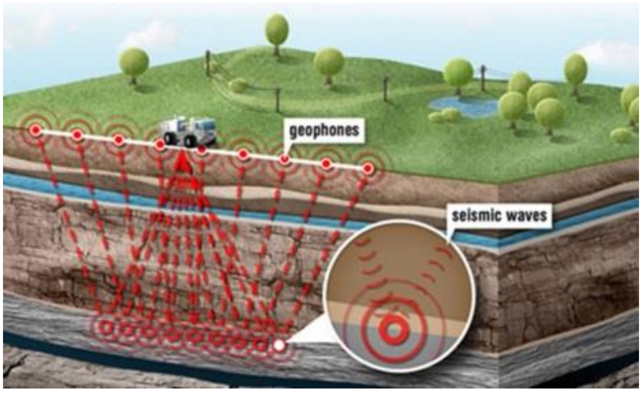
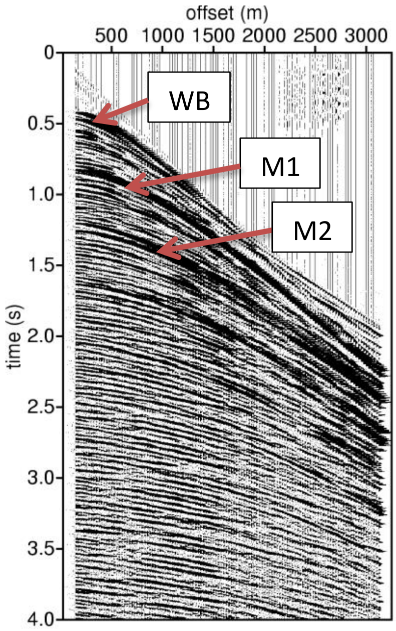
# Acoustic geo-imaging using all scattering effects

*B.Sc. and M.Sc. topics under supervision of Dr. Eric Verschuur (d.j.verschuur@tudelft.nl)*

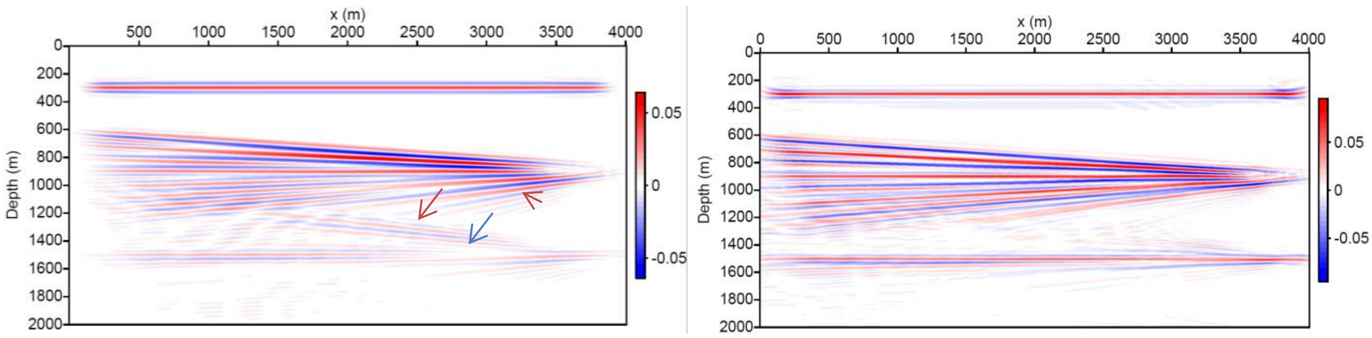
## Introduction




Seismic imaging aims at creating a structure of the subsurface via reflection measurements done at the Earth's surface, such as shown on the right hand side, for various geophysical applications. Although the main use of this technique is still exploration and monitoring of hydrocarbon energy sources ('oil and gas'), we observe an increased interest in this technology for applications that are related to the energy transition, e.g. storage of CO2 and H2 in previous gas reservoirs and the investigation of the subsurface for geo-thermal activities. Furthermore, near-surface applications can be geared towards safe placement of wind turbines or other mining activities (metals). In many of these applications the maximum data utilization from minimal acquisition efforts will become an important theme.

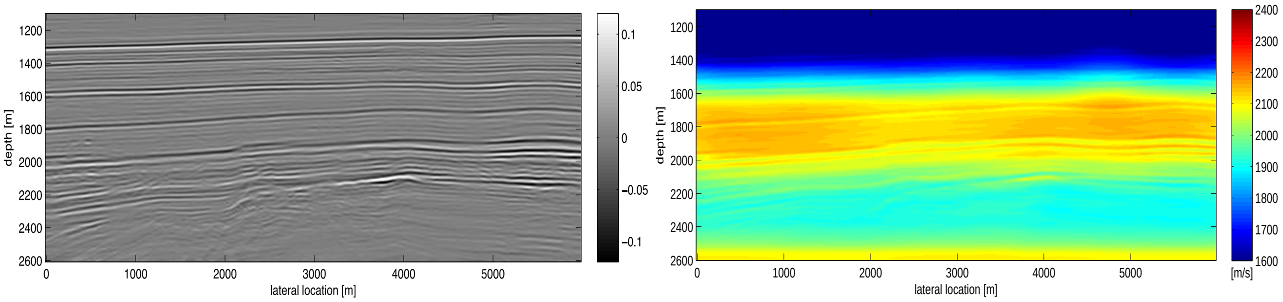



Every subsurface layer will give a reflection event back to the surface. However, wavefields will also reflect multiple times between those layers, as visible in the seismic record shown on the right, where a clear repetition of reflection events can be observed (WB=Water Bottom, M1 is 1st order multiple reflection, M2 is 2nd order multiple). Note that this image shows the recorded time signals as a function of the distance from source to the receivers (called offset). Usually these multiple reflections are considered noise and are removed from the data before we image the resulting primary reflections. However, multiples can contribute to the illumination of the subsurface. Therefore, Full Wavefield Migration (FWM) has been developed, in which the multiples are actively used in the imaging process. See below an example of FWM, where strong internal scattering (red arrows) is properly explained and the imprint on the deepest boundary (blue arrow) is resolved.




*Example for imaging using a wedge-shaped fine-layered model with top and bottom flat reflector. Left) Traditional image without including the multiples, creating cross-talk and imprint on the lowest flat reflector. Right) Full wavefield image multiples included. Note the resolved imprint on the lower reflector.*

In addition to estimating the reflection properties, also the background velocity model needs to be determined, because the Earth is a very heterogeneous medium. This can be done in the same imaging process, where also the propagation velocity profile becomes an unknown and is updated based on wavefield tomography. We call this the Joint Migration Inversion (JMI) approach. Below an example on field data from the North Sea is shown. It is visible that JMI provides both a high-resolution image (left picture) and an estimated velocity profile (right picture).

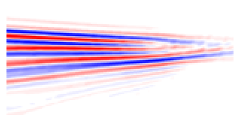



*Example for JMI applied to a field dataset from offshore Norway: left) Estimated image. Right) Estimated velocity profile.*

## Assignments

In the field of FWM and JMI we have several subtopics related the work that is being done by the Ph.D. students of our group in the context of the Delphi Research consortium (www.delphi-consortium.com). Topics are:

- **Source property estimation**. Both FWM and JMI need a good description of the source properties. If the wrong source field is used, multiple scattering will be over- or underestimated. Therefore, an automatic procedure for estimating these properties needs to be developed (B.Sc. topic).
- **Amplitude preprocessing via Machine Learning**. The JMI process cannot easily handle measurements with strong expression of angle-dependent reflection (AVO, amplitude versus offset) effects. Therefore, the effects need to be scaled down. Via ML we want to transform data with AVO effects to data without these effects, such that these can be used as input for velocity estimation (B.Sc. topic/M.Sc. topic).
- **On-the-fly compression techniques**. During the involved wavefield modeling process in FWM and JMI, wavefields need be stored in memory, which can be a hurdle for the implementation. Therefore, applying on-the-fly compression and restoring the wavefield when needed, the memory requirements can be greatly reduced. This is more a HPC-related topic. Optionally, this topic can also be steered in the direction of finding optimum compression techniques for seismic data based on a Deep Learning algorithm (B.Sc./M.Sc. topic).
- **Interpolation of point source responses via Machine Learning**. During the imaging process, the acoustic response of a source towards all subsurface offset locations must be calculated in a heterogeneous model. This can be done in a top-down recursive process, but in this case no so-called turning waves or waves that travel beyond 90 degrees from the vertical direction can be modeled. In this research project we want to model omni-directional wavefields by providing a limited number of modeled wavefields in all direction and use ML to extract the acoustic response for any source/receiver combination. (M.Sc. topic).
- **Improving FWM in case of thin layer and strong transmission effects**. In the shown example of FWM with thin layers (see also →) we face the issue that band-limitation of the data makes it difficult to discriminate thin layers. Therefore, we would like to improve the FWM process by imposing sparseness on the reflectivity, such that reflection/transmission can be pushed to a higher resolution (B.Sc./M.Sc. topic).



These assignments require theoretical analysis and subsequent algorithm development and testing, applied in Python, Matlab or C. The basic FWM and JMI algorithms are already available in Matlab, Python and C.