Seismic imaging

Lecture 2

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Module outline

Day 1 morning- Introduction to seismic data

Lecture 1: Physical principles

Lecture 2: Data acquisition

Lecture 3: Key data processing steps

Day 1 afternoon- Exercises

Exercise 1: Synthetic seismic models

Exercise 2: NMO corrections and velocity analysis

We will discuss the “solutions” to the exercises during the afternoon sessions (and these will be recorded)

Lecture outline

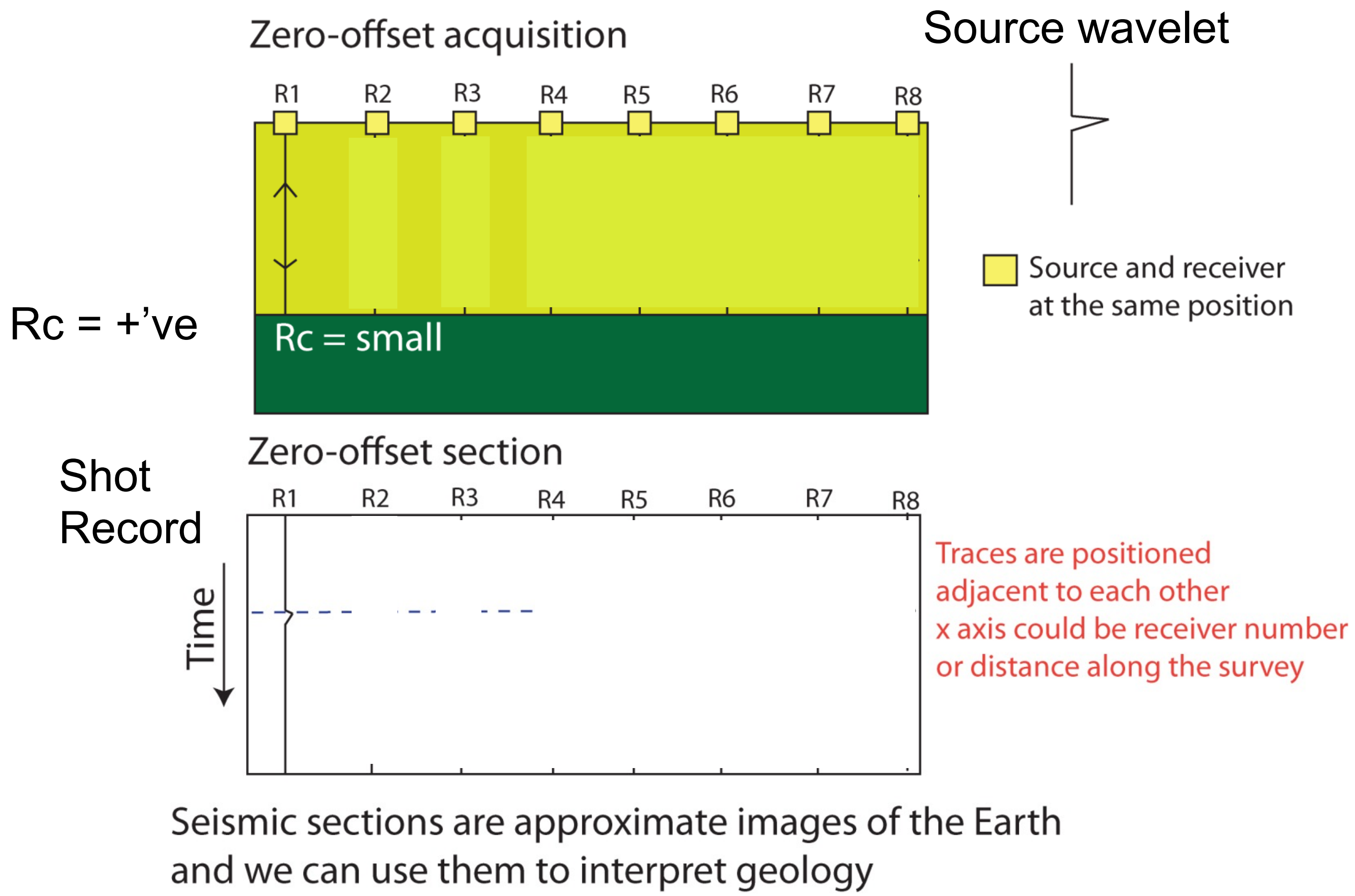
Objectives of lecture 2:

Learn how seismic reflection surveys are conducted and what equipment is used

i) Experiment design
ii) Sources and receivers
iii) The ideal wavelet

Zero-offset survey

The easiest way to create a SEISMIC SECTION (a cross-section under the ground) is to conduct a zero-offset survey. This is when you have one source and one receiver in the same place (e.g. at R1):



In Ex 1 you will be modelling your own zero-offset survey to produce 2D synthetic seismic sections

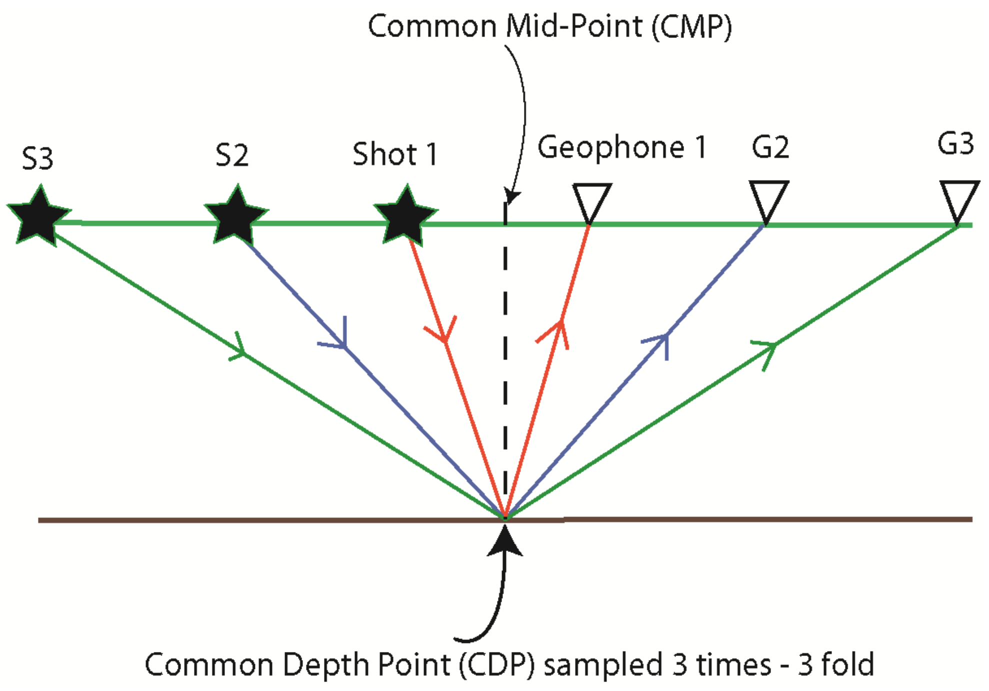
The problem is, reflection coefficients are very small, so the reflections have low amplitude

CMP profiling

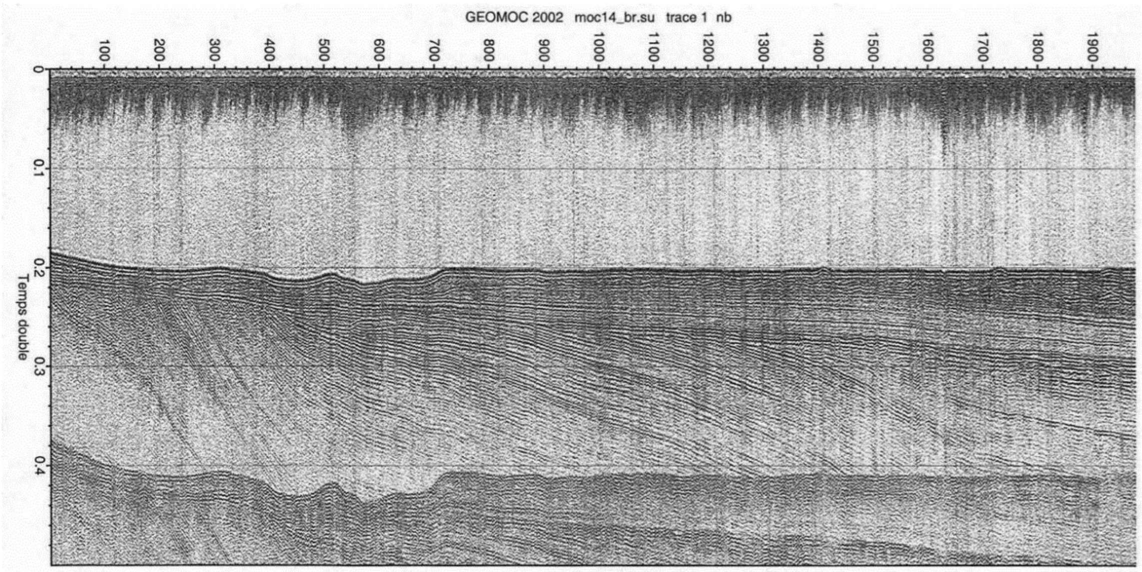
•To get around this problem we don't use just one source and one receiver. We design surveys that image the same point in the subsurface for multiple source-receiver pairs. This is called **Common mid-point profiling**

• This allows us to improve our signal to noise ratio (S/N) by stacking (adding) traces with the same CMPs

• **This is a key, fundamental idea behind the seismic reflection technique**

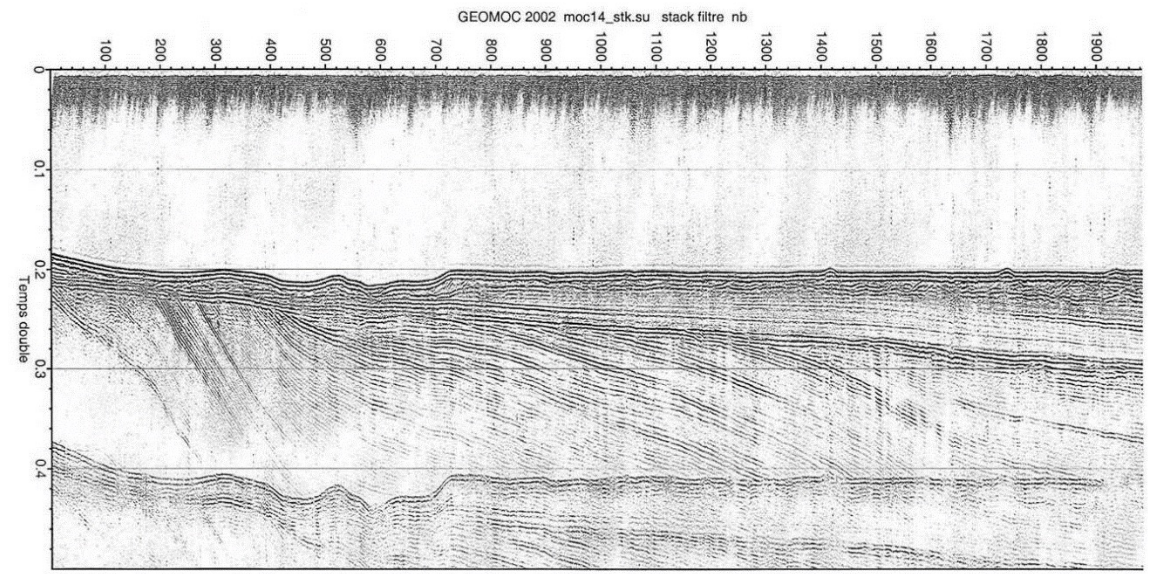


Zero-offset (single channel) vs CMP profiling (multi-channel)



Single channel data

Very noisy-reflections not clear



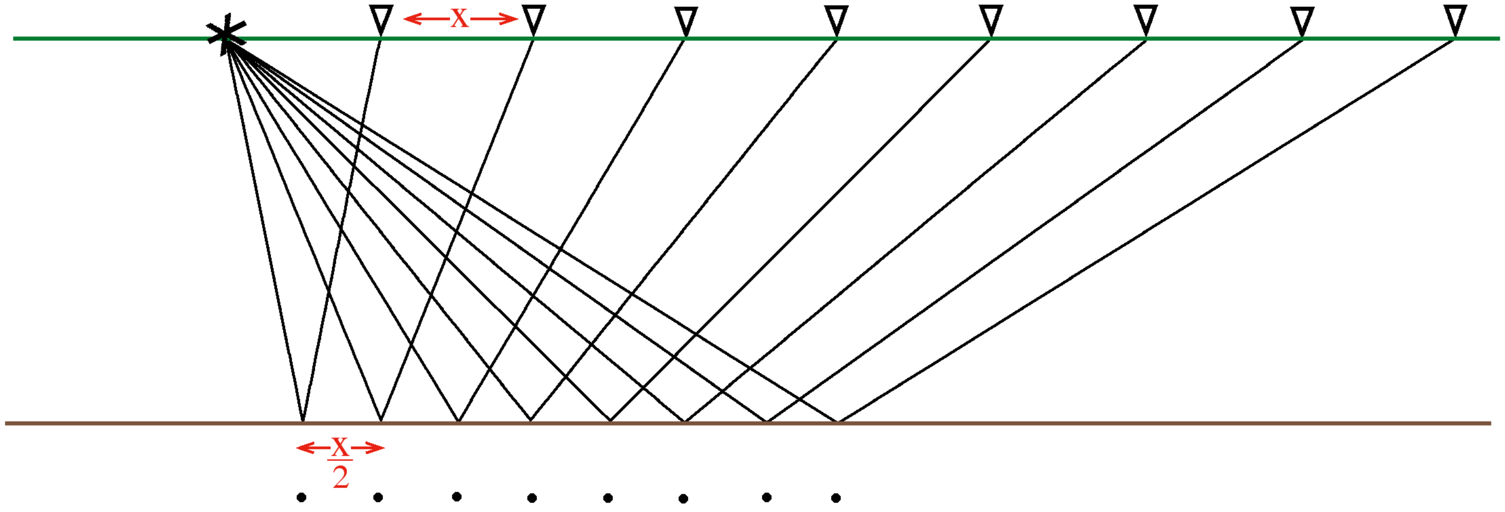
Multi channel data

Much sharper and reflections clearer

2D Survey geometry for CMP profiling

In order to conduct a multi-channel survey we need lots of receivers, and we need to ensure we are imaging the same points in the subsurface with each ‘shot’ (source)

The “roll-along” method is an efficient way to acquire seismic reflection data that is very amenable to stacking:



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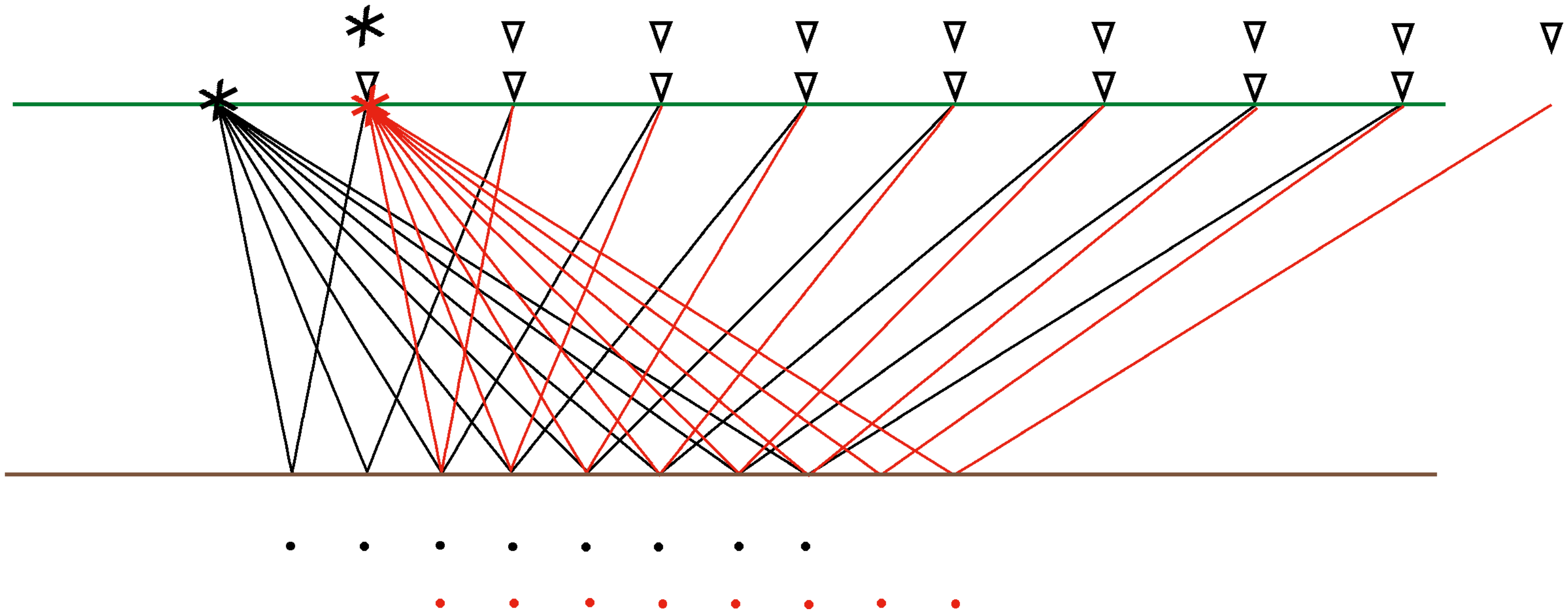
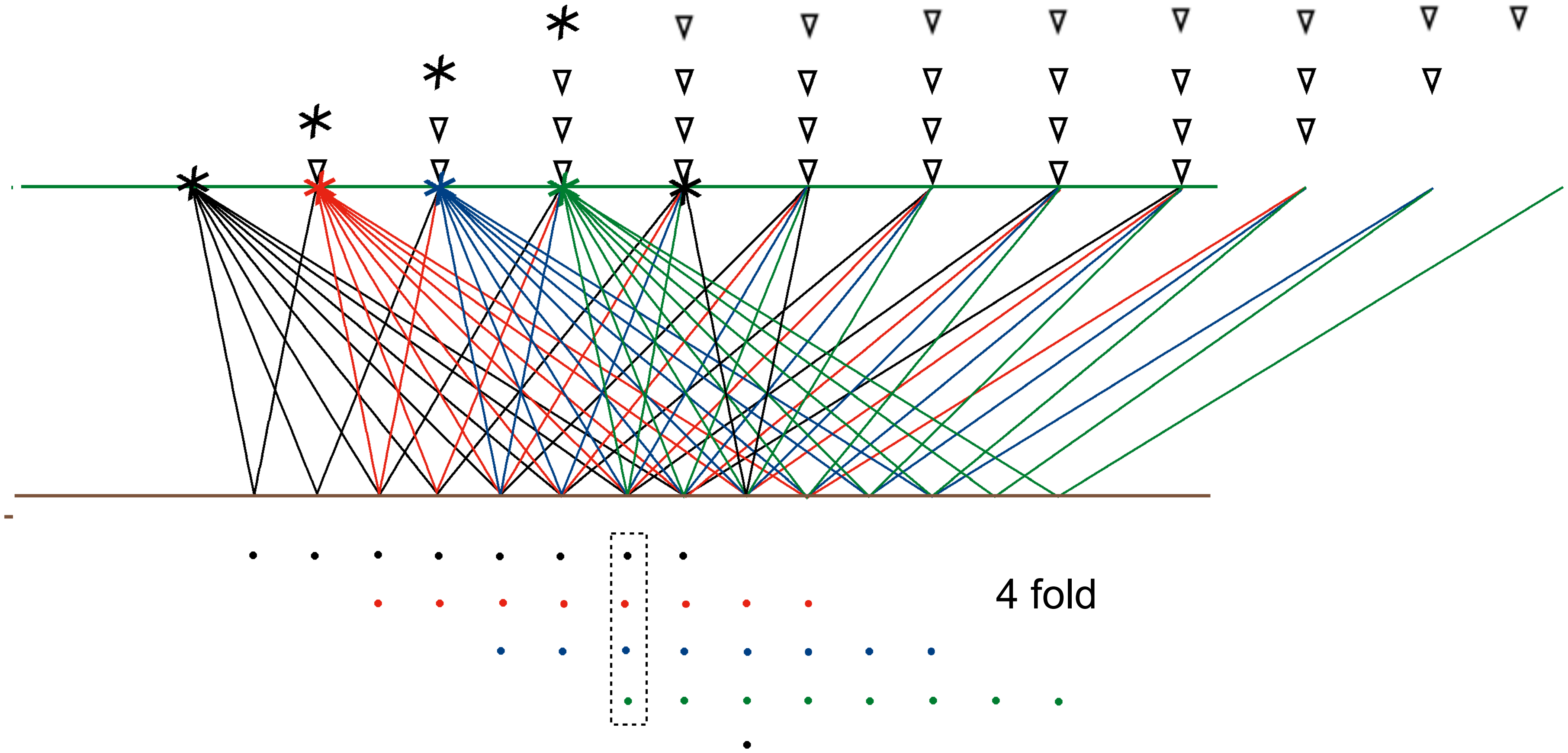


2D Survey geometry for CMP profiling

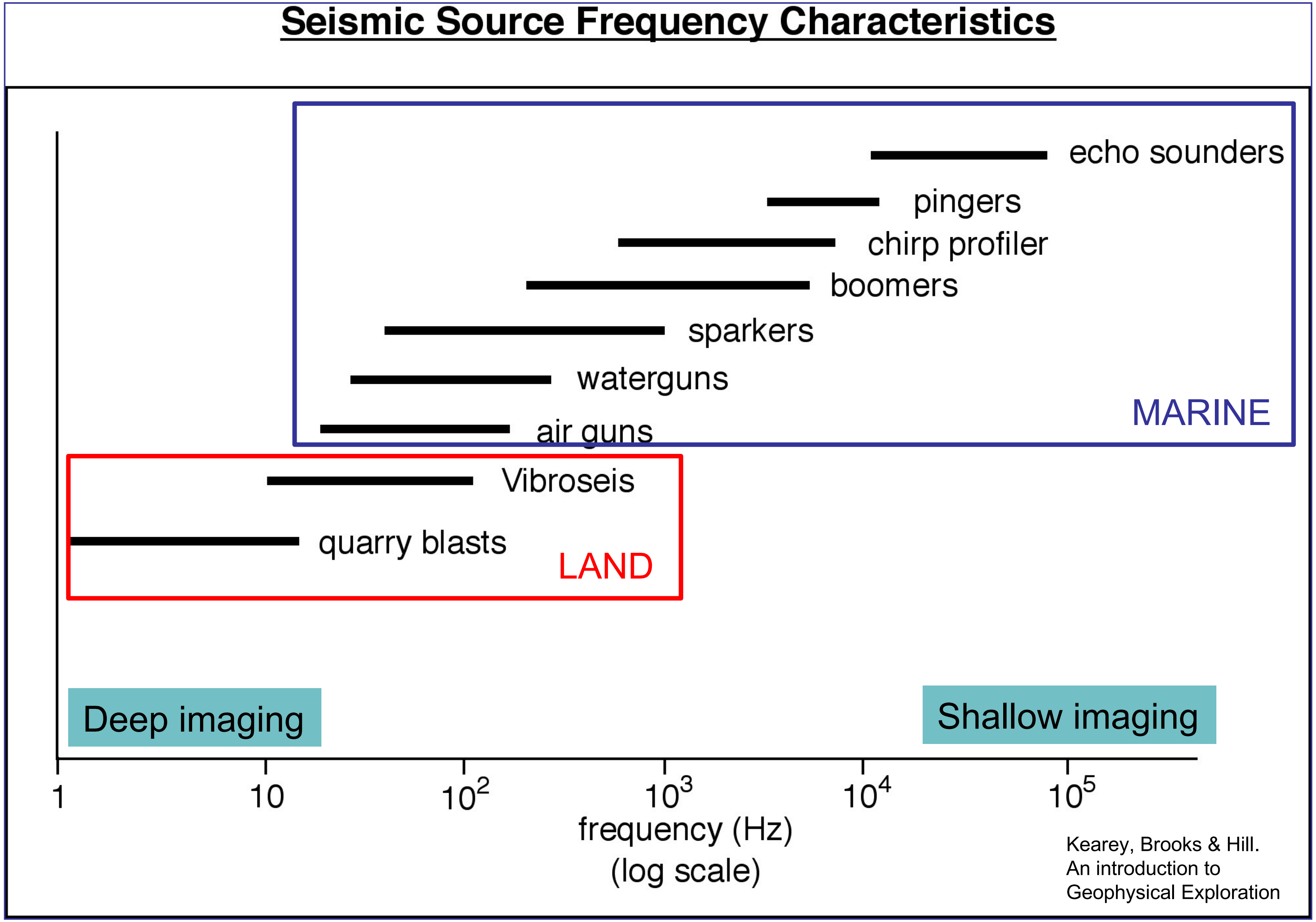
This technique is called **Common depth point profiling**



Seismic Sources: what we do not do…

https://www.youtube.com/watch?v=UiNhC9K7KjQ

Seismic Sources



High frequencies get absorbed and scattered more easily in the Earth. High-frequency sources can not image as deep as low-frequency sources, but they provide higher resolution (more detailed) images

Consider the depth to your target of interest and the resolution you need (it is a compromise)
High freq= lots of detail BUT limited depth
Low freq = low-resolution BUT deep imaging

Land sources

Dynamite

Dynamite is buried in a drilled hole and then detonated.

Vibroseis

Truck mounted vibrator coupled to the ground

	Dynamite	Vibroseis
Advantages	High energy, High data quality, All terrain	Quick and cheap (comparatively), As much energy as you want – simply add more trucks!,
Disadvantages	Damage and permit problems, Cost ~50% more than Vibroseis sources, can have difficult drill conditions	A lot of land needs to be cleared, only used on relatively flat ground

Marine sources

Low frequency sources:

- Airguns – penetrate up to 15 km

High frequency sources:

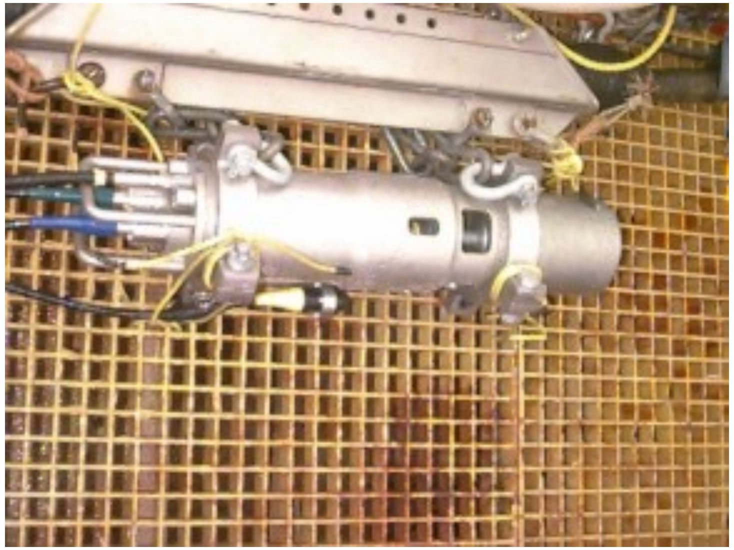
- Sparkers – up to around 2 km
- Pingers – few m to couple of 10's m

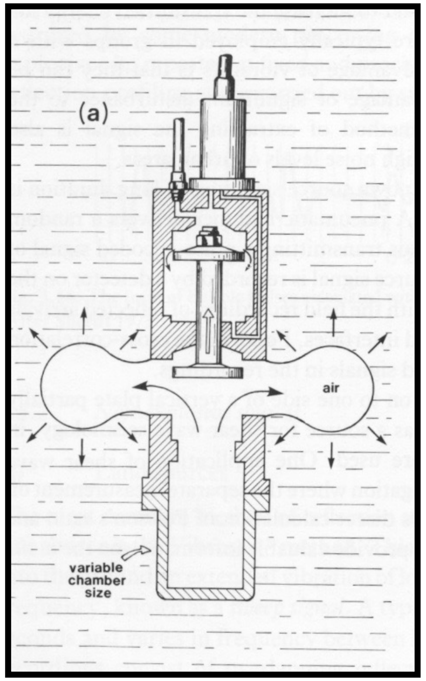
COURTESY: WESTERNGECO LLC

Depth of penetration will depend on properties of the sediments

Airguns (15 – 400 Hz)

- Can image up to 15 km deep. Used in crustal scale geoenergy applications.
- Pneumatic source in which a chamber is filled from a compressor.
- Rapid decompression of this chamber forms a large, expanding air bubble, which generates a pressure wave.



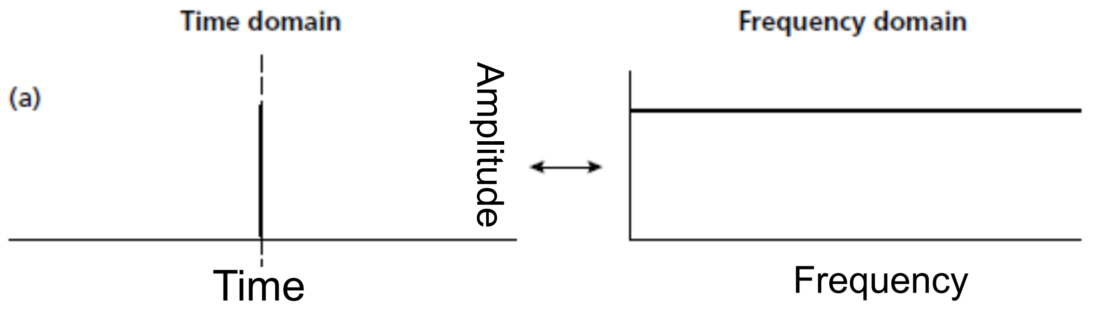


From Kearey, Brooks and Hill, 2002.

http://www.youtube.com/watch?v=WpbIB3xToZ4

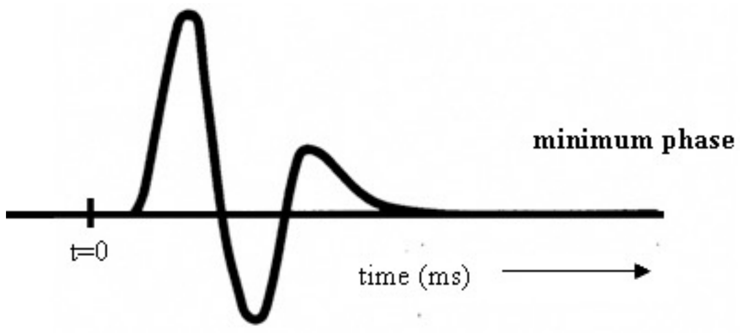
The ‘ideal’ wavelet

- An ideal source wavelet would be a **spike** and it would be **repeatable**
- Provides the highest temporal resolution – no matter how closely spaced two reflectors are they could still be resolved
- Maximum amplitude at every frequency



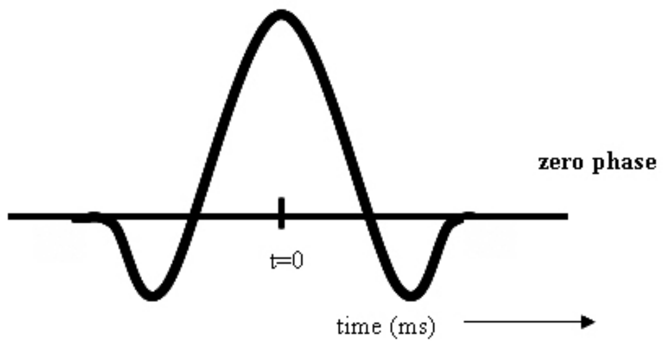
- The “**Minimum-phase**” wavelet is the closest we can get to the ideal wavelet during seismic acquisition.

- Minimum-phase wavelet has zero amplitude at t=0, and maximum amplitude a short time later



The ‘ideal’ wavelet

• For interpretation purposes it would be more useful if the maximum energy of the wavelet occurred at t=0, so a reflection from a horizon would be represented by a peak or a trough rather than a point of zero amplitude.



- The **Ricker wavelet** is “**zero-phase**”, it’s max amplitude occurs at t=0. It is impossible to create during acquisition, but we can convert a minimum-phase input wavelet into a Ricker wavelet during seismic processing

- When we process seismic data we can design a **filter that when convolved with** a wavelet (e.g. Minimum-phase) can shape it into another wavelet (eg. Zero-phase). This process is called DECONVOLUTION.

In Exercise 1 you will produce synthetic seismic models using a Ricker wavelet.

At the end of Ex 1 you can explore how the same models would look if you used more complex wavelet shapes.

Airgun environmental considerations

- Airguns have highest energy at relatively low frequencies of 10-200 Hz, this overlaps with the frequency of sound produced by whales in particular

- There is concern of the impact of airguns on marine mammals including 1) physical injury (e.g. hearing loss), 2) stress, 3) masking echolocation signals and having behavioral impacts

- Airgun surveys employ a range of mitigation measures including 1) “ramping up” the airgun arrays, 2) having marine mammal observers to locate mammals and stop airguns, 3) design of surveys to avoid particular areas/times

http://cms.iucn.org

Weir and Dolman 2007, Journal of International Wildlife Law and Policy

Airgun environmental considerations

http://www.pge.com

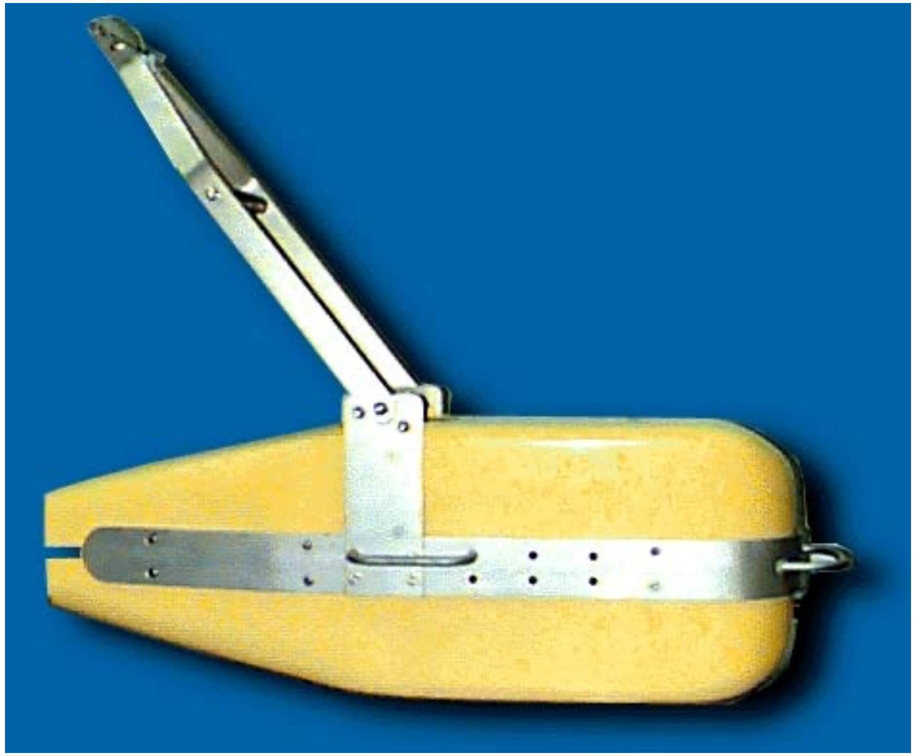
http://www.ga.gov.au/about/projects/marine/marine-seismic-surveys-and-the-environment

Sparkers (0.1 – 2.0 kHz)

- Comprises many electrodes mounted on a single frame.
- By discharging across these electrode we vaporize the surrounding sea water, producing a rapidly expanding plasma bubble.
- Similar to airguns this produces our sound source.

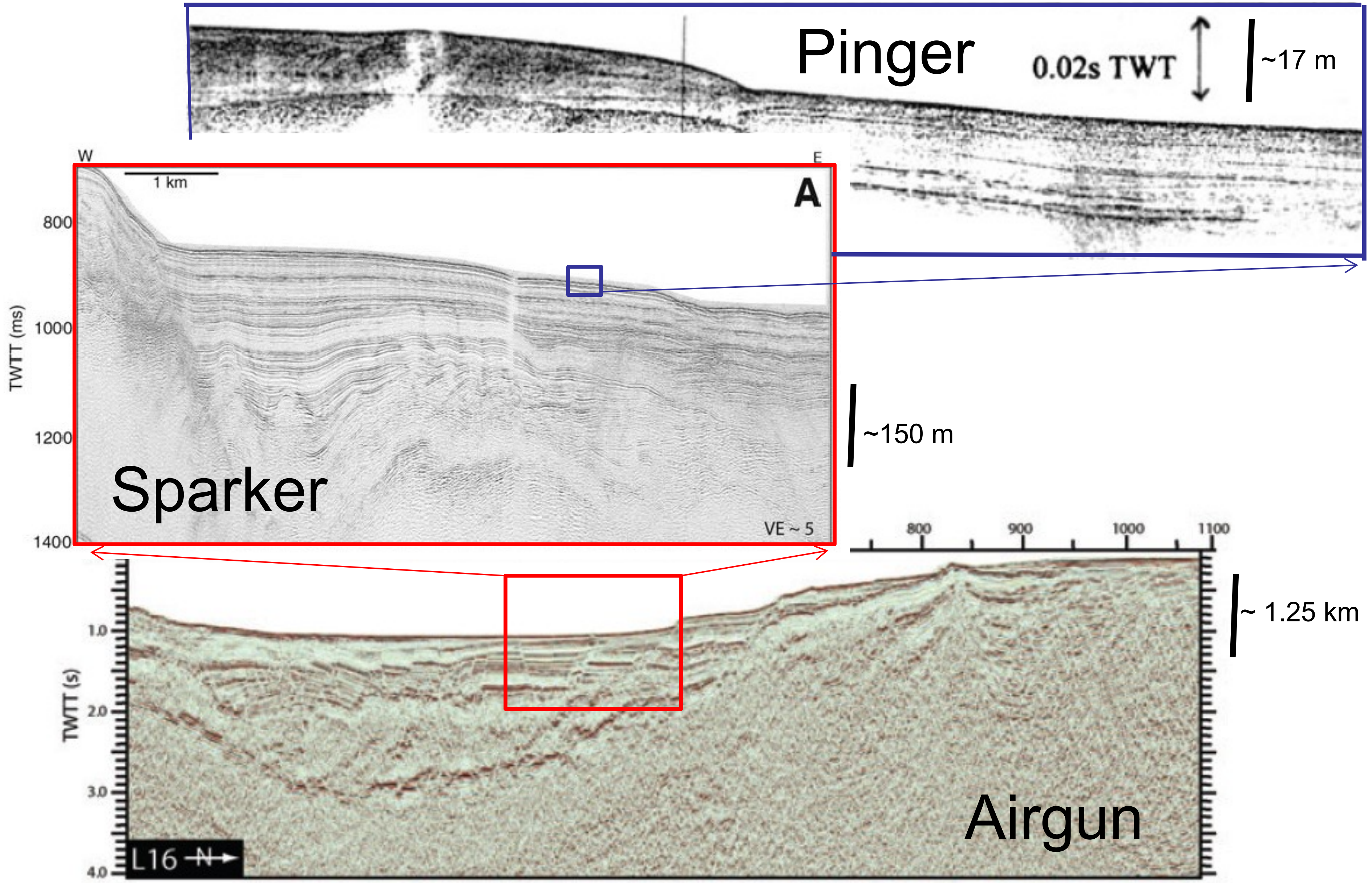
Pinger (commonly 3.5 kHz)

- Generate the acoustic source by passing electrical energy through a piezoelectric crystal.
- This causes the crystal to physically deform and thereby generate pressure wave.
- Crystal acts as a transceiver, i.e., receives reflected energy as well.



Piezoelectricity (also called the **piezoelectric effect**) is the appearance of an electrical potential (a voltage, in other words) across the sides of a crystal when you subject it to mechanical stress (by squeezing it).

Marine source data comparison



Key points

1) In order to produce a high-quality seismic image we need to image points in the subsurface multiple times and then stack (add) them together. This is called Common Depth Point profiling

2) The key elements of a seismic imaging survey are sources and receivers

3) There are lots of different sources that differ in their frequency and therefore the depth to which they can image (high frequencies get absorbed and scattered more easily in the Earth so high-frequency sources can not image as deep as low-frequency sources).

4) When designing a seismic survey you need to consider the target depth and how detailed (how well resolved) your image needs to be