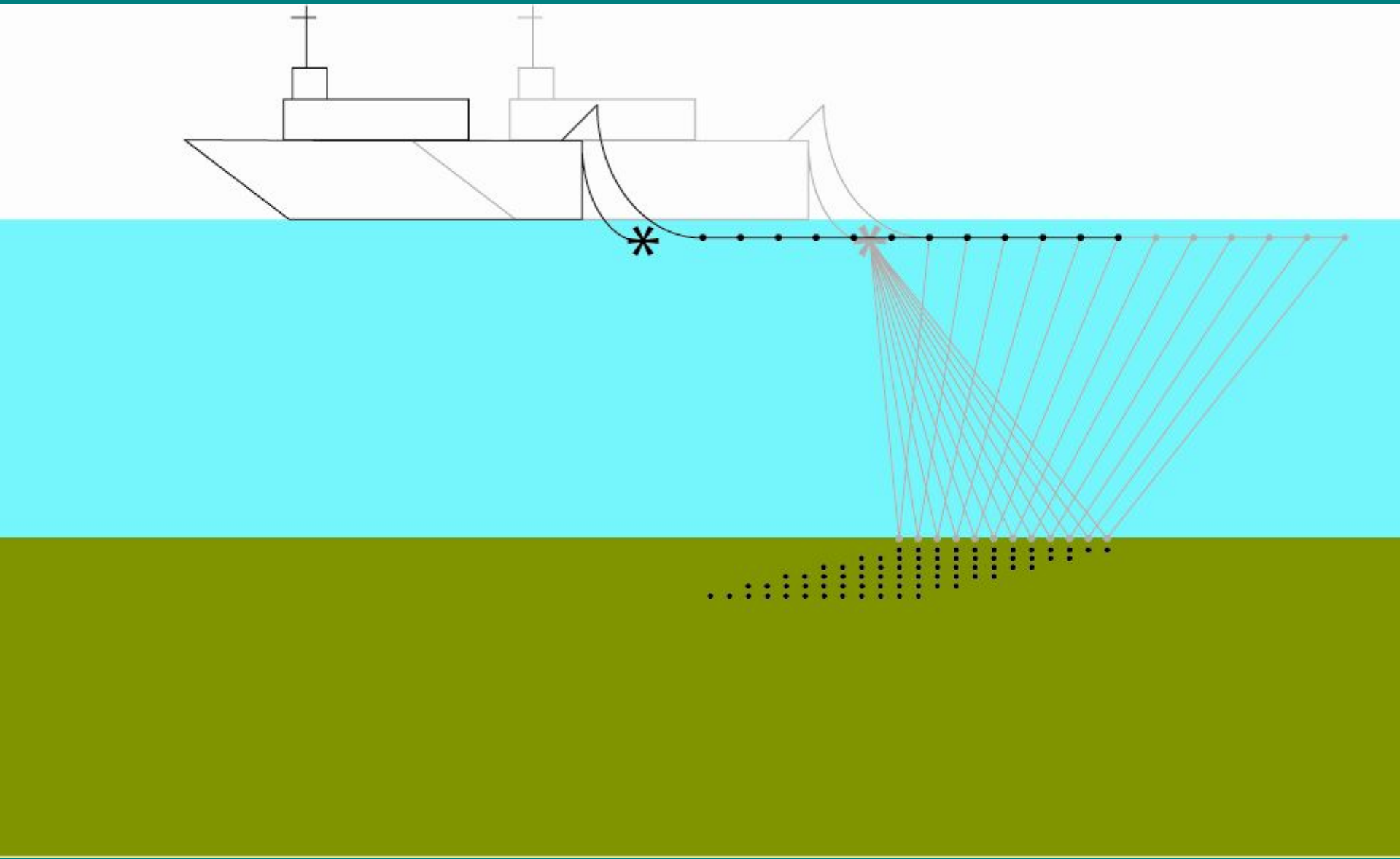


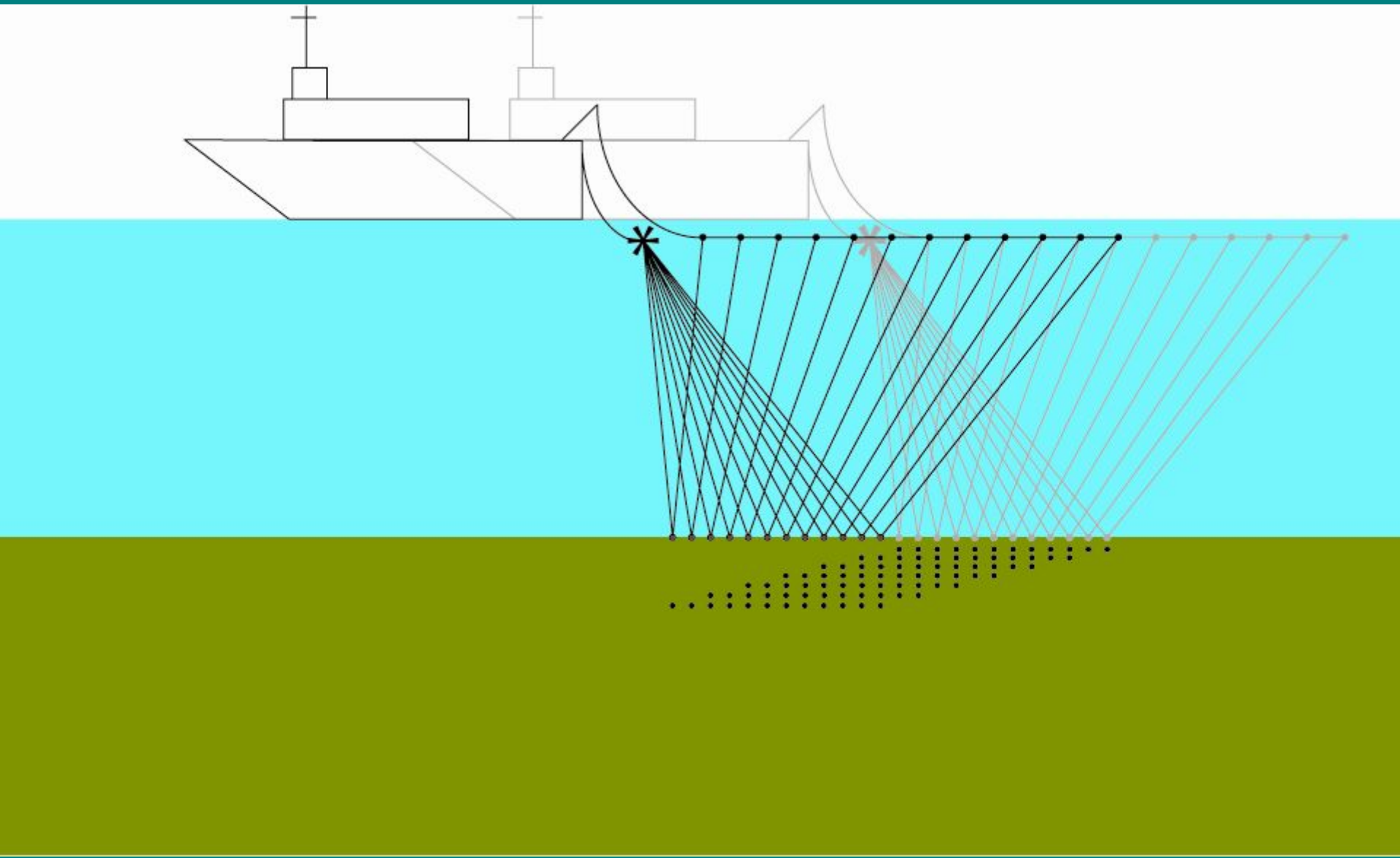


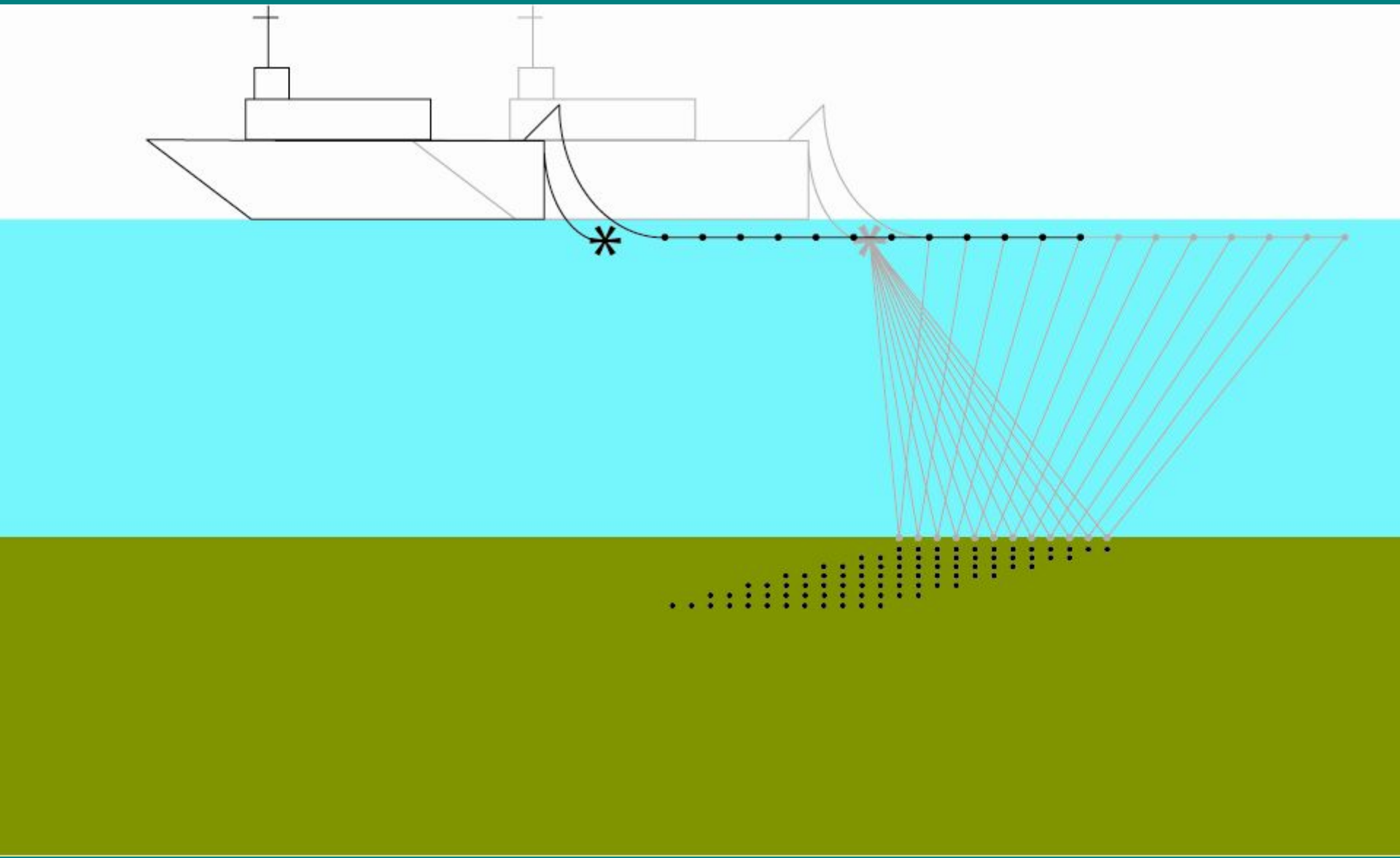


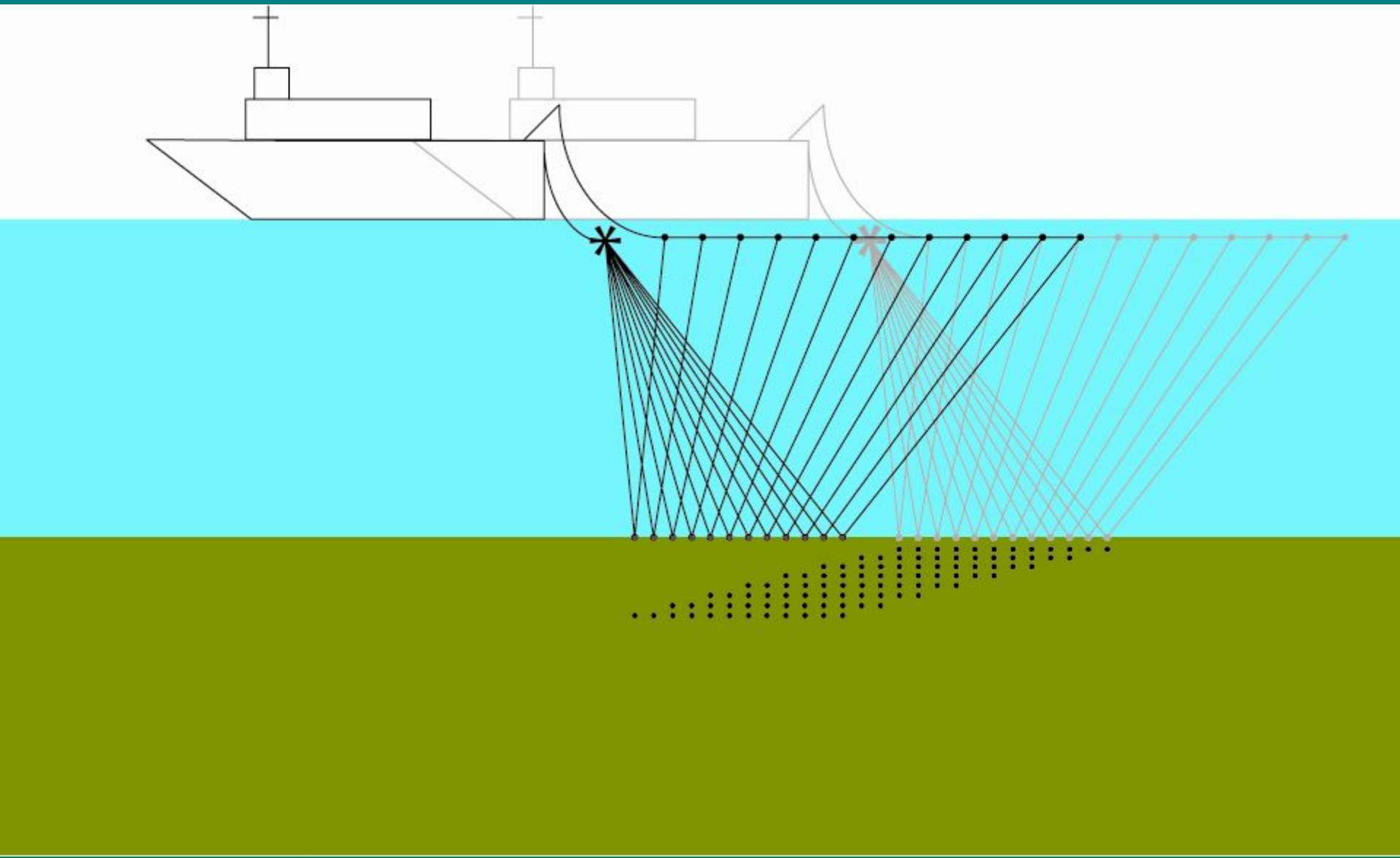


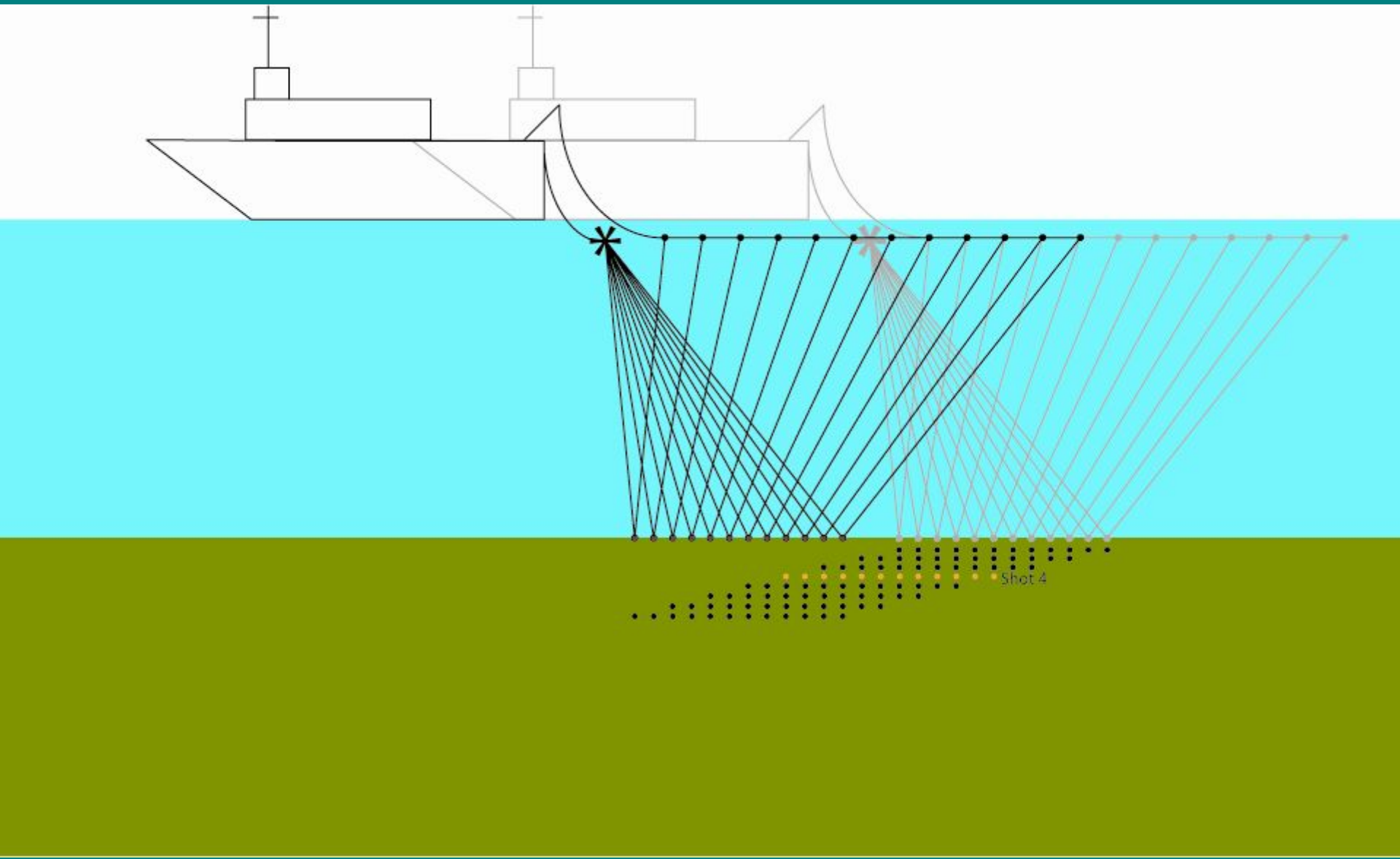


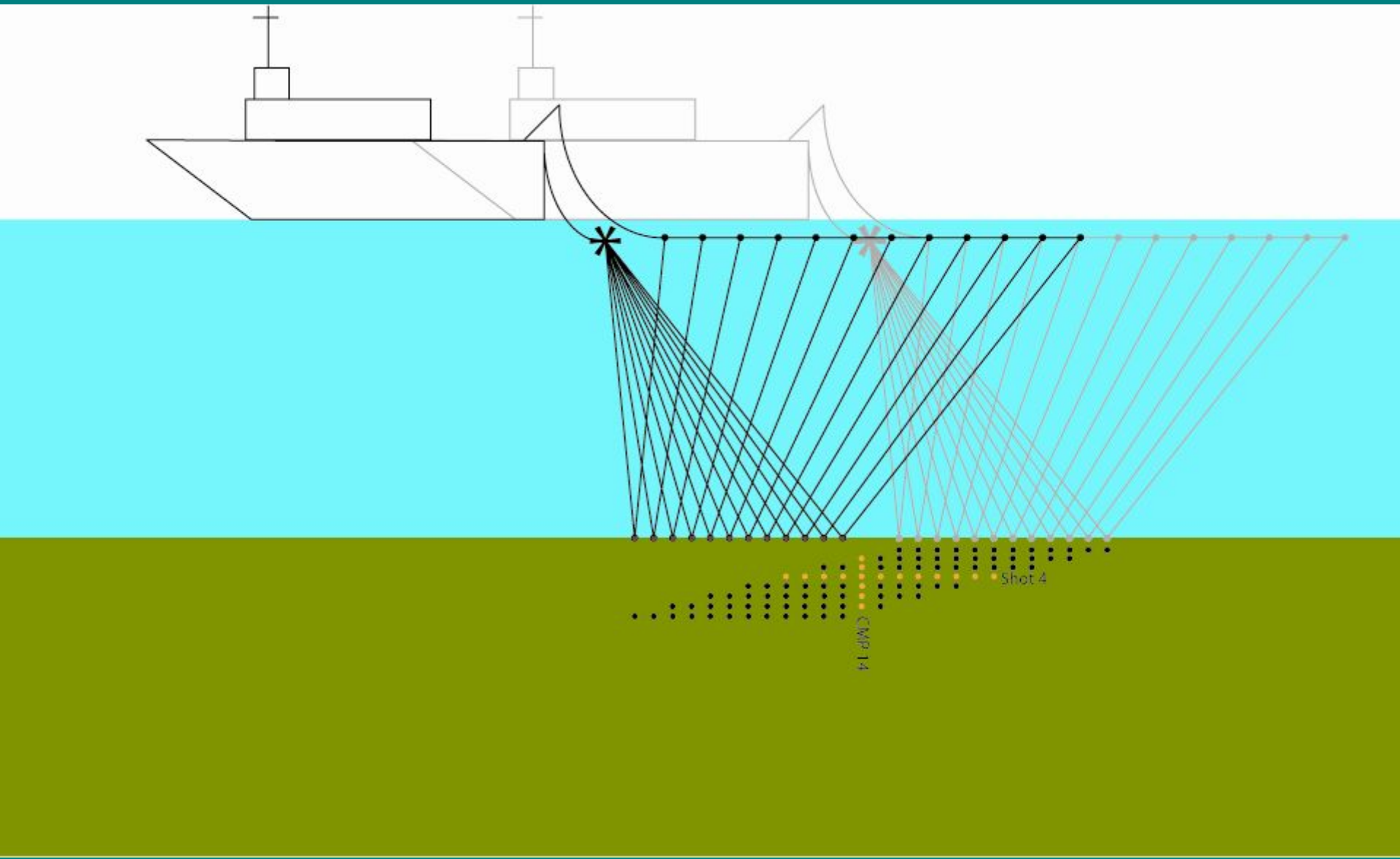


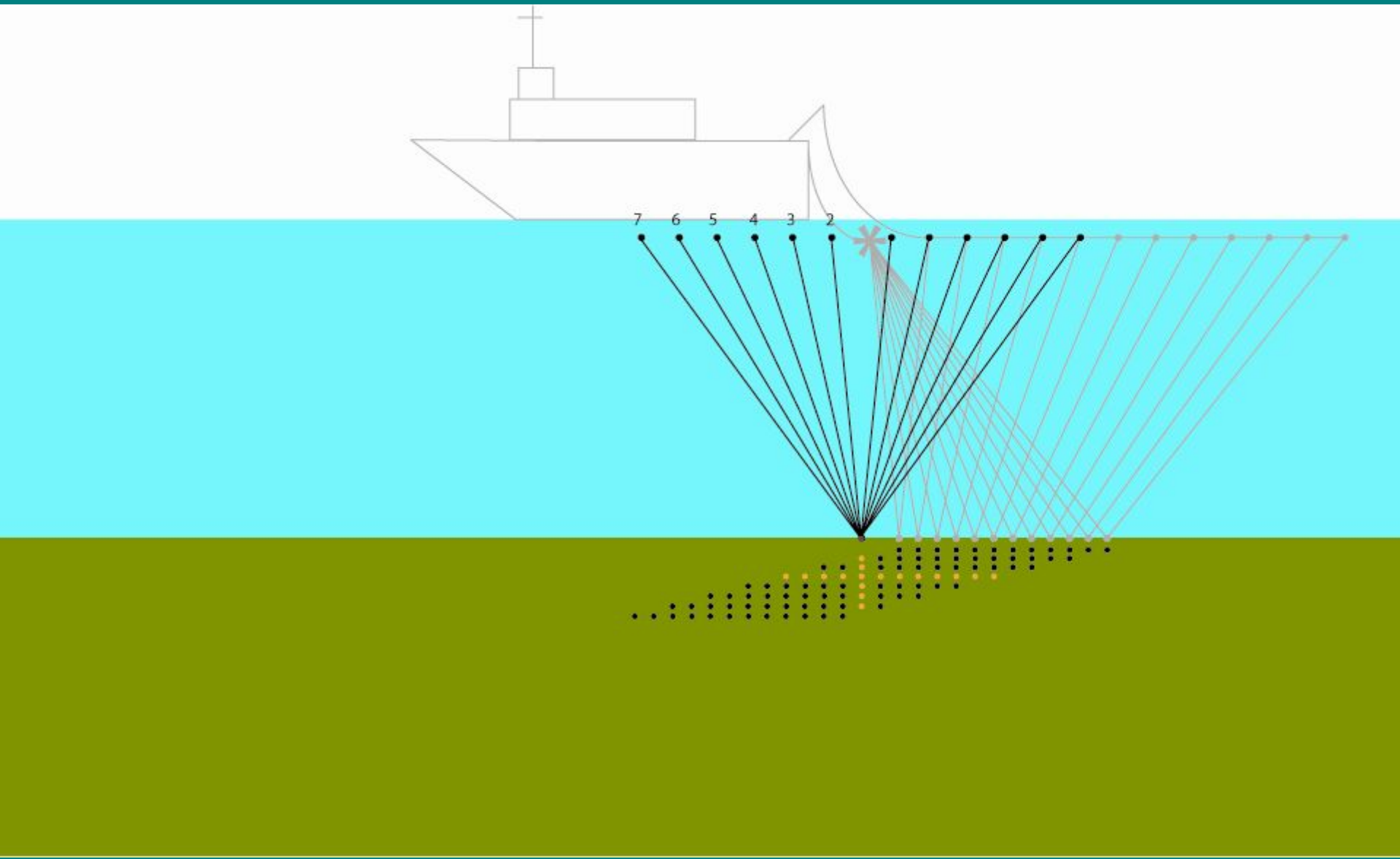







Shot 4


Shot 4
CMP 14

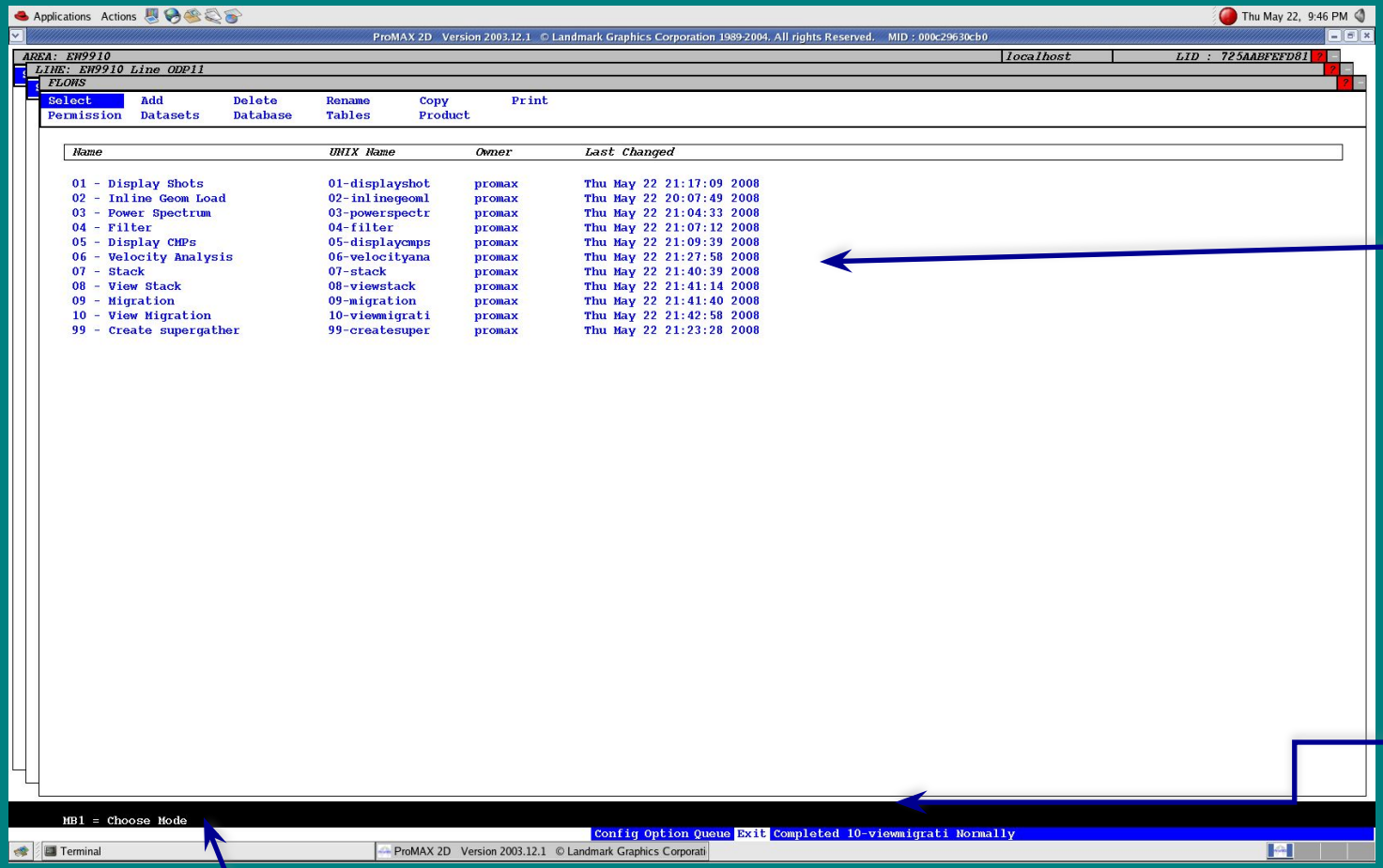

7
6
5
4
3
2

Starting ProMAX

- Type Promax on the command line
- *Select the survey*
- *Select the line that includes your name*

Anatomy of ProMAX

Click on the *EW9910* area, then *EW9910 Line ODP11*



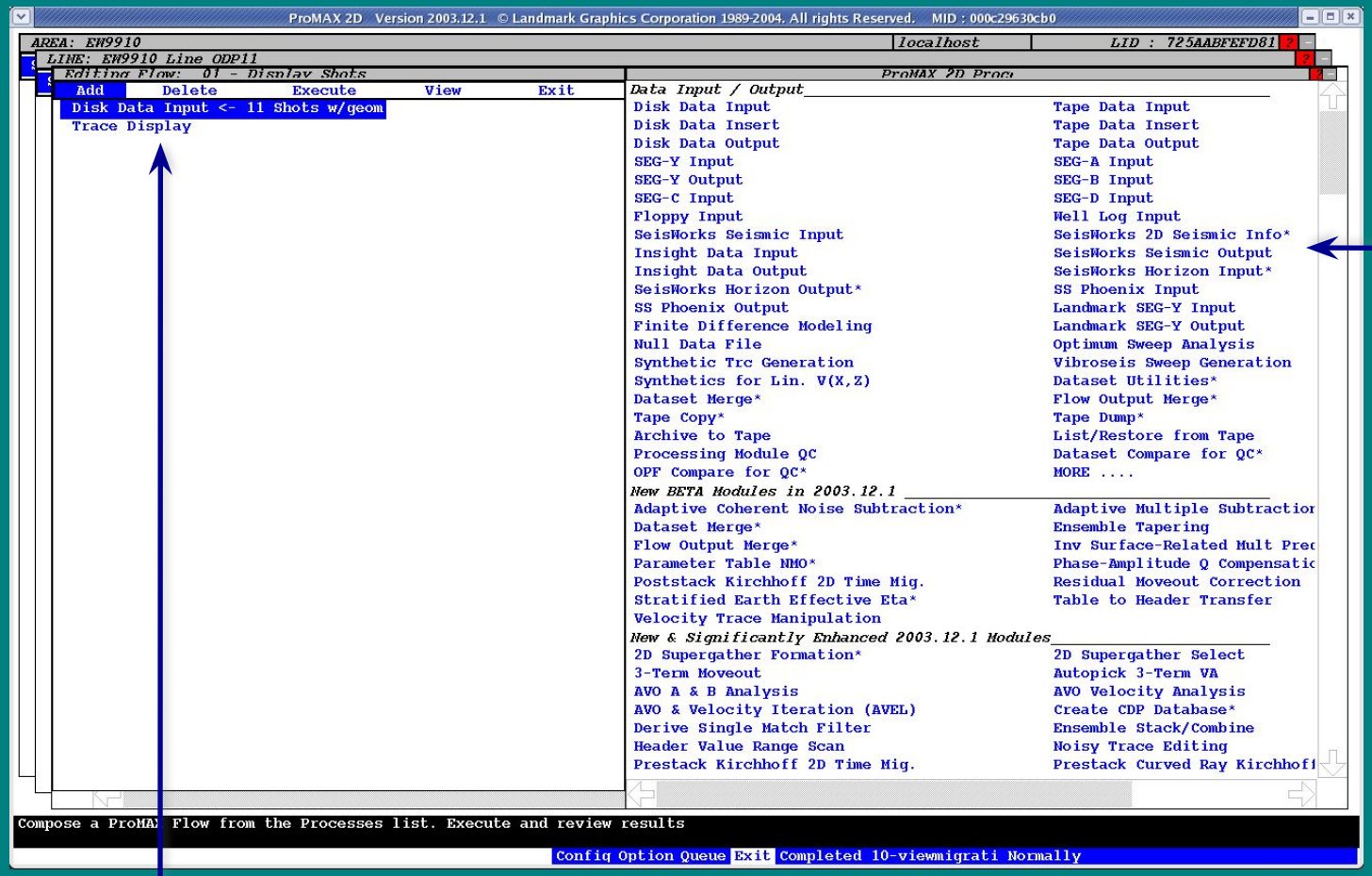
List of flows – operations that we will apply to the data

Status of any jobs that are running

This area tells you what each of your mouse buttons will do – ProMAX uses three mouse buttons

Anatomy of ProMAX

Click on 01 – Display Shots

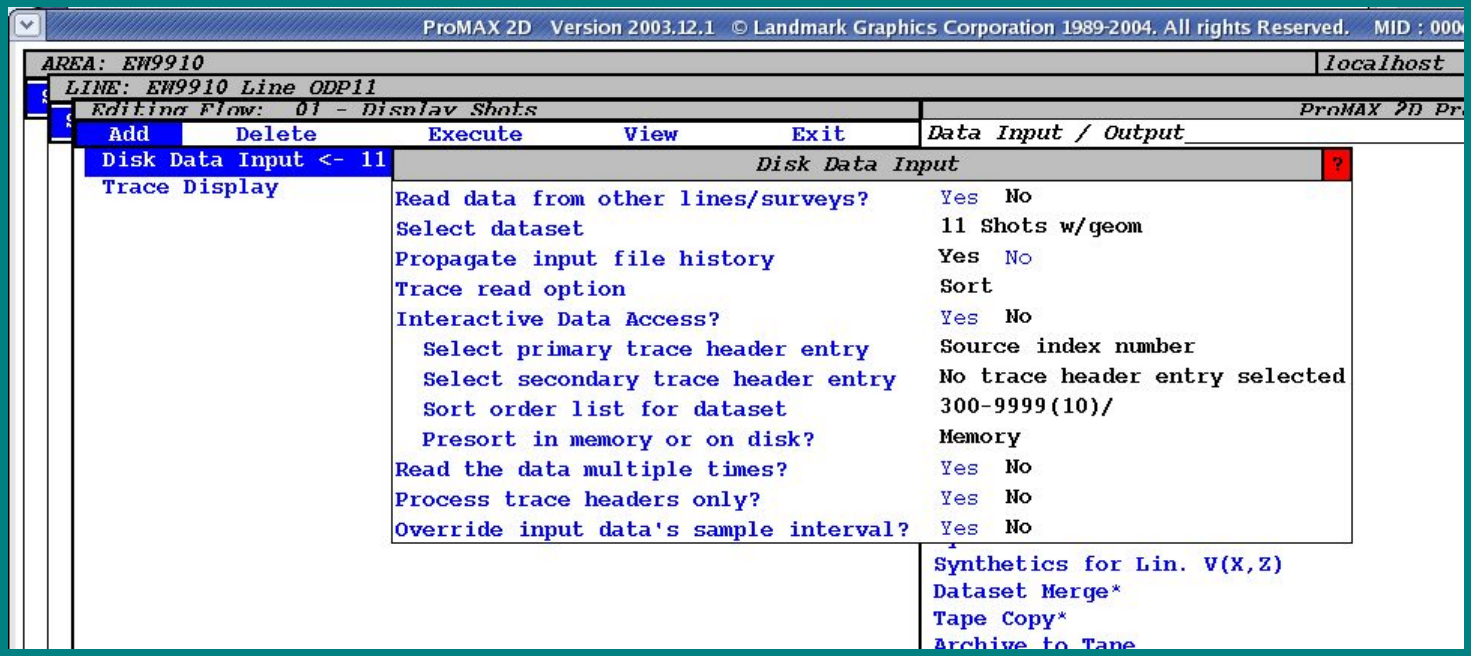


This flow reads in the seismic data and displays it

List of individual processes – things we can do to the data. Flows are built up of a sequence of processes. Click on one and it will appear in the left-hand window. Delete and processes accidentally added by clicking on delete in the left-hand window

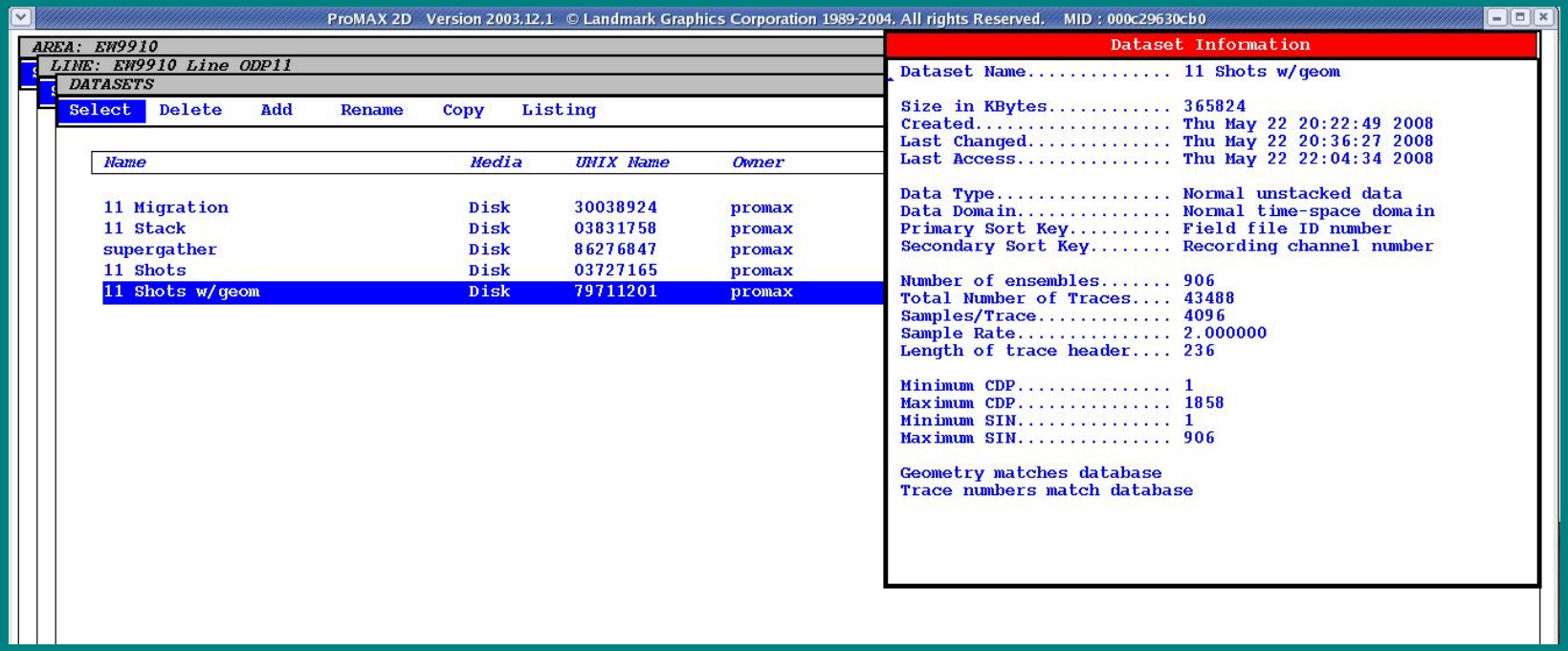
Anatomy of ProMAX

Click on Disk Data Input with the middle mouse button. This will parameterize the process. Here we see that we are reading in *11 Shots w/geom* (raw shot file with navigation added to the headers), sorting the data by *Source index number* (shot number), reading in every 10th shot from shot 300 to the end of the file



Anatomy of ProMAX

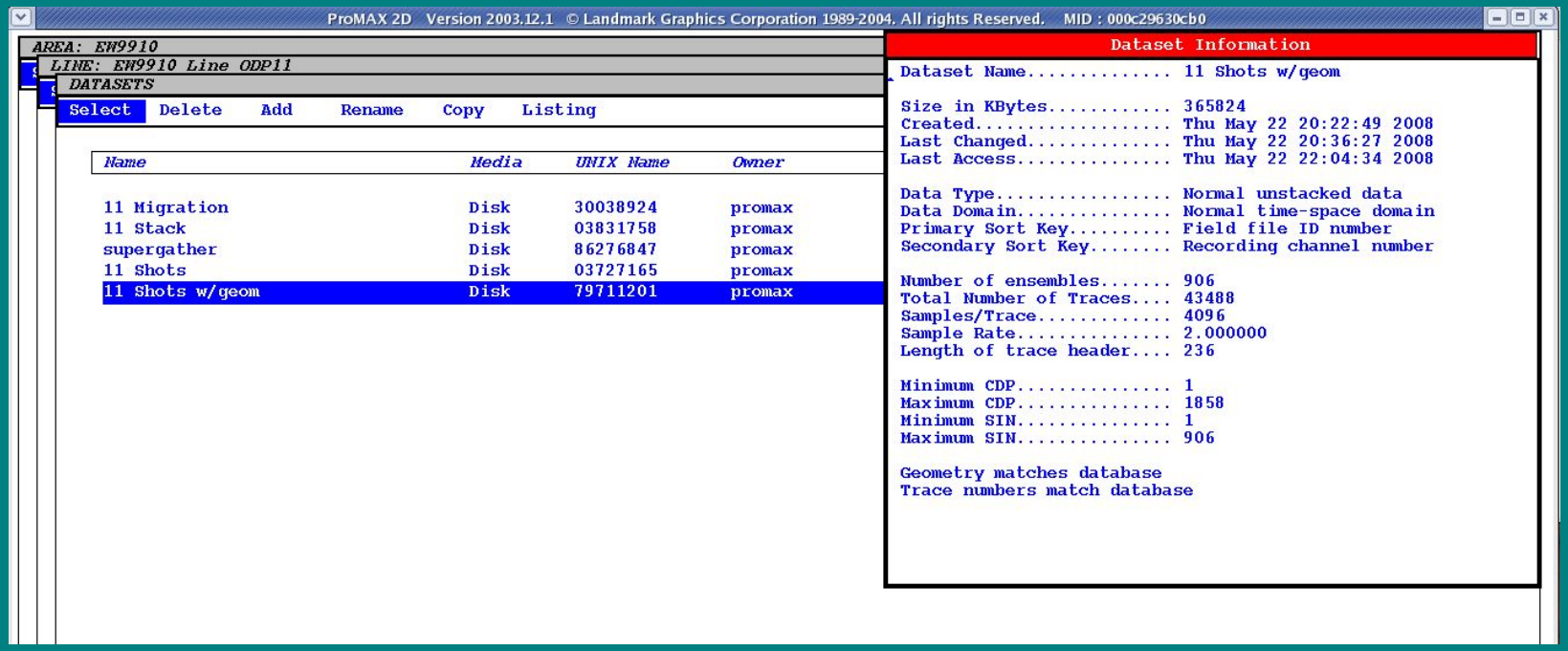
Clicking on the data file *11 Shots w/geom* with the left-hand mouse button (LHMB) will take you to a list of data files. Click on *11 Shots w/geom* with the middle mouse. The details of the data file are now displayed



We can now see how many traces there are in the file, the sample rate (in milliseconds), how many samples there are per-trace, the minimum and maximum CDP, and the minimum and maximum shot (*SIN*). Moving your cursor to the top of the screen will take you back to the flow

Anatomy of ProMAX

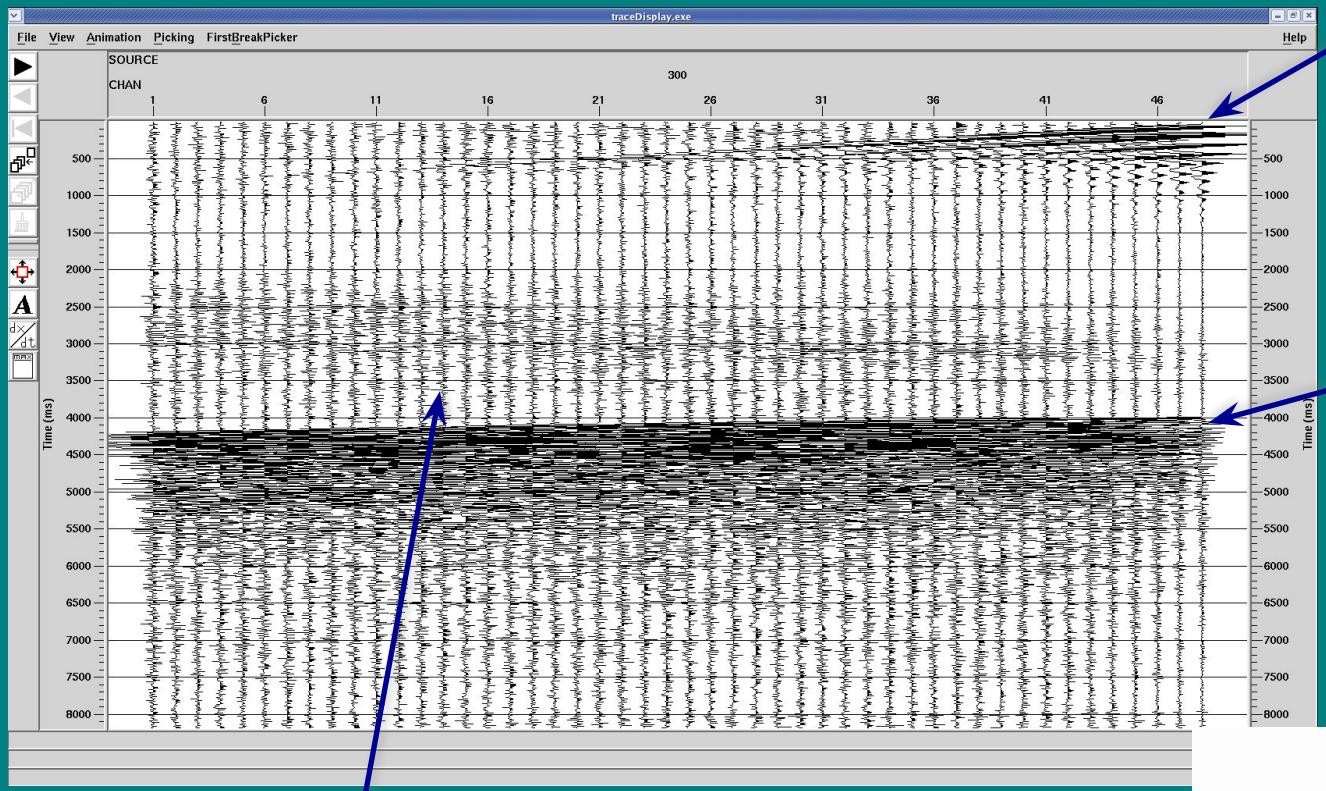
Clicking on the data file *11 Shots w/geom* with the left-hand mouse button (LHMB) will take you to a list of data files. Click on *11 Shots w/geom* with the middle mouse. The details of the data file are now displayed



We can now see how many traces there are in the file, the sample rate (in milliseconds), how many samples there are per-trace, the minimum and maximum CDP, and the minimum and maximum shot (*SIN*). Moving your cursor to the top of the screen will take you back to the flow

Displaying a Shot

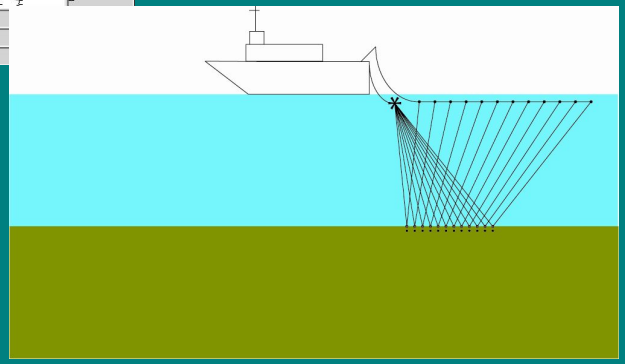
Clicking on Execute with the LHMB



Direct ray path – sound travels directly from the airgun array to the hydrophones – forms a straight line

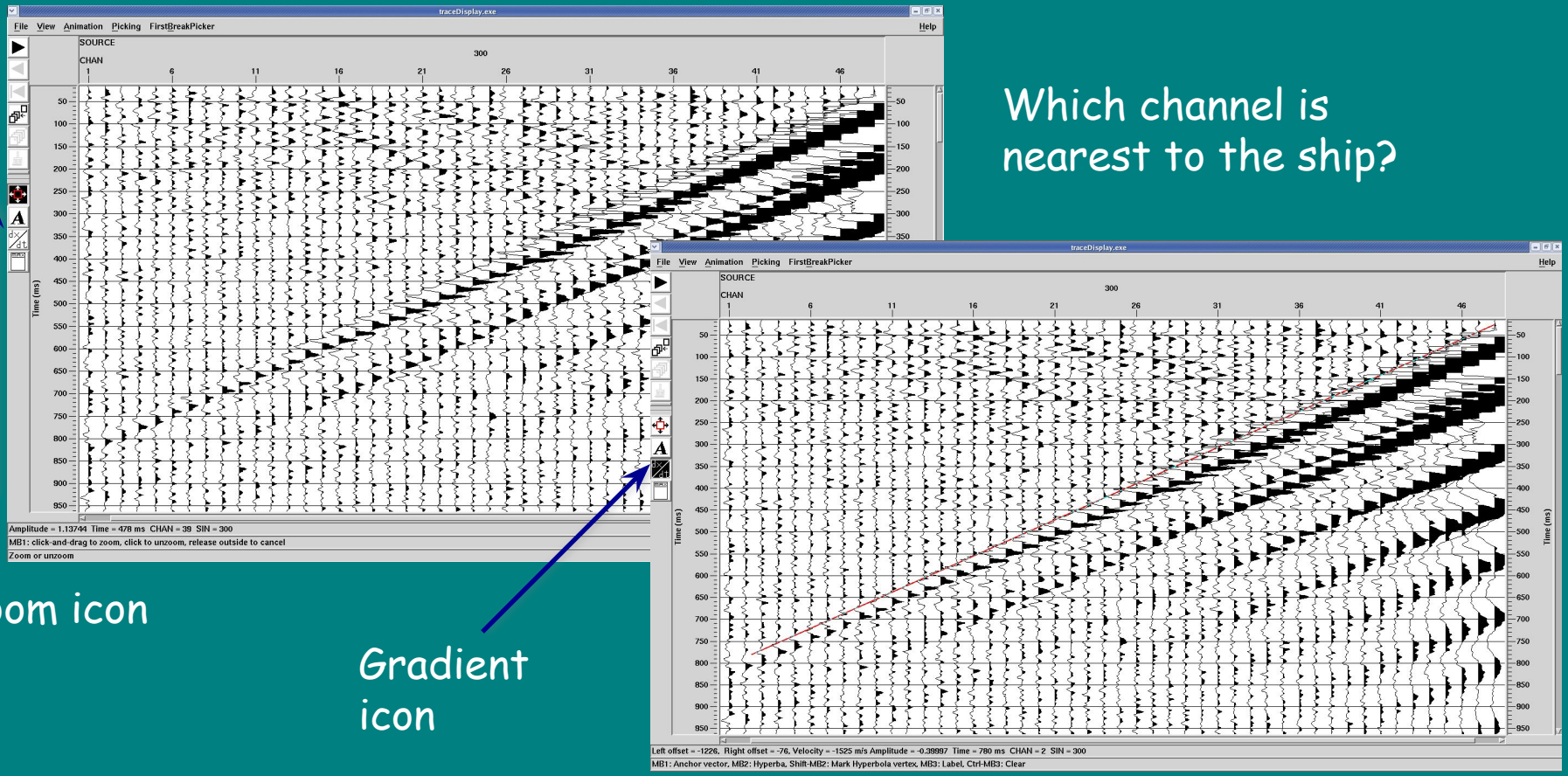
Reflected ray path – sound bounces of the seafloor and underlying layers – forms a hyperbola

Water column noise



Water Velocity

Clicking on the zoom icon. By holding down the LHMB and dragging a box, zoon into the area where we see the direct wave. The gradient of the direct wave gives us the water velocity. Click on the gradient icon. By holding down the LHMB, drag a line that follows the first arrival of the direct wave. The corresponding velocity will be displayed at the bottom of the screen



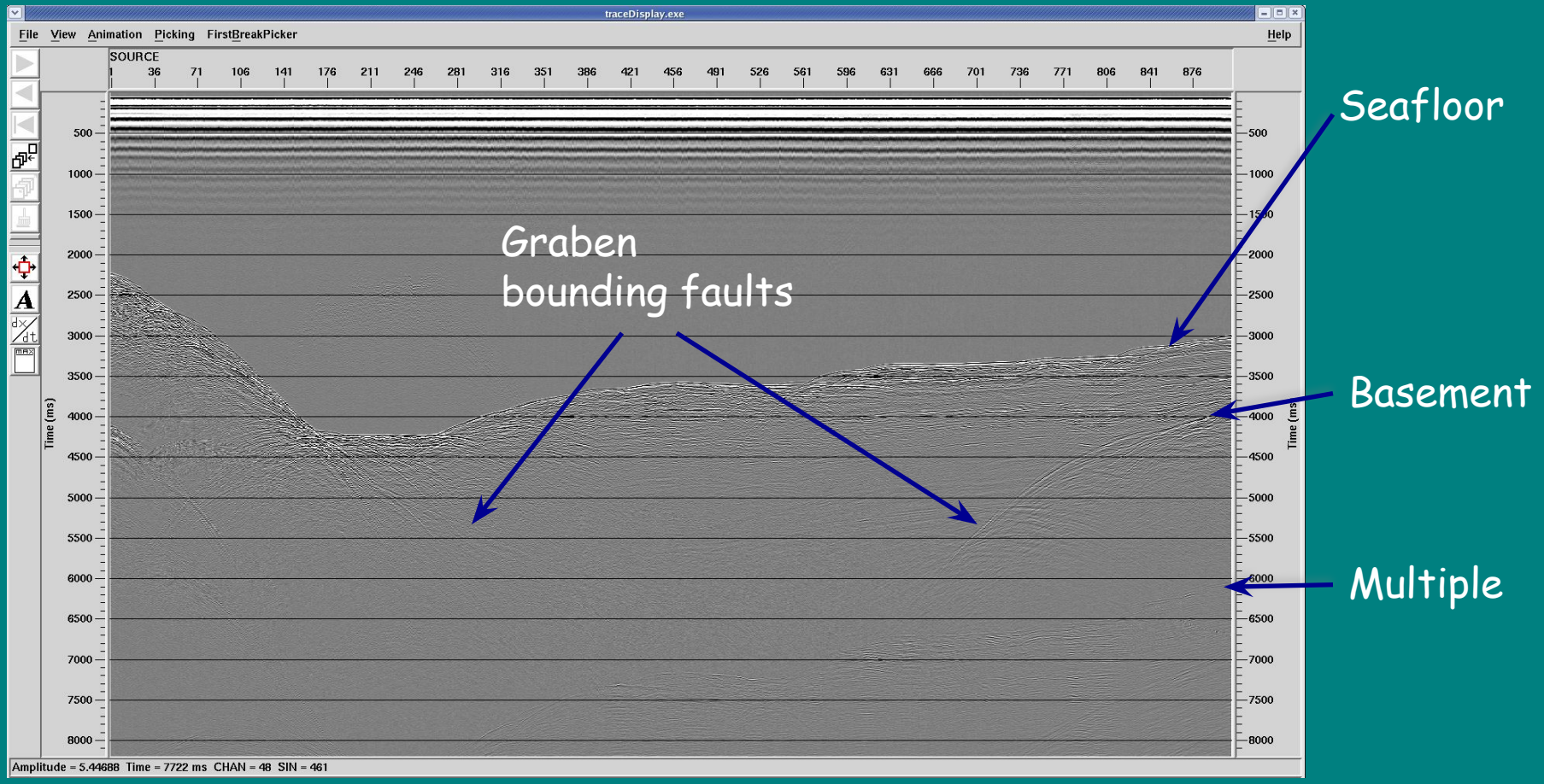
Which channel is nearest to the ship?

Zoom icon

Gradient icon

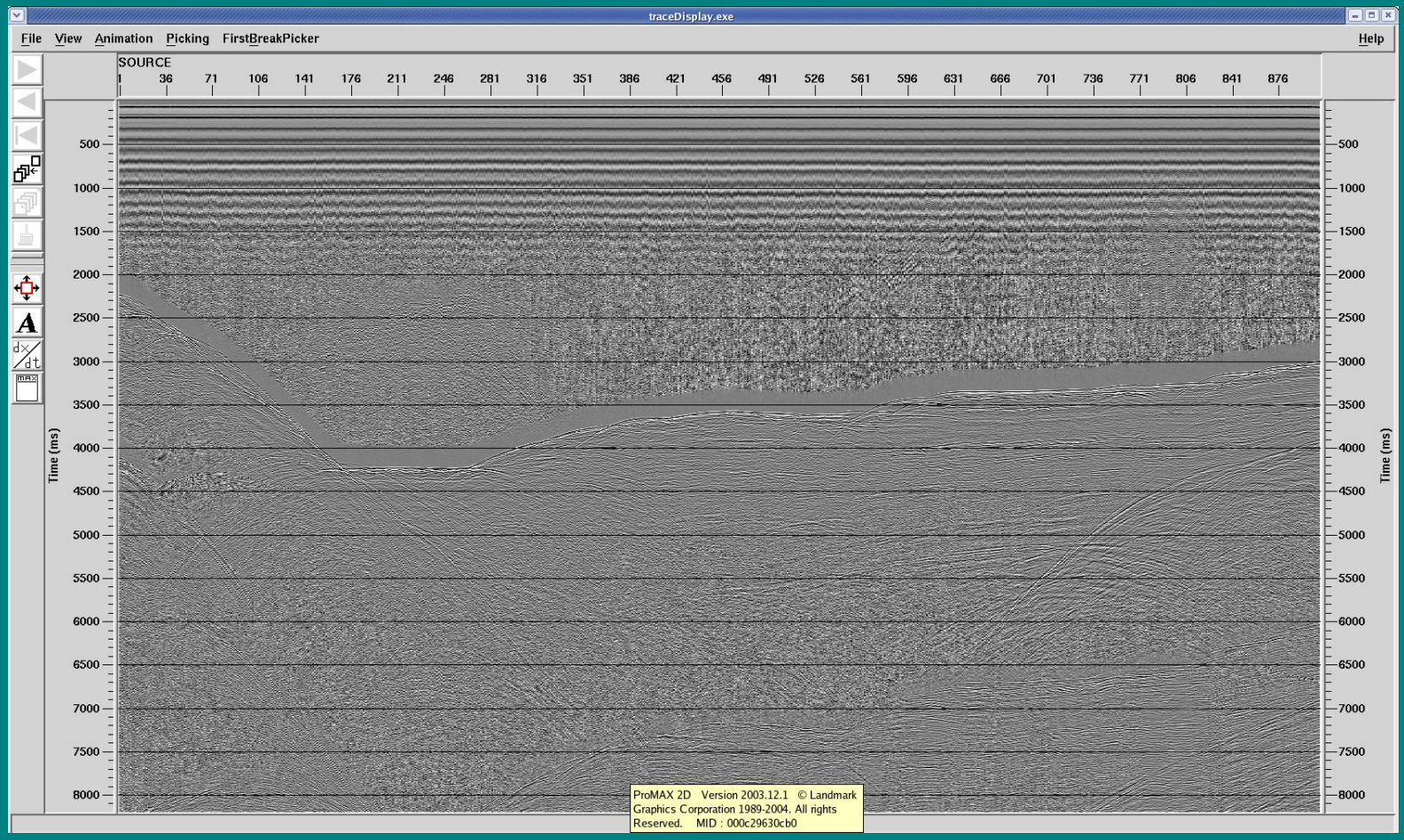
Near-Trace Plot

When we are collecting data we want to see it as quickly as possible – one way of doing this is by displaying a near-trace plot. This is simply a display of the channel nearest to the ship for each shot. This will give us the first glimpse of what we are looking at in terms of geology. Go back to the list of processes and click on 02 – Near Trace Plot. Execute the flow.



Near-Trace Plot

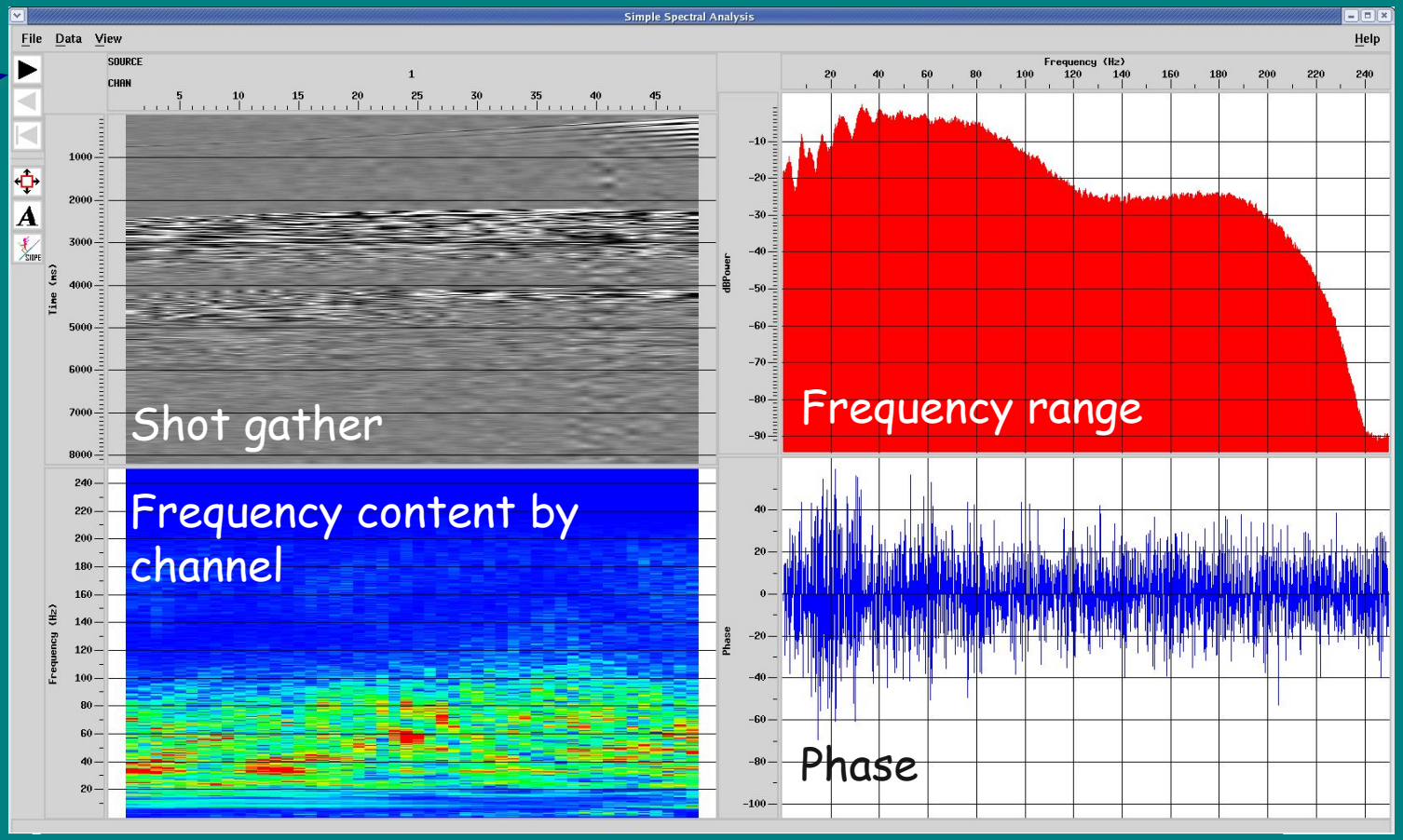
Go back to the flow *02 – Near Trace Plot* and uncomment *Automatic Gain Control* by clicking on it with the right-hand mouse button (RHMB). This will add gain to the section, enhancing the deeper reflectors



Power Spectrum

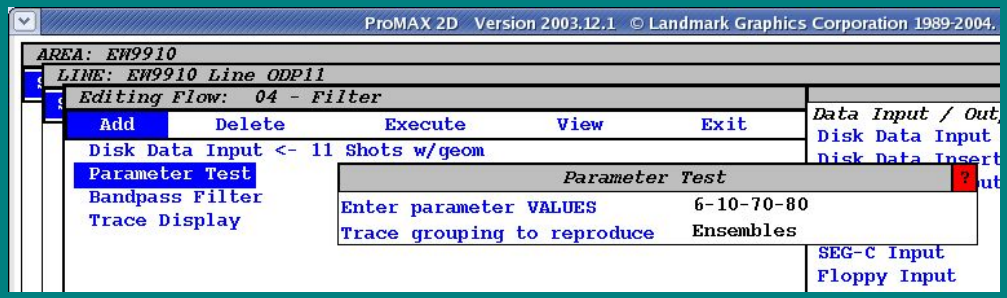
Go back the list of flows. Click on the flow *03 – Power Spectrum* and execute it. This flow is setup to show the frequency content of every 10th shot. We use a plot like this to determine characterize the range of frequencies in data, and possibly identify noise

Click on the arrow to go to the next shot

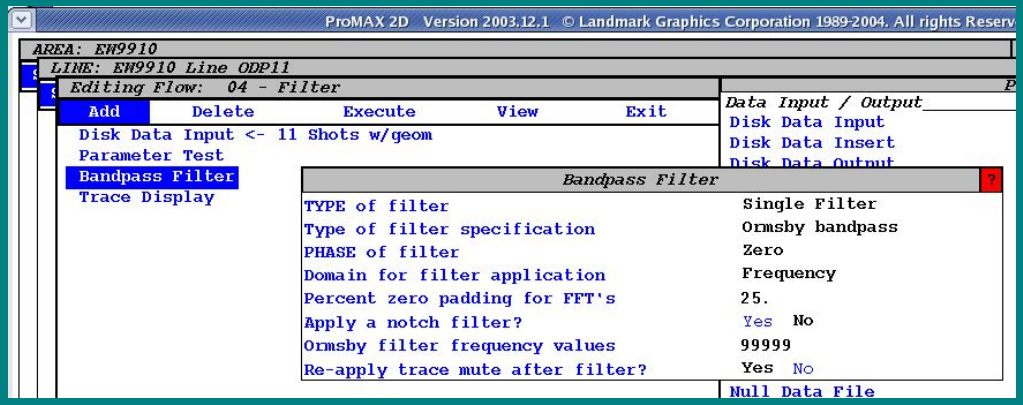


Filtering

We can use a bandpass filter to remove frequencies below and above a certain range. We are now going to test some filter parameters using the process *04 - Filter*



The filter defined in *Parameter Test* will remove all frequencies below 6 Hz and above 80 Hz. All frequencies between 10 and 70 Hz will be kept. A ramp is applied to intermediate values



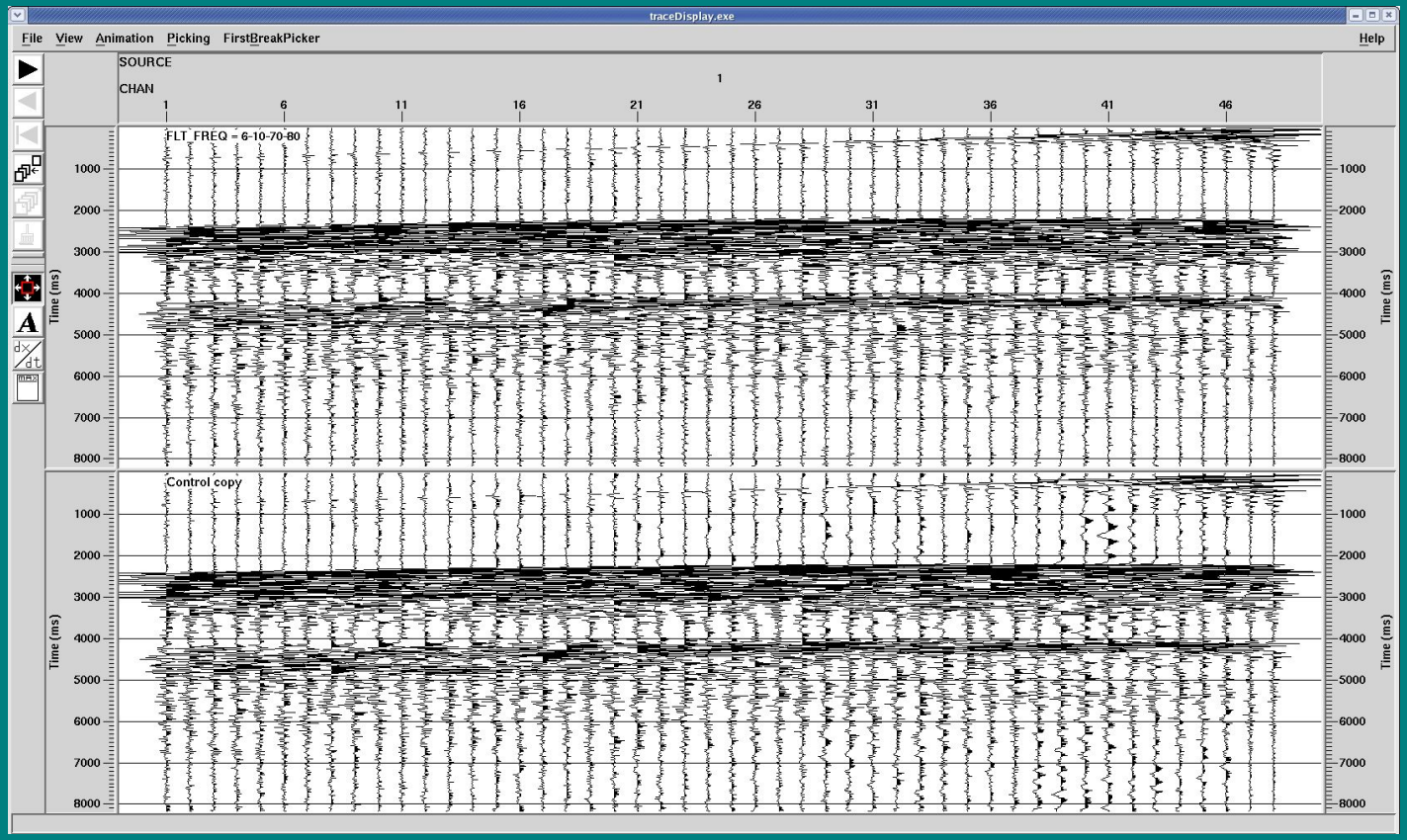
The number *99999* next to filter values indicates that the actual filter value comes from the *Parameter Test* process

Execute the flow

Filtering

For each shot a filtered and unfiltered (*Control copy*) version of the data is displayed. Advance to the next shot by clicking on the arrow.

- Zoom in to look at the data in detail
- Try some different filters



Removing NMO

The reason for having so many (24 in this case) traces in a CMP is so that we can stack (sum) the traces for a given CMP.

- Noise cancels out
- Real signal (geology) is amplified
- Signal to noise ratio increase

- First we must remove Normal Moveout (NMO) – the difference in travel time that is the result of varying ray path lengths

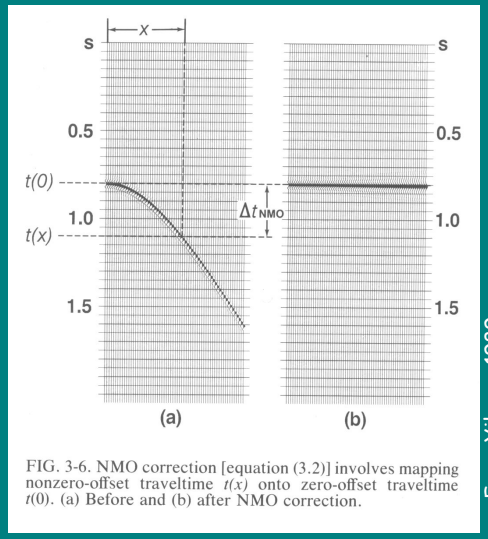


FIG. 3-6. NMO correction [equation (3.2)] involves mapping nonzero-offset traveltime $t(x)$ onto zero-offset traveltime $t(0)$. (a) Before and (b) after NMO correction.

From Yilmaz, 1989

$$\Delta T = t_x - t_0 = \frac{x^2}{2V^2 t_0}$$

$$V = \frac{x}{\sqrt{2t_0 \Delta T}}$$

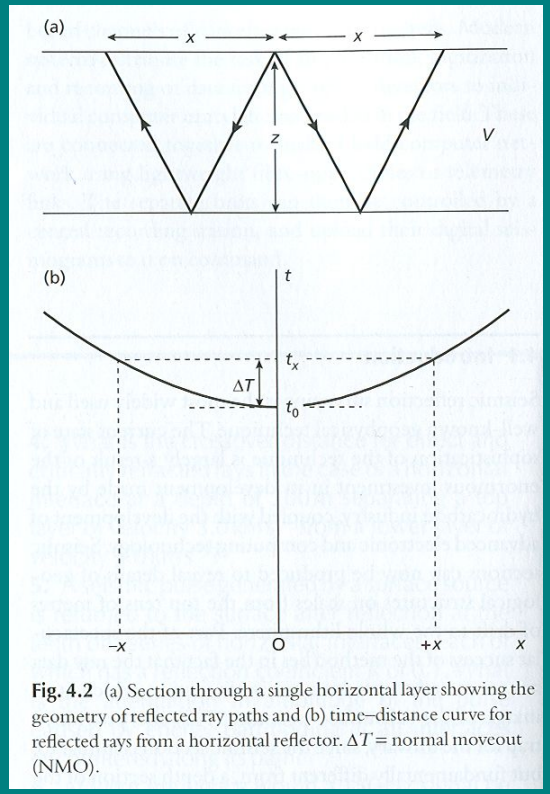
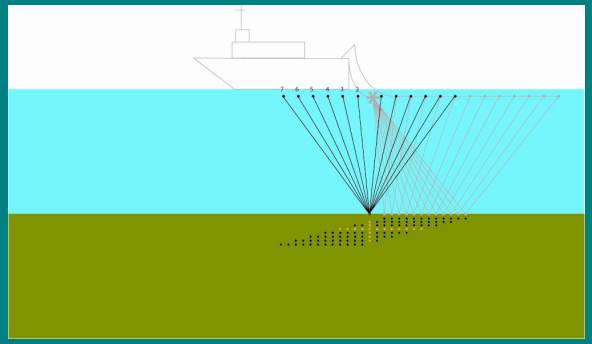
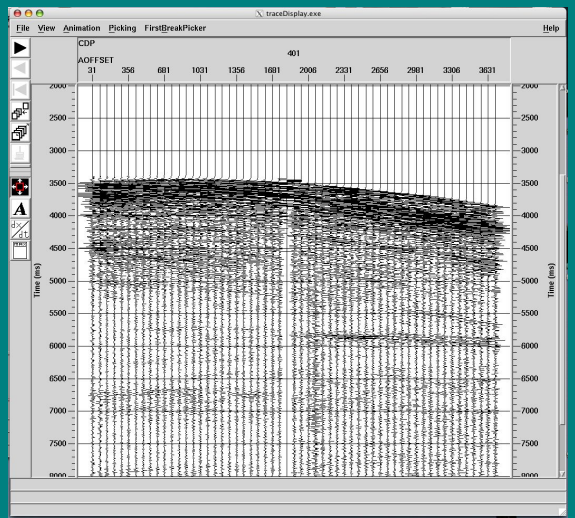


Fig. 4.2 (a) Section through a single horizontal layer showing the geometry of reflected ray paths and (b) time–distance curve for reflected rays from a horizontal reflector. ΔT = normal moveout (NMO).

From Kearey, Brooks, and Hill, 2002





Removing NMO in Practice – Velocity Analysis

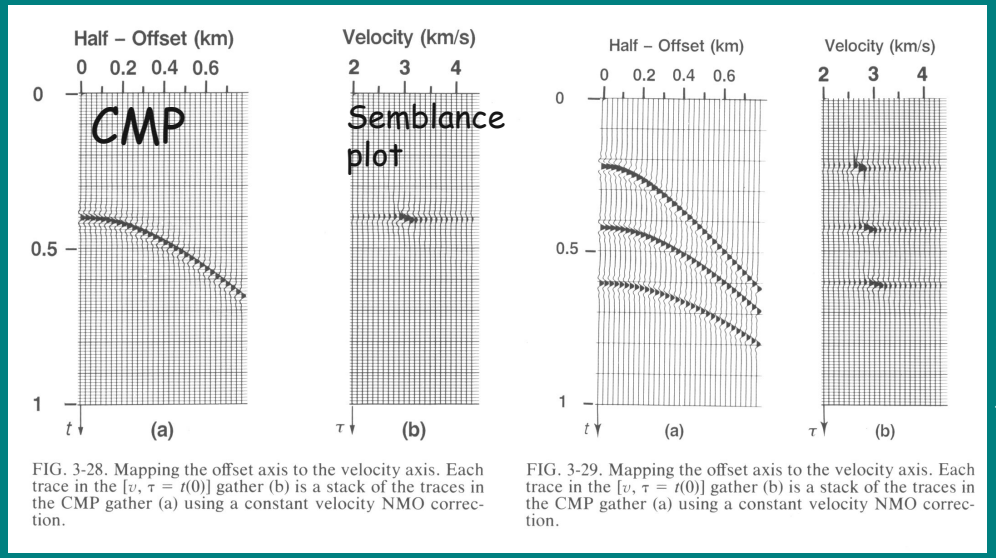


FIG. 3-28. Mapping the offset axis to the velocity axis. Each trace in the $[v, \tau = t(0)]$ gather (b) is a stack of the traces in the CMP gather (a) using a constant velocity NMO correction.

FIG. 3-29. Mapping the offset axis to the velocity axis. Each trace in the $[v, \tau = t(0)]$ gather (b) is a stack of the traces in the CMP gather (a) using a constant velocity NMO correction.

From Yilmaz, 1989

Nowadays velocity analysis is carried out using semblance plots – these show how well the data stacks (i.e. a reflector is coherent across a stack after NMO is applied) for a given two-way travel time and velocity

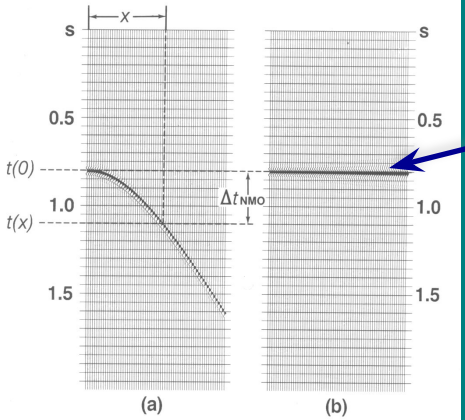
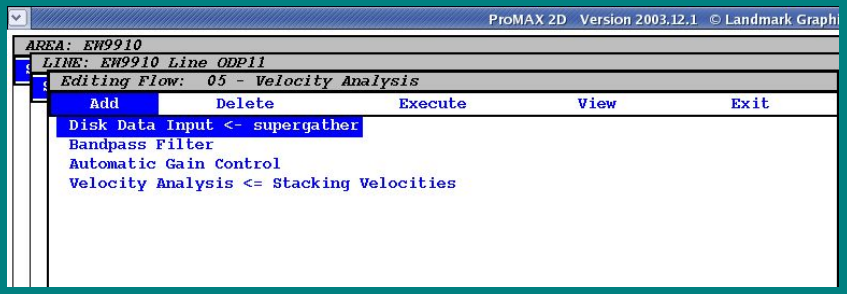


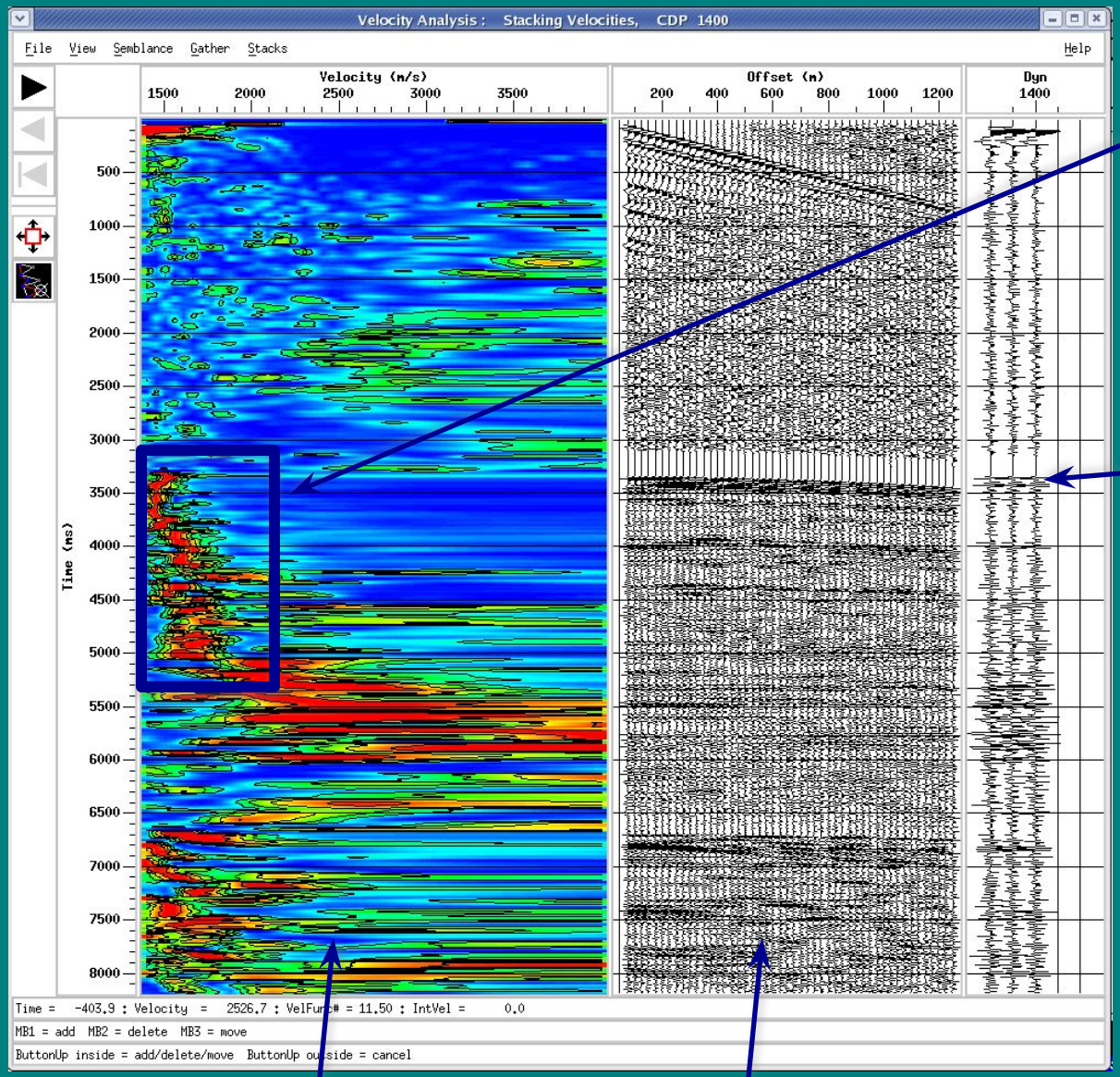
FIG. 3-6. NMO correction [equation (3.2)] involves mapping nonzero-offset traveltime $t(x)$ onto zero-offset traveltime $t(0)$. (a) Before and (b) after NMO correction.

NMO has been removed correctly and the reflector is now coherent

Go back to the *flows* list in ProMAX and select *05 – Velocity Analysis* – click on *Execute*



Velocity Analysis



Click on the zoom icon and zoom into this area

Dynamic stack

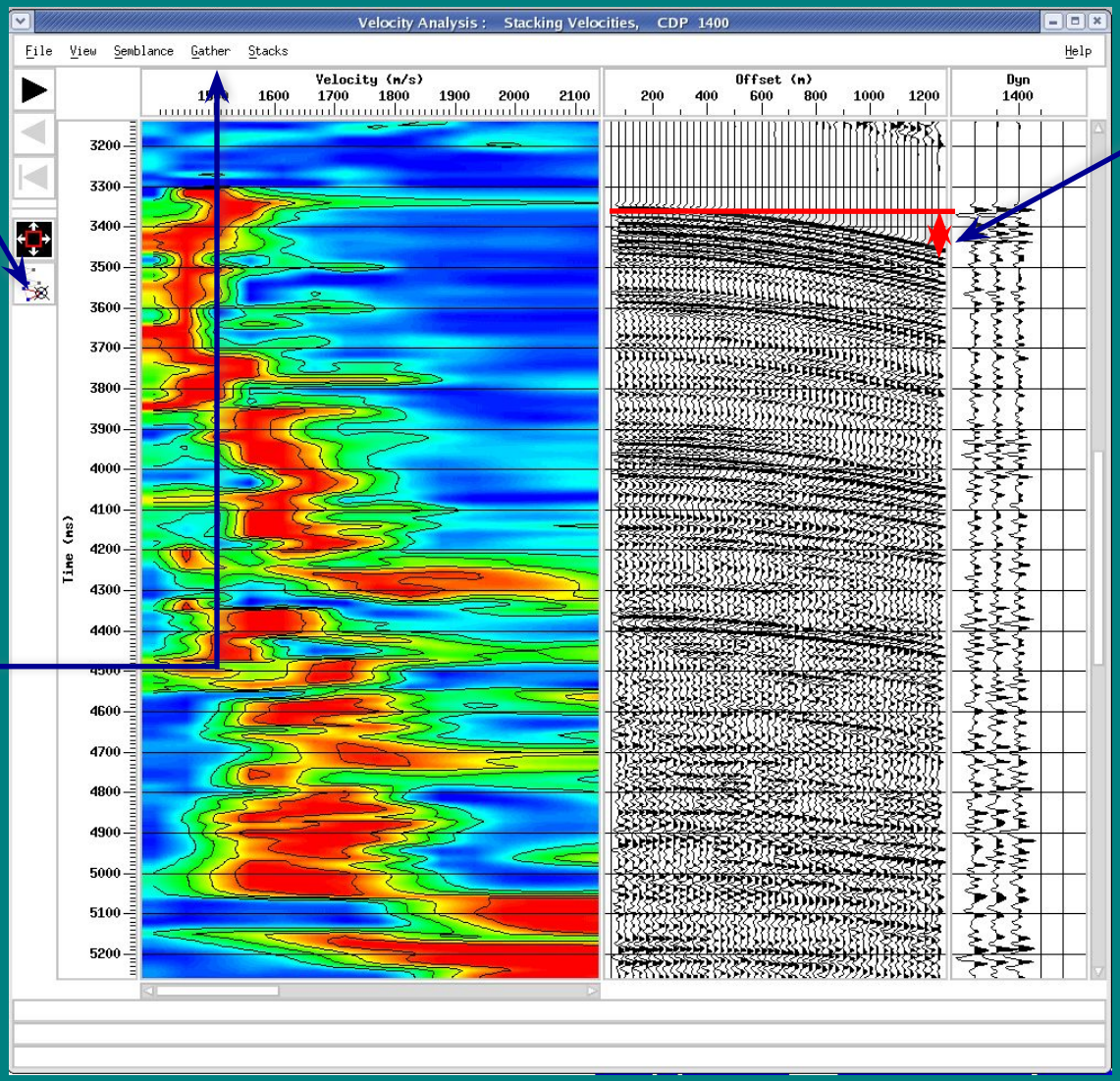
Semblance plot

CMP

Velocity Analysis

Click on the pick icon to pick velocity/time point on the semblance plot

Click on *Gather - Apply NMO* to see NMO applied as you pick



NMO

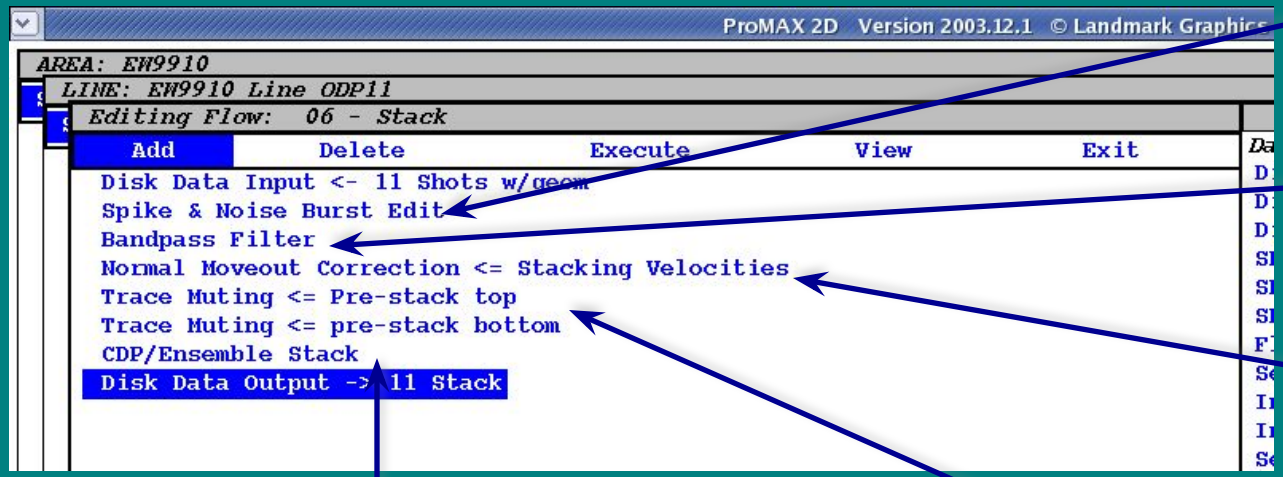
Add velocity/time points to the semblance plot such that the NMO is removed for the major reflectors.

- Zoom in and out as necessary
- Do not pick the multiple
- Save your picks

Stacking

Go back to the list of flows.

- Click on *06 – Stack*
- This flow uses your velocity picks and other that were picked earlier to stack the data
- The traces in each CMP are summed to form one trace



Removes some residual noise and spikes

Applies a bandpass filter to the data

Applies the NMO correction using the picked velocities

Traces in each CMP are stacked

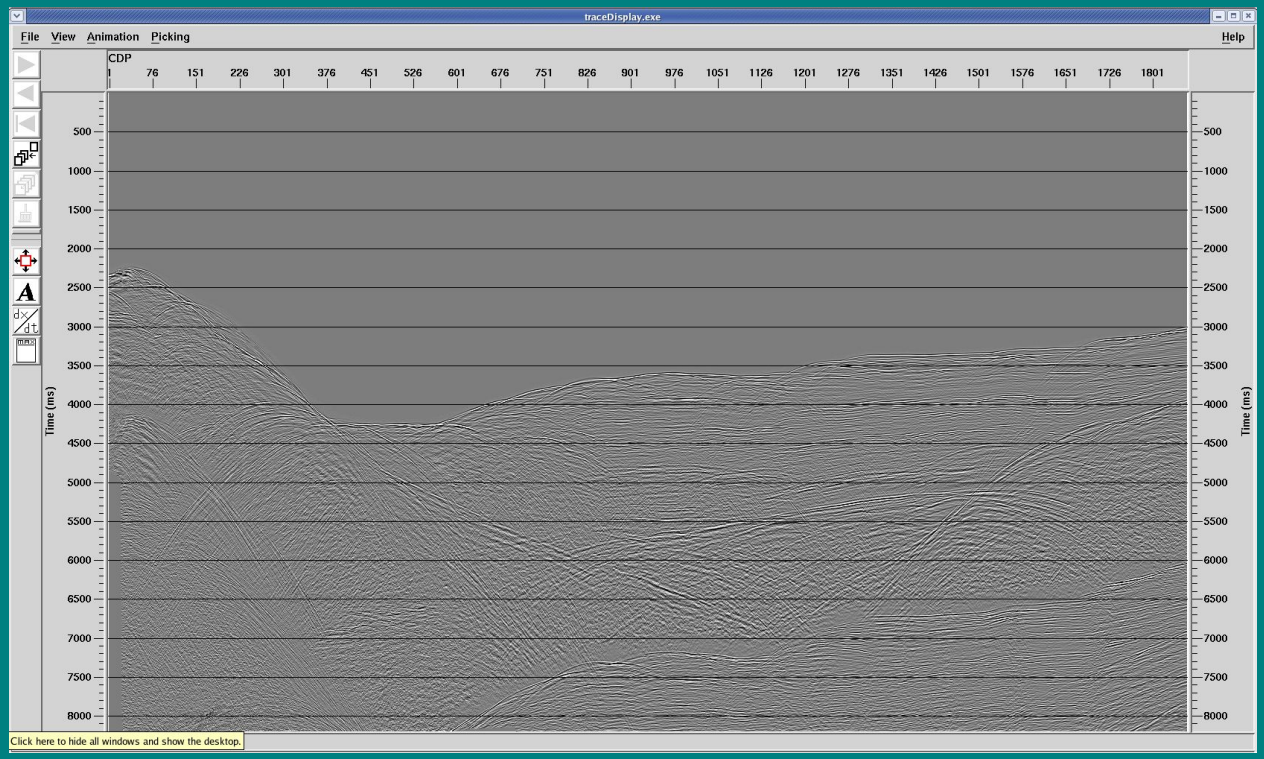
Trace mutes to remove stretched traces and attenuate multiple

Execute the flow – this will take some time…..

View Stack

Go back to the list of flows.

- Click on *07 – View Stack*
- Execute the flow
- You will see that the image is now much better than our original near trace plot
- You can start to see stratigraphy
- However, the are lots of diffractions and reflectors are not in their correct subsurface location – we need to migrate



Migration

In an un-migrated time section reflectors do not represent the true subsurface geometry.

- See examples below…

From Kearey et al., 2002

(A)

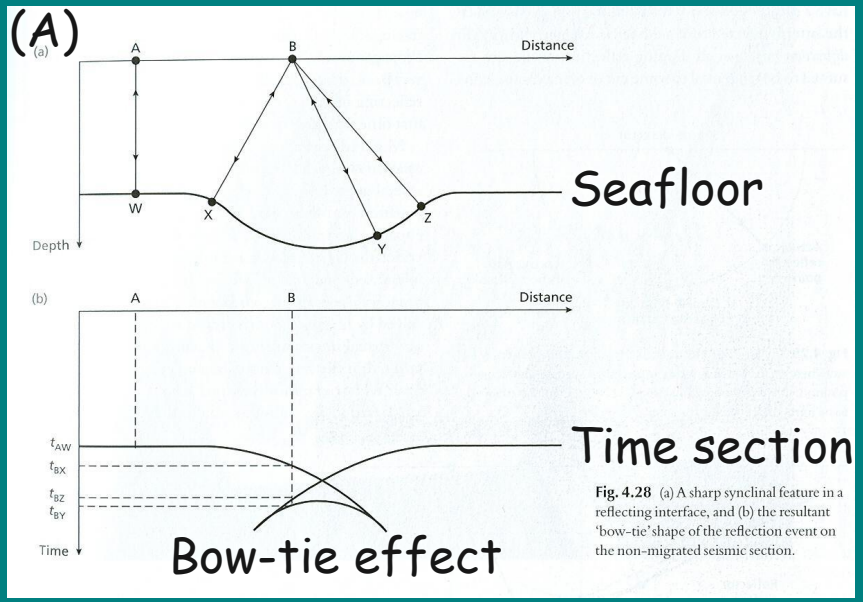


Fig. 4.28 (a) A sharp synclinal feature in a reflecting interface, and (b) the resultant 'bow-tie' shape of the reflection event on the non-migrated seismic section.

(B)

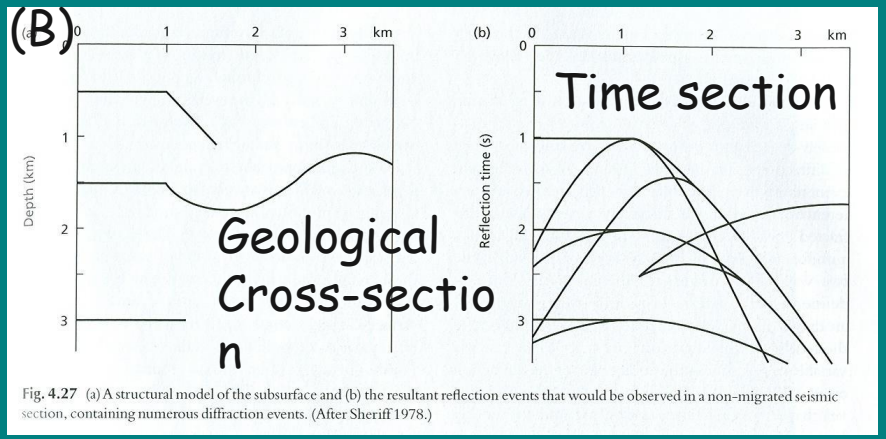
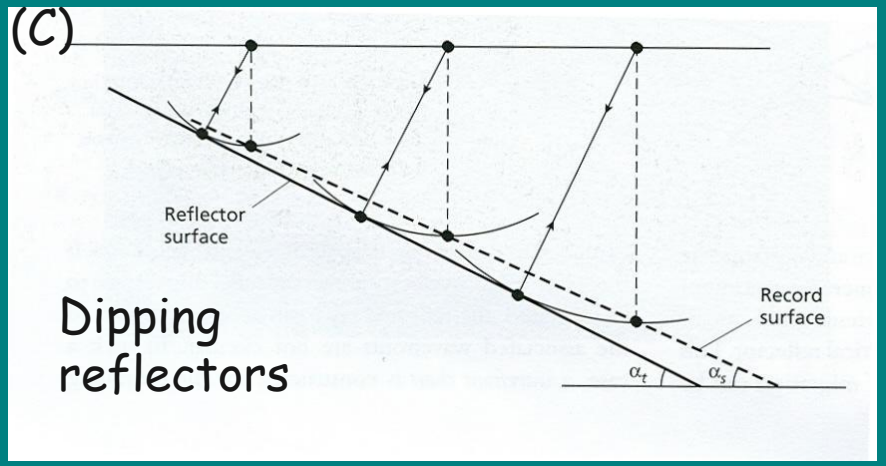


Fig. 4.27 (a) A structural model of the subsurface and (b) the resultant reflection events that would be observed in a non-migrated seismic section, containing numerous diffraction events. (After Sheriff 1978.)

(C)



(A) a syncline on the seafloor is imaged as a "bow-time section

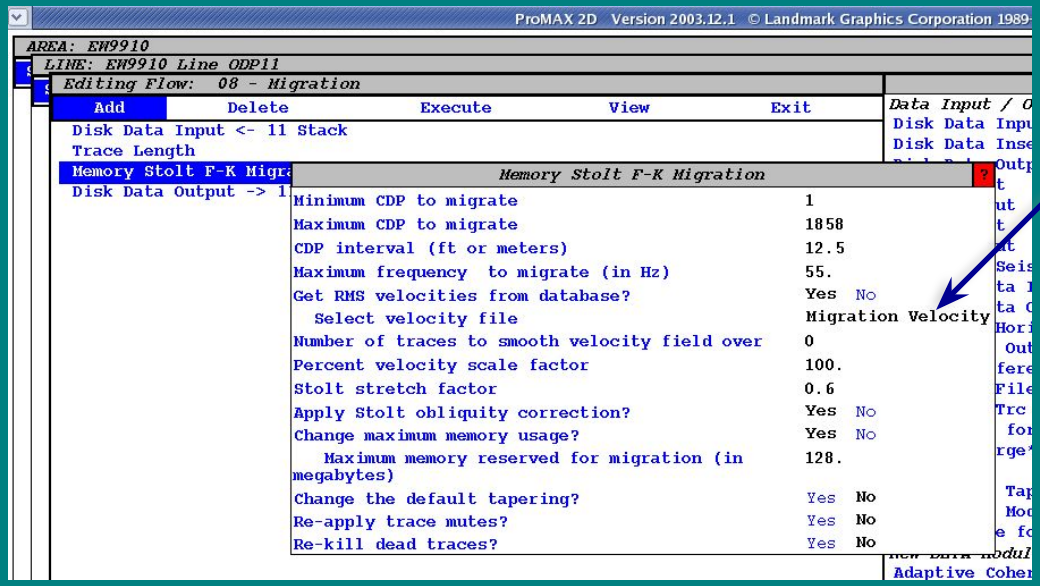
(B) The addition of diffractions from the end of reflectors results in a very complex time section

(B) A dipping reflector is shallower in a time section

Migration

Go back to the list of flows.

- Click on *08 – Migration*



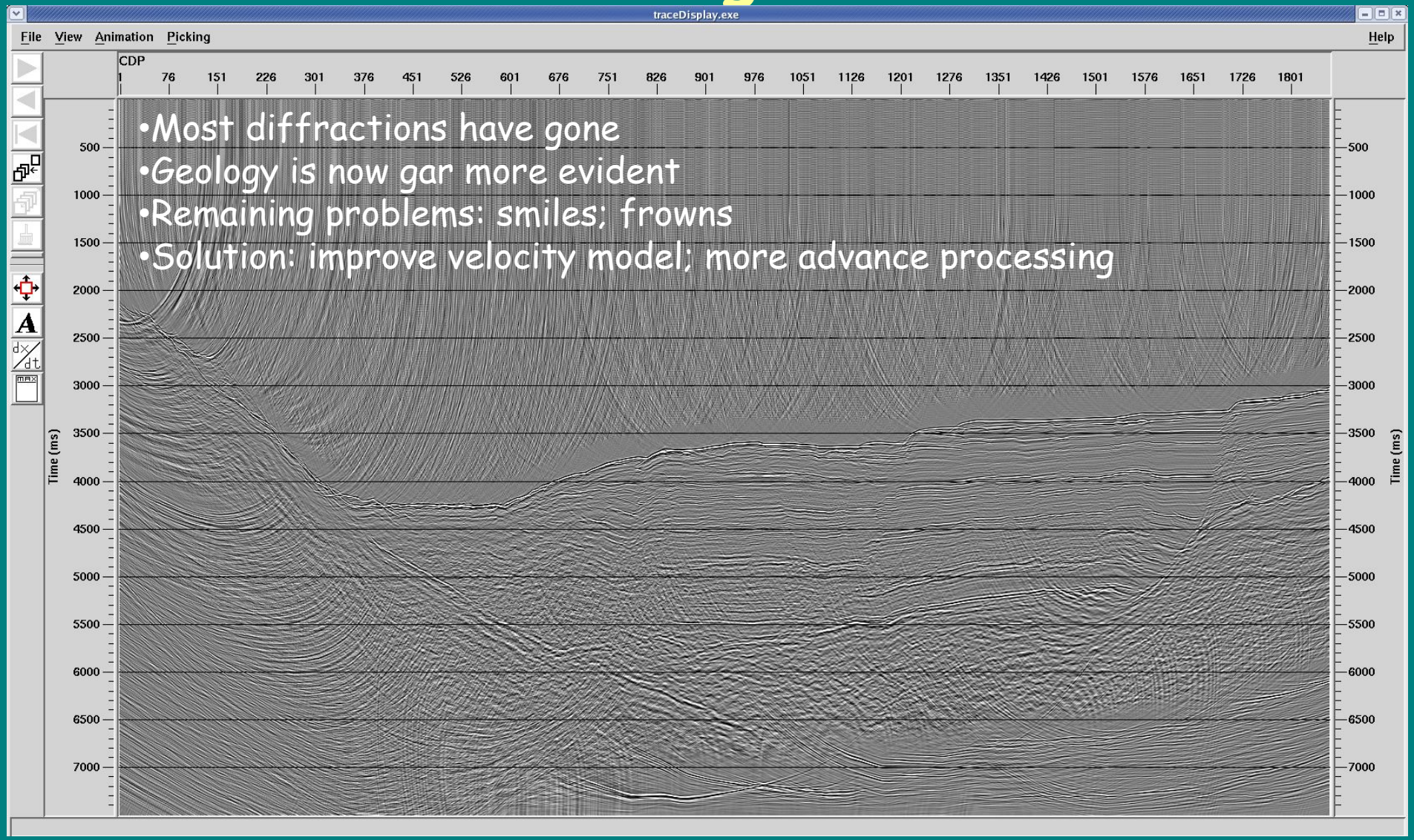
Using a velocity model that was made earlier we will migrate the data

There are a number of ways of migrating the data – all are mathematically very complex….

Execute the flow. This will take some time

When it has finished running, Click on *09 – View* Migration and execute the flow

View Migration



- Why is this still not equivalent to a geological cross-section?